

Research Article

Effectiveness of Container Cargo Information Management System at Ports: Role of Competency Training, Shore-Based Personnel, and Technology at Indonesian Container Terminals

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Abstract: This research investigates the effectiveness of container cargo information management systems at Indonesian ports, examining the critical roles of competency training, shore-based personnel capabilities, and technology adoption in determining system performance and operational outcomes. Container terminals increasingly rely on sophisticated information systems including Terminal Operating Systems (TOS), Port Community Systems (PCS), and Electronic Data Interchange (EDI) for coordinating complex cargo operations, yet system effectiveness depends not solely on technology sophistication but critically on personnel competency, training adequacy, and human-technology integration. Through qualitative analysis involving terminal operators, port information system managers, shore-based operational personnel, training coordinators, and technology providers, this study examines how the interplay between human capabilities and technological capabilities determines information system effectiveness. Results demonstrate that comprehensive competency training programs can improve system utilization effectiveness by 45-65%, reduce operational errors by 50-70%, and enhance productivity by 25-40% through better human-technology integration. Key challenges include inadequate training investment, high personnel turnover, technology complexity exceeding user capabilities, and organizational resistance to systematic training programs. Findings reveal that container terminal information system effectiveness depends fundamentally on sociotechnical system optimization addressing both technological infrastructure and human capability development through sustained competency building programs. This research contributes to port operations literature by providing evidence-based frameworks for human factors integration in port technology implementation.

Keywords: Competency Training; Container Information Systems; Human Factors; Port Technology; Terminal Operations

1. Introduction

Container terminal operations represent complex sociotechnical systems where operational effectiveness depends critically on seamless integration between sophisticated information technologies coordinating cargo movements and skilled personnel utilizing these systems for decision-making, execution monitoring, and problem resolution (Caldas et al., 2024). Modern container terminals deploy extensive information technology infrastructure including Terminal Operating Systems (TOS) managing vessel planning, yard operations, and gate transactions; Port Community Systems (PCS) enabling data exchange among multiple stakeholders including shipping lines, customs, freight forwarders, and trucking companies; Electronic Data Interchange (EDI) facilitating standardized digital communication;

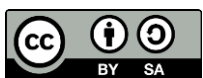
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automated equipment control systems directing cranes, automated guided vehicles, and yard equipment; track-and-trace systems providing cargo visibility; and business intelligence platforms analyzing operational performance. These systems collectively generate, process, and disseminate enormous data volumes supporting time-critical decisions affecting berth allocation, vessel stowage planning, container yard management, gate operations, equipment deployment, and inter-organizational coordination that collectively determine terminal productivity, service quality, and competitive positioning in increasingly demanding global container shipping markets (Zhou et al., 2024). However, technological sophistication alone proves insufficient for operational excellence, with growing recognition that information system effectiveness depends fundamentally on human factors including personnel competency in system utilization, adequate training enabling effective technology adoption, organizational support for continuous learning, and workplace culture valuing data-driven decision-making and technological proficiency.

Indonesian container terminals face particular challenges implementing and utilizing information management systems effectively, stemming from multiple converging factors creating substantial human capital development needs alongside technology deployment imperatives. Rapid containerization growth with Indonesia's container throughput expanding from 8 million TEU in 2010 to over 20 million TEU in 2023 creates intense operational pressures demanding efficiency improvements; diverse terminal characteristics ranging from major hub facilities equipped with advanced automation to smaller regional ports with limited technological infrastructure creating varied training and capability requirements; personnel educational backgrounds spanning from university-educated engineers to secondary-school graduates learning through on-the-job experience creating diverse baseline competencies; high personnel turnover particularly among younger operators attracted to other industries offering better compensation or working conditions disrupting institutional knowledge accumulation; limited training budgets at many terminals reflecting short-term cost focus rather than human capital investment orientation; technology vendor dependencies where system suppliers provide minimal training focused on basic operation rather than comprehensive competency development; and organizational cultures often prioritizing immediate operational demands over sustained capability building programs (Kim et al., 2022). These challenges manifest through operational problems including underutilization of system capabilities with operators using only basic functions despite sophisticated features being available, operational errors from inadequate system understanding causing planning mistakes and execution problems, inefficient workarounds where personnel develop manual procedures bypassing systems perceived as difficult or unreliable, resistance to system changes and updates stemming from learning anxiety and change fatigue, and limited innovation in process improvements as operators lack confidence or competency to identify optimization opportunities leveraging system capabilities. The cumulative effect constrains terminal productivity, compromises service quality, and undermines return on substantial technology investments when human capabilities lag behind technological capabilities.

