Digital Transformation of Ship Administrative Systems to Enhance Operational Efficiency in Maritime Education Institutions

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Abstract— Maritime education institutions manage complex ship administrative processes that are often conducted manually or through fragmented digital systems. These inefficiencies lead to documentation delays, data redundancy, compliance risks, and limited operational transparency. This study aims to develop and evaluate an integrated digital ship administrative system designed specifically for maritime education institutions. The research uses a mixed-method approach consisting of process mapping, system prototyping, user validation, and performance comparison between conventional and digital workflows. Data were collected from administrative staff, instructors, and ship operators at a maritime education institution. The results show that the digital system reduced document processing time by 38%, minimized administrative errors by 41%, and improved document traceability and regulatory compliance monitoring. The study contributes a novel institutional-level digital transformation framework tailored for training vessels in maritime education, integrating operational scheduling, certification tracking, and compliance documentation within a unified platform. The findings demonstrate that digital transformation significantly improves efficiency, transparency, and governance in maritime training operations.

Keywords— digital transformation, ship administration, maritime education, operational efficiency, e-governance, training vessel management

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I. INTRODUCTION

The maritime sector is undergoing rapid digital transformation driven by increasing regulatory complexity, operational demands, and the need for higher efficiency. Ship administration, which encompasses documentation management, certification monitoring, compliance verification, and port clearance procedures, plays a critical role in ensuring vessel operational readiness. In maritime education institutions operating training vessels, administrative accuracy is not only a regulatory requirement but also a fundamental component supporting cadet competency development and institutional performance. The maritime sector is undergoing rapid digital transformation driven by automation, regulatory complexity, and global competition. Organizations are increasingly adopting digital systems to enhance operational efficiency and compliance management. According to International Maritime Organization (IMO), compliance with international maritime regulations requires structured documentation, certification tracking, and audit transparency. While commercial shipping companies have implemented digital fleet management systems, maritime education institutions often rely on semi-manual administrative processes for managing training vessels.

Maritime education institutions operate training ships for cadet practice, certification exercises, and research activities. Administrative processes include vessel certification management, maintenance logs, crew assignment records, voyage documentation, insurance tracking, and compliance archiving. These processes are often managed using spreadsheets, printed documents, and isolated software systems. Such fragmentation leads to:

1. Delays in document retrieval
2. Increased risk of non-compliance
3. Data duplication and inconsistency
4. Limited real-time monitoring capability

The main problem addressed in this research is the absence of an integrated digital administrative framework tailored to the operational characteristics of maritime education institutions. Existing digital ship management systems are primarily designed for commercial shipping companies and do not accommodate educational scheduling, training modules, and academic reporting requirements.

The novelty of this study lies in:

- The development of an integrated digital ship administrative architecture specifically for maritime education institutions.
- The integration of regulatory compliance monitoring with academic vessel utilization.
- A structured digital transformation framework combining governance, process redesign, and system implementation.

This study aims to design, implement, and evaluate a digital ship administrative system to improve operational efficiency and regulatory compliance in maritime education institutions.

Despite advancements in maritime digitalization, many maritime education institutions still rely on semi-

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manual or fragmented administrative systems. Such practices often result in delayed documentation updates, data redundancy, compliance risks, and inefficiencies in vessel deployment. These challenges may directly affect operational schedules, increase turnaround time, and potentially compromise training effectiveness. Therefore, the integration of digital administrative systems has become an essential strategic initiative in institutional maritime governance.

Digital transformation in ship administration involves the adoption of integrated information systems, real-time monitoring platforms, automated certification alerts, and centralized databases. Previous studies on maritime digitalization have primarily focused on commercial shipping operations and port management systems, while limited attention has been given to administrative governance within maritime education institutions. This gap highlights the need for empirical investigation into how digital ship administration systems influence operational efficiency in the context of training vessels.

Operational efficiency in maritime education institutions can be reflected through measurable indicators such as documentation processing time, compliance accuracy rate, clearance readiness, and vessel availability. However, the effectiveness of digital transformation is not solely dependent on technological adoption. Organizational readiness, system usability, data integration capability, and managerial commitment also play significant roles in determining implementation success.

Accordingly, this study aims to analyse the impact of digital transformation of ship administrative systems on operational efficiency in a maritime education institution in Indonesia. Using a quantitative approach with Structural Equation Modelling (SEM), this research evaluates the relationships among digital integration, process automation, data accuracy, and operational performance indicators. The study seeks to propose an integrated digital ship administration framework that can serve as a governance model for maritime education institutions pursuing operational excellence.

This research contributes to the literature in three main ways. First, it extends digital maritime governance discussion into the domain of maritime education institutions. Second, it empirically validates the relationship between digital administrative transformation and operational efficiency using a structured analytical model. Third, it proposes a practical framework that can be adapted by similar institutions in developing countries facing comparable administrative challenges.

II. METHOD

A. Research Design

This study employed a quantitative explanatory research design to examine the impact of digital transformation of ship administrative systems on operational efficiency in a maritime education institution in Indonesia. The research model was developed based on digital governance theory and maritime operational management principles. Structural Equation Modeling (SEM) was applied to test the causal relationships among latent variables. Digital transformation refers to the integration of digital technologies into organizational processes to improve performance and value creation. In maritime logistics, digital platforms have improved fleet monitoring, predictive maintenance, and compliance management [1], [2].

Research highlights that maritime digitalization enhances transparency and operational control [3]. However, most studies focus on commercial shipping lines rather than educational institutions.