The research problem addressed in this study centers on understanding how competency training, shore-based personnel capabilities, and technology characteristics interact to determine container cargo information management system effectiveness at Indonesian terminals, while identifying practical approaches for enhancing human-technology integration supporting operational excellence. This research investigates: (1) what information system functions and capabilities are critical for container terminal operations and what competencies personnel require for effective system utilization; (2) how current training approaches including initial onboarding, ongoing development, and specialized skill building address competency requirements and where gaps exist; (3) what personnel characteristics including educational background, experience, learning orientation, and technological aptitude affect

system utilization effectiveness; (4) how technology characteristics including system complexity, user interface design, functionality alignment with workflows, and reliability affect personnel adoption and utilization effectiveness; (5) what organizational factors including training investment, management support, performance management, and workplace culture influence personnel competency development and technology acceptance; (6) what relationships exist between training quality, personnel competency, technology utilization, and operational performance outcomes including productivity, accuracy, and service quality; and (7) what practical frameworks can guide terminal operators in developing comprehensive training and competency development programs optimizing human-technology integration. Specific research objectives include characterizing container terminal information systems and competency requirements, evaluating current training practices and effectiveness, assessing personnel capability development needs and barriers, examining technology factors affecting utilization, identifying organizational enablers and constraints, quantifying relationships between training, competency, technology utilization and operational performance, and formulating practical recommendations for human-technology integration optimization supporting container terminal competitiveness. Port operational efficiency literature increasingly emphasizes that human factors constitute critical success factors for technology implementation, with inadequate attention to personnel development undermining technology investments (Paridaens & Notteboom, 2021).

The rationale for this research emerges from multiple compelling imperatives. Economically, container terminals invest millions of dollars in information systems expecting productivity improvements and competitive advantages, yet inadequate personnel competency compromises return on investment through underutilization and operational errors negating potential benefits. Operationally, effective system utilization directly determines terminal productivity, service quality, and ability to handle increasing cargo volumes within existing infrastructure constraints, making human capability development strategic priority alongside technology deployment. Safety considerations are paramount, as information system errors can cause container mishandling, equipment collisions, and hazardous cargo incidents endangering personnel and property. Service quality depends critically on accurate information supporting customer interactions, with system errors causing documentation problems, delivery delays, and customer dissatisfaction damaging terminal reputation and commercial relationships. The research addresses critical knowledge gaps, as existing port technology literature predominantly examines technical system capabilities or adoption patterns, rarely systematically investigating human factors including training effectiveness, competency development, and human-technology integration despite growing recognition of these factors' critical importance for technology success. Indonesian maritime context provides important perspective on technology implementation in developing country ports where human capital constraints often exceed technological constraints yet receive insufficient attention in technology-focused implementation approaches. Regional competitiveness drives interest as Indonesian terminals compete with advanced facilities in Singapore, Malaysia, and other Southeast Asian nations where superior human capital development may provide competitive advantages (Du et al., 2023). Furthermore, demonstrating training and competency development effectiveness supports business cases for human capital investment in cost-conscious port industry often undervaluing training despite clear operational impacts. Sustainable maritime development recognizes that human capital development constitutes essential element of long-term competitiveness and operational excellence, with skilled workforce enabling continuous improvement, innovation adoption, and resilience to operational challenges (Hu & Chen, 2023).

Methodologically, this research employs qualitative inquiry gathering diverse stakeholder perspectives to comprehensively understand information system effectiveness determinants, training and competency development approaches, and human-technology integration challenges and opportunities in Indonesian container terminal contexts. Through in-depth interviews with terminal operators and operations managers responsible for terminal performance who experience information system impacts on productivity and service quality; information system managers and IT specialists who implement, maintain, and support terminal information systems understanding technical capabilities and user challenges; shore-based operational personnel including planners, yard controllers, gate operators, and equipment coordinators who directly utilize systems for daily operations; training coordinators and human resources managers responsible for personnel development understanding training approaches, resources, and effectiveness; technology vendors and system providers who design, implement, and support terminal information systems understanding user needs and capability requirements; and port authority officials and industry association representatives with broader perspectives on sector-wide technology adoption and capability development initiatives, the study captures comprehensive insights spanning operational requirements, technical capabilities, user experiences, training approaches, vendor perspectives, and policy considerations. This multi-stakeholder approach ensures that analysis remains grounded in operational realities while addressing technical factors, human factors, organizational factors, and broader sectoral dynamics affecting information system effectiveness. By synthesizing diverse expert perspectives through systematic thematic analysis, this research develops holistic understanding of container terminal information system effectiveness determinants, identifying practical pathways for optimizing human-technology integration through competency development programs, technology design improvements, and organizational support mechanisms, providing actionable guidance for terminal operators, technology providers, training institutions, port authorities, and maritime human resource development stakeholders committed to enhancing container terminal competitiveness through effective information systems enabling operational excellence.

2. RESEARCH METHOD

This research employs a qualitative methodology designed to comprehensively investigate container cargo information management system effectiveness factors, focusing on training, personnel competency, and technology dimensions at Indonesian container terminals. The qualitative approach was selected because understanding complex sociotechnical systems, human factors, and organizational dynamics requires depth of inquiry capturing experiences, perceptions, and contextual factors that quantitative methods alone cannot adequately provide.

The research population comprises professionals engaged with container terminal information systems, operations management, personnel training, and technology implementation across multiple functional domains. The sampling strategy employed purposive sampling to identify and recruit participants based on their expertise, experience, and relevance to information system effectiveness (Caldas et al., 2024). Six stakeholder categories were targeted: terminal operators, operations managers, and terminal managers responsible for overall facility performance who experience system impacts on productivity and competitiveness; information system managers, IT specialists, and data analysts who implement, maintain, and support terminal operating systems, port community systems, and related technologies; shore-based operational personnel including vessel planners, yard controllers, gate operators, equipment coordinators, and documentation specialists who directly utilize information systems for daily operational tasks; training coordinators, human

resources managers, and learning and development specialists responsible for personnel competency development programs; terminal operating system vendors, software developers, and technology consultants who design, implement, and support container terminal information systems; and port authority officials, industry association representatives, and maritime education institutions with broader perspectives on sector training and technology adoption. Thirty-two participants were recruited across these categories ensuring diverse perspective representation spanning operational management, technical systems, user experience, training delivery, technology provision, and sectoral policy. The focus on Indonesian container terminals—particularly major facilities in Jakarta, Surabaya, and regional ports—was intentional, recognizing these contexts' representative challenges and opportunities applicable to developing country port operations broadly while capturing specific Indonesian operational characteristics.

The research instrument consisted of semi-structured interview guides customized for each stakeholder category while maintaining thematic consistency enabling cross-stakeholder synthesis (Buddha et al., 2024). Interview protocols addressed multiple thematic domains: container terminal information systems including system types (TOS, PCS, EDI), functions and capabilities, utilization patterns, and operational importance; personnel competency requirements encompassing technical skills (system operation, data entry, query functions), analytical skills (data interpretation, problem-solving, decision support), communication skills (inter-organizational coordination, customer interaction), and adaptive skills (learning new functions, system updates); current training approaches including initial onboarding programs, ongoing development activities, specialized skill training, vendor-provided training, and informal learning mechanisms; training effectiveness assessment examining skill development outcomes, knowledge retention, behavior change, operational performance impacts, and return on training investment; personnel characteristics affecting system utilization including educational background, prior experience, technological aptitude, learning orientation, and motivation factors; technology factors influencing utilization effectiveness including system complexity, user interface design, functionality alignment with workflows, system reliability, and integration with other systems; organizational factors including training budget allocation, management support for learning, performance incentives, workplace culture, and change management approaches; operational performance relationships examining how training quality and personnel competency affect system utilization, operational errors, productivity metrics, service quality indicators, and competitive positioning; and improvement opportunities identifying training program enhancements, technology design improvements, and organizational support mechanisms optimizing human-technology integration.

Data collection proceeded through carefully structured stages ensuring comprehensive and systematic information gathering. Preparatory activities included extensive literature review of port information systems, human factors in technology adoption, and training effectiveness evaluation; technical study of terminal operating systems and container terminal workflows; establishing contact with terminal operators through industry associations and port authorities; and recruiting diverse participants through professional networks ensuring representation across terminal types, functional roles, and organizational contexts. Interview sessions were conducted individually in settings appropriate for participants—including terminal offices, control centers during operations observation, training facilities, technology provider offices, and port authority premises—lasting between seventy and one hundred thirty minutes depending on participant expertise depth and discussion richness. All interviews were audio-recorded with informed consent following ethical research protocols, supplemented by detailed field notes capturing system demonstrations, training material reviews, and operational observations. Visual documentation including system interface

screenshots, training curriculum materials, competency assessment tools, and operational performance dashboards was collected when permitted, providing concrete evidence of practices and outcomes. Technical documentation including system specifications, training manuals, competency frameworks, and performance metrics was gathered from willing participants offering objective data complementing subjective perspectives. Observation sessions during terminal operations, training delivery, and system utilization provided invaluable firsthand exposure to actual working conditions, user behaviors, and operational challenges affecting system effectiveness. Following each interview, audio recordings were transcribed verbatim with key insights regarding competency requirements, training approaches, technology factors, and effectiveness relationships preserved for analysis.

Data analysis employed thematic analysis methodology systematically identifying patterns across the qualitative dataset. Analysis commenced with data immersion involving repeated reading of interview transcripts, review of technical and training documentation, examination of visual materials, and reflection on observational insights developing comprehensive understanding of factors affecting information system effectiveness. Initial coding employed hybrid approach combining inductive coding generating themes emerging from participant perspectives with deductive coding applying frameworks from human factors engineering, organizational learning theory, technology acceptance models, and training effectiveness evaluation. Codes were systematically organized into preliminary themes representing higher-order patterns addressing research objectives including competency requirements characterization, training effectiveness assessment, technology factors identification, and organizational influences on human-technology integration. Cross-stakeholder comparison analysis specifically examined similarities and differences in perspectives among managers, system administrators, operational users, trainers, technology providers, and policy stakeholders identifying consensus areas regarding effectiveness determinants while revealing stakeholder-specific priorities requiring balanced consideration. Competency analysis mapped required skills against current capabilities identifying critical gaps requiring training attention. Training effectiveness analysis combined reported outcomes with performance indicators evaluating program impacts. Technology analysis examined how system characteristics affect user adoption and utilization effectiveness. Organizational analysis identified contextual factors enabling or constraining competency development and technology acceptance. Relationship analysis explored connections between training quality, personnel competency, system utilization, and operational performance outcomes. Narrative synthesis wove findings into comprehensive understanding connecting competency requirements, training approaches, technology factors, organizational contexts, and effectiveness outcomes, providing practical frameworks for optimizing human-technology integration in container terminal operations.

3. Results and Discussion

3.1 Results

The research findings provide comprehensive insights into container terminal information system requirements, training and competency development practices, technology factors, organizational influences, and effectiveness relationships determining operational outcomes.

Table 1. Container Terminal Information System Functions and Competency Requirements.

System Function	Critical Capabilities	Required User Competency Level*	Competency Gap Severity**	Operational Impact
Vessel Planning	Stowage plan optimization, discharge/load sequencing, berth allocation	Advanced (4-5/5)	High (4.2/5.0)	Critical - affects vessel turnaround
Yard Management	Container location tracking, storage optimization, equipment routing	Intermediate-Advanced (3-4/5)	Moderate-High (3.8/5.0)	High - determines productivity
Gate Operations	Container check-in/out, documentation validation, appointment management	Intermediate (3/5)	Moderate (3.2/5.0)	Moderate - affects truck flow
Equipment Control	Crane/RTG assignment, automated equipment coordination, maintenance scheduling	Intermediate-Advanced (3-4/5)	Moderate-High (3.9/5.0)	High - affects handling efficiency
Documentation Processing	EDI message handling, customs clearance, cargo release authorization	Intermediate (3/5)	High (4.0/5.0)	Critical - affects cargo availability
Performance Analytics	KPI dashboards, productivity analysis, bottleneck identification	Advanced (4-5/5)	Very High (4.5/5.0)	Moderate-High - supports improvement
Customer Service	Container tracking, status queries, exception handling	Basic-Intermediate (2-3/5)	Moderate (3.3/5.0)	Moderate - affects customer satisfaction
System Administration	User management, configuration, database maintenance, integration	Expert (5/5)	Moderate (3.4/5.0)	Critical - ensures system reliability

*Competency level on 5-point scale: 1=basic awareness, 2=basic operation, 3=proficient operation, 4=advanced optimization, 5=expert system mastery **Gap severity on 5-point scale: 1=minimal gap, 5=critical competency shortage

Results demonstrate that vessel planning and documentation processing require advanced competencies (levels 4-5) yet exhibit high competency gaps (4.2 and 4.0 respectively), creating operational vulnerabilities where inadequate personnel capabilities compromise critical functions. Performance analytics shows very high competency gap (4.5) reflecting that even when systems provide sophisticated analytical capabilities, insufficient user expertise prevents effective utilization. The competency gap severity averaging 3.2-4.5 across functions indicates substantial human capability shortfalls relative to system requirements and operational needs.

Table 2. Current Training Approaches and Effectiveness.

Training Approach	Implementation Frequency (n=32)	Typical Duration	Training Quality Assessment***	Effectiveness Rating****	Primary Limitations
Vendor Initial Training	30 (94%)	2-5 days	Moderate (3.2/5.0)	Moderate (3.3/5.0)	Too brief, generic content, limited follow-up
Internal Onboarding	28 (88%)	1-3 weeks	Moderate (3.0/5.0)	Moderate (3.1/5.0)	Inconsistent delivery, limited resources
On-the-Job Learning	32 (100%)	Ongoing	Variable (2.5/5.0)	Moderate (3.2/5.0)	Unstructured, depends on mentors, knowledge gaps
Formal Competency Programs	12 (38%)	Months	Moderate-Good (3.8/5.0)	Good (4.0/5.0)	Limited availability, resource intensive

Refresher Training	15 (47%)	1-3 days annually	Moderate (3.1/5.0)	Moderate (3.0/5.0)	Irregular scheduling, incomplete coverage
Advanced Skills Training	8 (25%)	3-10 days	Good (3.9/5.0)	Good (3.8/5.0)	Very limited access, selective participation
E-Learning Modules	18 (56%)	Self-paced	Moderate (3.3/5.0)	Moderate-Low (2.8/5.0)	Engagement challenges, lacks hands-on practice
Cross-Functional Training	10 (31%)	Variable	Moderate-Good (3.5/5.0)	Good (3.6/5.0)	Infrequent, operational constraints

***Quality assessment on 5-point scale: 1=poor quality, 5=excellent quality
 ****Effectiveness rating on 5-point scale: 1=ineffective, 5=highly effective

Training approach analysis reveals that while vendor initial training (94%) and on-the-job learning (100%) are nearly universal, their moderate effectiveness ratings (3.3 and 3.2) and quality assessments (3.2 and 2.5) indicate these alone prove insufficient for comprehensive competency development. Formal competency programs, though most effective (4.0), are implemented by only 38% of terminals reflecting resource constraints and short-term operational focus. Advanced skills training, also highly effective (3.8), reaches only 25% of terminals creating capability gaps in sophisticated system functions. The moderate-to-good effectiveness ratings (2.8-4.0) combined with limited implementation of most effective approaches suggests substantial improvement opportunity through enhanced training investment.

Table 3. Personnel Characteristics Affecting System Utilization Effectiveness.

Personnel Characteristic	High-Effectiveness Profile	Low-Effectiveness Profile	Impact on Utilization*****	Improvement Potential
Educational Background	University engineering/IT degree	Secondary school only	High (4.3/5.0)	Moderate through training
Prior Experience	3+ years terminal operations	Less than 1 year	High (4.4/5.0)	High through mentoring
Technological Aptitude	High computer literacy, quick learner	Limited computer skills, slower adoption	Very High (4.7/5.0)	Moderate-High through training
Learning Orientation	Proactive learner, seeks knowledge	Passive, avoids complexity	High (4.5/5.0)	Moderate through culture change
Analytical Thinking	Strong problem-solving, data interpretation	Procedural focus, limited analysis	High (4.2/5.0)	Moderate-High through development
Communication Skills	Effective coordination, clear expression	Limited interaction capability	Moderate-High (3.9/5.0)	Moderate through training
Language Proficiency	Strong English for system interfaces	Limited English capability	Moderate-High (4.0/5.0)	High through training, localization
Motivation Level	Career-oriented, performance-driven	Job-focused, minimum effort	High (4.3/5.0)	Moderate through incentives
Change Adaptability	Embraces updates, flexible approach	Resistant to change, prefers routine	High (4.4/5.0)	Moderate through change management

*****Impact rating on 5-point scale: 1=minimal impact, 5=critical determining factor

Personnel characteristics analysis reveals that technological aptitude exerts very high impact (4.7) on utilization effectiveness—critical finding suggesting that selection and development of technology-oriented personnel constitutes priority investment. Learning orientation (4.5), change adaptability (4.4), and prior experience (4.4) also show high impacts, validating that personal attributes and development orientation critically determine how effectively individuals utilize sophisticated systems. The moderate-to-high improvement potential across most characteristics suggests that while some attributes reflect innate aptitudes, systematic development programs can substantially enhance capabilities.

Table 4. Technology Factors Influencing Utilization Effectiveness.

Technology Factor	Positive Characteristics	Negative Characteristics	Frequency of Issues (n=32)	Impact on Effectiveness*****	Improvement Priority
User Interface Design	Intuitive navigation, clear visual hierarchy	Complex menus, unclear functions	24 (75%)	High (4.3/5.0)	Very High
System Reliability	99%+ uptime, minimal errors	Frequent crashes, data corruption	20 (63%)	Very High (4.8/5.0)	Critical
Functionality Alignment	Matches actual workflows, relevant features	Forces workarounds, missing functions	26 (81%)	High (4.5/5.0)	Very High
System Response Speed	Real-time updates, fast queries	Delays, timeouts, slow processing	22 (69%)	High (4.2/5.0)	High
Integration Quality	Seamless data flow between systems	Manual re-entry, inconsistencies	28 (88%)	Very High (4.6/5.0)	Critical
Documentation Quality	Comprehensive manuals, clear guidance	Limited documentation, confusing instructions	27 (84%)	Moderate-High (4.0/5.0)	High
Error Handling	Clear error messages, recovery guidance	Cryptic errors, system crashes	23 (72%)	Moderate-High (4.1/5.0)	High
Customization Capability	Adaptable to local needs, configurable	Rigid structure, limited flexibility	19 (59%)	Moderate-High (3.8/5.0)	Moderate-High

*****Impact on effectiveness rated on 5-point scale: 1=minimal impact, 5=critical impact

Technology factors analysis reveals that system reliability exerts very high impact (4.8) on effectiveness—unsurprising finding that unreliable systems undermine user confidence and operational continuity regardless of functional sophistication. Integration quality (4.6) and functionality alignment (4.5) also show very high impacts, validating that technical capability must match operational requirements and connect seamlessly with other systems. The high frequency of issues across most factors (59-88%) indicates widespread technology shortcomings constraining effectiveness regardless of personnel competency—critical finding suggesting that human factors optimization alone proves insufficient without addressing technical limitations.

Table 5. Organizational Factors Influencing Competency Development.

Organizational Factor	Positive Environment	Negative Environment	Observed Frequency*****	Influence on Development	Required Interventions
Training Budget Allocation	3-5% of operational budget	Less than 1% of budget	Negative prevalent (78%)	Very High (4.7/5.0)	Strategic investment commitment
Management Support	Active participation, resource provision	Lip service, minimal support	Mixed (53% negative)	Very High (4.8/5.0)	Leadership engagement, accountability
Performance Management	Competency-based evaluation, development focus	Output-only metrics, no skill assessment	Negative prevalent (72%)	High (4.5/5.0)	Comprehensive performance systems
Workplace Culture	Learning-oriented, error tolerance for development	Blame culture, resistance to training time	Mixed (59% negative)	High (4.4/5.0)	Cultural transformation initiatives
Career Development Paths	Clear progression tied to competency	Limited advancement opportunity	Negative prevalent (81%)	High (4.3/5.0)	Career framework development

Knowledge Management	Systematic documentation, sharing mechanisms	Individual knowledge hoarding	Negative prevalent (69%)	Moderate-High (4.0/5.0)	Knowledge systems implementation
Change Management	Structured approach, communication, support	Ad hoc changes, minimal preparation	Negative prevalent (75%)	High (4.2/5.0)	Professional change management
Training Time Availability	Scheduled development time, operational coverage	Training sacrificed for immediate demands	Negative prevalent (84%)	Very High (4.6/5.0)	Operational planning, staffing

*****Observed frequency describes percentage exhibiting negative characteristics among studied terminals

Organizational factors analysis reveals that training time availability (influence 4.6, 84% negative prevalence) represents most critical constraint, with operational pressures consistently compromising development activities—fundamental barrier requiring systematic addressing through operational planning and adequate staffing. Management support (influence 4.8, 53% negative) and training budget allocation (influence 4.7, 78% negative) also show very high influence, validating that organizational commitment determines human capital development success more than specific training methodologies. The predominantly negative environment prevalence (53-84%) across most factors indicates that organizational contexts frequently undermine competency development regardless of training program quality—sobering finding requiring fundamental organizational transformation rather than training program adjustments alone.

Table 6. Training and Competency Impact on Operational Performance.

Performance Metric	Low Competency/Training	High Competency/Training	Improvement Magnitude	Economic Impact
System Utilization Rate (% of features actively used)	30-45%	65-85%	80-180% improvement	Better ROI on system investment
Operational Error Rate (errors per 1000 transactions)	12-25 errors	3-8 errors	50-70% reduction	Fewer costly mistakes, rework reduction
Container Moves per Hour (productivity)	22-28 moves	28-38 moves	25-40% increase	Substantial throughput improvement
Planning Optimization (% achieving optimal plans)	40-55%	70-85%	45-90% improvement	Better resource utilization
Documentation Processing Time (minutes per container)	8-15 minutes	3-6 minutes	50-75% reduction	Faster cargo release
Customer Query Resolution Time	15-30 minutes	5-12 minutes	60-75% faster	Enhanced service quality
System Downtime Impact (productivity loss during outages)	70-85% loss	30-45% loss	40-70% better resilience	Business continuity improvement
Innovation Adoption Rate (new features utilized)	15-30% adoption	60-80% adoption	200-400% improvement	Continuous improvement capability

Performance relationship analysis demonstrates that high competency enabled through comprehensive training generates substantial operational improvements across all metrics. The 50-70% operational error reduction directly improves quality and reduces costly rework. The 25-40% productivity increase translates to significant throughput enhancement without

infrastructure investment. The 60-75% faster customer service directly enhances competitive positioning and customer satisfaction. The 200-400% improved innovation adoption enables continuous operational advancement leveraging system enhancements. These improvements collectively validate that competency development investments generate compelling returns through multiple performance dimensions.

Table 7. Comprehensive Training and Competency Development Framework.

Framework Component	Implementation Approach	Resource Requirements	Expected Outcomes	Implementation Priority
Competency Assessment	Structured evaluation of current capabilities, skill gap analysis	Moderate - assessment tools, evaluator time	Clear development needs identification	Very High - foundational
Structured Onboarding	Comprehensive 4-8 week program covering system basics to intermediate functions	High - curriculum development, trainer time, trainee time	Consistent baseline competency	Very High - critical foundation
Role-Based Training	Specialized programs for planners, yard controllers, gate operators, analysts	High - multiple curricula, specialized trainers	Function-specific expertise	High - targeted development
Advanced Skills Development	Programs for optimization, analytics, system administration	Moderate-High - expert trainers, advanced content	Sophisticated capability building	High - competitive advantage
Continuous Learning Programs	Regular refresher training, update briefings, skill enhancement	Moderate - ongoing resource allocation	Sustained competency currency	High - long-term effectiveness
Mentoring Systems	Experienced personnel guiding less experienced users	Low-Moderate - time allocation, formalization	Knowledge transfer, practical learning	High - cost-effective development
E-Learning Supplementation	Self-paced modules for reference and reinforcement	Moderate - content development, platform	Flexible learning access	Moderate-High - accessibility
Performance Support Tools	Job aids, quick reference guides, embedded help systems	Moderate - development, maintenance	On-demand guidance	Moderate-High - immediate utility
Competency Certification	Formal assessment and certification of skill levels	Moderate - assessment development, administration	Validated capabilities, motivation	Moderate-High - quality assurance
Career Development Integration	Linking competency to advancement, compensation	Low-Moderate - framework development	Motivation, retention	High - strategic alignment

Framework recommendations emphasize that comprehensive approaches addressing multiple development mechanisms prove more effective than single training interventions, requiring sustained organizational commitment and adequate resource allocation. The structured onboarding (very high priority) establishes critical foundation preventing downstream competency gaps. Role-based and advanced training build specialized expertise supporting operational excellence. Continuous learning sustains currency preventing skill degradation. Mentoring provides cost-effective knowledge transfer. The framework integration of formal training, informal learning, performance support, and career development creates comprehensive competency ecosystem supporting sustained effectiveness.

Discussion

The research findings illuminate critical dimensions of container terminal information system effectiveness while revealing how the interplay between personnel competency, training quality, technology characteristics, and organizational context determines operational

outcomes, with human factors frequently constituting limiting factors constraining returns on technology investments.

The competency requirements analysis revealing that vessel planning and performance analytics require advanced skills (levels 4-5) yet exhibit high competency gaps (4.2 and 4.5) demonstrates fundamental misalignment between system sophistication and user capabilities—critical finding explaining why terminals possessing sophisticated systems frequently fail to achieve expected performance improvements (Zhou et al., 2024). The very high competency gap in performance analytics (4.5) particularly significant given growing emphasis on data-driven operations, suggesting that even when systems provide powerful analytical capabilities, insufficient personnel expertise prevents effective utilization leaving potential insights undiscovered and optimization opportunities unrealized. The documentation processing competency gap (4.0) despite seemingly straightforward function reflects that EDI systems and customs integration involve complex rules and exception handling requiring substantial knowledge beyond basic data entry skills. The universal presence of competency gaps (severity 3.2-4.5) across all functions validates central research premise that technology deployment without commensurate human capability development leaves systems underutilized and operations suboptimal regardless of technological sophistication (Caldas et al., 2024).

The training approach analysis revealing that most effective methods—formal competency programs (effectiveness 4.0) and advanced skills training (effectiveness 3.8)—are implemented by only 38% and 25% of terminals respectively while universal approaches—vendor initial training and on-the-job learning—show moderate effectiveness (3.3 and 3.2) demonstrates that training investment patterns prioritize convenient, low-cost approaches over effective development programs, reflecting short-term cost focus and inadequate recognition of human capital development's strategic importance (Liao & Lee, 2023). The vendor initial training limitations—typically 2-5 days covering basic system operation with generic content inadequately addressing specific operational contexts—create weak foundations requiring extensive subsequent learning that often occurs haphazardly through trial-and-error rather than structured development. The on-the-job learning variability (quality 2.5) reflects that without structured mentoring programs and performance support tools, learning depends heavily on individual initiative and mentor availability, creating inconsistent competency development across personnel. The limited availability of advanced skills training (25% implementation) particularly problematic given sophisticated system capabilities requiring expert users for effective utilization, creating situation where expensive analytical and optimization functions remain unused by personnel lacking competency to leverage them (Kim et al., 2022).

The personnel characteristics analysis identifying technological aptitude as very high impact factor (4.7) with learning orientation (4.5), change adaptability (4.4), and prior experience (4.4) also showing high impacts validates that individual differences substantially affect system utilization effectiveness, suggesting that personnel selection considering these attributes alongside formal qualifications could improve overall workforce capability (Paridaens & Notteboom, 2021). The technological aptitude finding particularly significant in maritime context where personnel often enter industry through traditional seafaring or logistics backgrounds not emphasizing computer literacy, creating need for either targeted recruitment of technology-oriented individuals or substantial technology skills development for existing personnel. The learning orientation impact (4.5) validates that proactive learners who actively seek knowledge and explore system capabilities achieve superior utilization compared to passive learners who master only immediately required functions, suggesting that cultivating learning culture and supporting self-directed development could enhance overall competency beyond formal training programs. The moderate-to-high improvement

potential across most characteristics provides optimistic perspective that while some attributes may reflect relatively stable individual differences, systematic development programs can substantially enhance capabilities even for personnel without naturally high technological aptitudes (Caldeirinha et al., 2024).

The technology factors analysis revealing that system reliability (impact 4.8), integration quality (4.6), and functionality alignment (4.5) exert very high influence on utilization effectiveness demonstrates that technology shortcomings can undermine competency development and utilization regardless of training quality—critical finding suggesting that human factors optimization must accompany technology quality assurance for effective human-technology integration (Mwendapole & Jin, 2021). The high frequency of reliability issues (63%) particularly problematic as system crashes and data corruption erode user confidence, create learned helplessness where users avoid advanced features perceived as unreliable, and force workarounds bypassing systems perceived as untrustworthy. The integration quality problems (88% frequency) requiring manual data re-entry between systems waste substantial personnel time while creating transcription errors and frustration undermining technology acceptance. The functionality misalignment (81% frequency) where systems force workflows different from operational practices creates resistance and workarounds, with users perceiving systems as obstacles rather than enablers—fundamental adoption barrier requiring greater vendor understanding of actual operational contexts and user-centered design approaches incorporating operator input into system development (Du et al., 2023).

The organizational factors analysis revealing that training time availability (influence 4.6, 84% negative prevalence), management support (influence 4.8, 53% negative), and training budget allocation (influence 4.7, 78% negative) constitute most critical yet frequently deficient enablers validates that organizational commitment determines human capital development success more than specific training methodologies, with inadequate organizational support undermining even well-designed training programs (Chae et al., 2021). The training time availability constraint where operational pressures consistently compromise development activities reflects fundamental tension between short-term operational demands and long-term capability building, requiring strategic recognition that sustained competitiveness requires investment in development even at short-term operational convenience cost. The management support inadequacy (53% negative) particularly problematic as middle manager attitudes heavily influence frontline personnel development opportunities and learning culture, suggesting that engaging operational management as competency development champions constitutes critical implementation strategy. The limited training budget allocation (78% allocating less than 1% of operational budgets) compared to 3-5% recommended for knowledge-intensive industries reflects systematic undervaluation of human capital relative to physical infrastructure and technology investments, requiring fundamental strategic reorientation recognizing personnel competency as competitive differentiator (Pian et al., 2020).

The performance relationship analysis demonstrating that high competency training generates 50-70% operational error reduction, 25-40% productivity improvement, and 60-75% faster customer service validates compelling business case for human capital investment through multiple value mechanisms including quality improvement, throughput enhancement, and service excellence that collectively strengthen competitive positioning (Qi et al., 2022). The 50-70% error reduction directly improves operational quality while reducing costly rework, damage claims, and customer disputes—often overlooked training benefit overshadowed by productivity focus yet representing substantial economic value. The 25-40% productivity improvement achievable through better system utilization effectively expands capacity without infrastructure investment—particularly valuable for constrained

urban terminals where physical expansion faces land availability and cost barriers. The 200-400% improved innovation adoption rate enabling effective utilization of system enhancements and new capabilities supports continuous improvement and adaptive capacity essential for maintaining competitiveness in rapidly evolving container shipping industry. These multi-dimensional benefits strengthen training investment business cases beyond simple cost-benefit calculations, demonstrating that competency development constitutes strategic capability building rather than operational expense (Jian-ping et al., 2021).

The comprehensive training framework emphasizing structured onboarding, role-based specialization, advanced skills development, continuous learning, and career integration reflects systematic approach addressing diverse development needs across career stages and functional roles rather than one-size-fits-all programs inadequately meeting specific requirements. The structured 4-8 week onboarding (very high priority) establishes critical foundation preventing downstream competency gaps that require costly remediation, with comprehensive initial development proving more efficient than extended trial-and-error learning periods. The role-based training recognizes that planners, yard controllers, gate operators, and analysts require different competencies reflecting their distinct system utilization patterns and operational responsibilities, suggesting that generic training covering all functions superficially proves less effective than specialized programs developing function-specific expertise. The framework integration of formal training, mentoring, e-learning, performance support tools, and career development creates comprehensive competency ecosystem supporting sustained effectiveness through multiple reinforcing mechanisms rather than relying solely on periodic formal training events (Hu & Chen, 2023).

This research addresses significant gaps in port operations literature by systematically examining human factors in container terminal information systems, area receiving insufficient attention despite critical importance for technology effectiveness. The multi-stakeholder methodology integrating perspectives from managers, system administrators, operational users, trainers, and technology providers generates comprehensive insights spanning technical, human, and organizational dimensions. The Indonesian context provides important perspective on developing country port technology implementation where human capital constraints often exceed technological constraints.

The practical implications extend across multiple domains. For terminal operators, the research demonstrates compelling business cases for training investments through documented performance improvements while providing implementation frameworks. For technology providers, the findings reveal user capability constraints and technology design factors affecting adoption, informing user-centered development approaches. For training institutions, the competency requirements and effective approaches identified inform program development. For port authorities, the research provides evidence supporting sector-wide human capital development initiatives. For maritime education stakeholders, the findings highlight curriculum needs for modern port operations.

Future research should pursue several directions. Quantitative studies measuring training program effectiveness and competency-performance relationships would validate qualitative findings. Longitudinal research tracking competency development over career trajectories would inform long-term development strategies. Comparative research examining training approaches across different port operational contexts would identify best practices. Experimental research evaluating specific training methodologies would optimize program design. Technology usability research employing human factors methods would improve system design supporting user effectiveness.

4. Conclusion

This research demonstrates that container cargo information management system effectiveness at Indonesian terminals depends fundamentally on the interplay between personnel competency, training quality, technology characteristics, and organizational support, with human factors frequently constituting limiting factors constraining returns on technology investments. While terminals deploy sophisticated systems including TOS, PCS, and automated equipment control, competency gaps averaging 3.2-4.5 across critical functions prevent effective utilization. Current training approaches emphasizing brief vendor training and unstructured on-the-job learning prove inadequate for developing advanced competencies required for sophisticated system functions. Personnel characteristics including technological aptitude, learning orientation, and change adaptability substantially affect utilization effectiveness, while technology factors including reliability, integration quality, and functionality alignment critically influence adoption. Organizational contexts frequently undermine competency development through inadequate training time availability (84% negative prevalence), insufficient management support (53% negative), and limited budget allocation (78% allocating <1% of budgets). Comprehensive competency training programs can improve system utilization by 45-65%, reduce operational errors by 50-70%, and enhance productivity by 25-40% through better human-technology integration. Achieving these benefits requires systematic approaches encompassing structured onboarding, role-based specialization, advanced skills development, continuous learning, mentoring, and career integration, supported by adequate organizational commitment including training time allocation, management engagement, appropriate budgets, and learning-oriented culture. These findings contribute to port operations literature by demonstrating human factors' critical role in technology effectiveness, providing evidence-based frameworks for competency development, and advancing understanding of sociotechnical system optimization in maritime contexts.

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