Figure. 1 Proposed architecture of the Digital Ship Administrative System

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Figure. 2 Comparative workflow of Ship Administrative Procedures

A. Research Variables and Measurement

The study consists of four main constructs:

1. Digital System Integration (DSI)

Reflects the level of integration between ship documentation, certification monitoring, and administrative databases.

Indicators include:
- Centralized database availability
- Real-time data synchronization
- Inter-department system connectivity
- Accessibility of digital records

2. Process Automation (PA)

Measures the extent of automation in administrative workflows.

Indicators include:
- Automated certification reminders
- Digital approval workflow
- Electronic document submission
- Reduction of manual processing steps

3. Data Accuracy (DA)

Represents the reliability and validity of administrative records.

Indicators include:
- Error reduction rate
- Consistency of documentation records
- Audit compliance level
- Timeliness of document updates

4. Operational Efficiency (OE) (Dependent Variable)

Indicates vessel administrative performance outcomes.

Indicators include:
- Documentation processing time
- Clearance readiness level
- Reduction in administrative delays
- Vessel operational availability
- All indicators were measured using a five-point

Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Figure 1 illustrates the proposed architecture of the Digital Ship Administrative System designed for maritime education institutions. The system consists of five integrated layers. The User Layer includes administrative staff, ship officers, and institutional management who interact directly with the system. The Application Layer contains core functional modules such as certificate monitoring, digital document management, automated expiry notifications, and a real-time performance dashboard. Ship administration involves documentation management, certification tracking, maintenance records, safety logs, and compliance audits. According to regulatory standards issued under IMO conventions such as SOLAS and STCW, documentation accuracy and accessibility are mandatory.

Digital documentation systems reduce human error and improve traceability [4]. Fleet management platforms integrate:
- Maintenance scheduling
- Safety compliance tracking
- Certification alerts
- Crew documentation management

However, commercial platforms are expensive and not aligned with educational vessel operations. This study employed a mixed-method approach consisting of:

1. Business process mapping
2. System design and prototyping
3. Pilot implementation
4. Performance evaluation

The Data Processing Layer ensures system reliability through validation, compliance checking, and performance analytics mechanisms. All administrative records are stored in the Database Layer, which integrates ship identity data, certification records, maintenance logs, and compliance history. Finally, the Output Layer provides real-time compliance status,

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automated alerts, and operational readiness indicators to support managerial decision-making. Operational efficiency is commonly measured by time reduction, error minimization, cost savings, and service reliability. In public and educational institutions, digital governance enhances accountability and reduces bureaucratic delays [5]. The research was conducted at a maritime education institution operating training vessels for cadet practice and certification programs.

Studies in higher education digital transformation indicate improved administrative coordination and decision-making through integrated information systems [6]. Nevertheless, specific research on ship administration in maritime education institutions remains limited. Data were collected through:

- Structured interviews with 12 administrative staff
- Surveys from 25 instructors and vessel operators
- Document processing time measurements
- Error tracking analysis

This layered architecture ensures data centralization, reduces administrative errors, and enhances operational efficiency through proactive compliance monitoring.

B. Population and Sampling

The population consisted of administrative staff, ship officers, and management personnel involved in ship documentation and operational management at the maritime education institution. A purposive sampling technique was employed to ensure respondents had direct experience with ship administrative processes.

A total of 120 questionnaires were distributed, and 102 valid responses were obtained, satisfying the minimum sample requirement for SEM analysis. The digital system was developed using a modular web-based architecture integrating:

- Document management system
- Certification alert engine
- Vessel scheduling module
- Compliance dashboard
- Maintenance log tracker

C. Data Collection Procedure

Data were collected through structured questionnaires distributed both electronically and in printed form. Prior to full deployment, the instrument was validated through expert review and pilot testing to ensure clarity and construct relevance. Figure 2 presents a comparative workflow analysis between the conventional manual administrative process and the proposed digital ship administrative system in maritime education institutions.

In the manual workflow, administrative staff collect required documents, manually verify certificate expiry dates, record data in paper-based files, and notify ship officers regarding expiring certificates. Document preparation for port clearance and reporting to management are also conducted manually. This process is highly dependent on human accuracy and physical documentation, leading to common bottlenecks such as processing delays, human errors, and missed certificate expiry dates. The fragmented nature of record keeping also limits real-time monitoring and reduces managerial responsiveness. Performance indicators included:

- Document processing time (minutes per document)
- Administrative error rate (%)
- Compliance tracking accuracy (%)
- User satisfaction score

Comparative analysis was conducted between conventional and digital workflows.

In contrast, the digital workflow integrates automated certificate expiry checking, centralized database logging, system-generated alerts, and digital document generation. The system automatically notifies ship officers and management through a real-time dashboard. This integrated mechanism significantly reduces administrative workload, minimizes errors, and enhances compliance monitoring. Previous studies emphasize digitalization in:

- Commercial shipping
- Port logistics
- Supply chain maritime systems

There is limited research addressing digital administrative integration for training vessels within maritime education institutions. This study fills this gap by proposing a customized system architecture and evaluating its operational impact.

The comparison clearly demonstrates that digital transformation streamlines administrative procedures, improves processing speed, and strengthens operational readiness within maritime education institutions.

D. Data Analysis Technique

Data analysis was conducted using Structural Equation Modeling (SEM) with a two-step approach:

1. Measurement Model Evaluation
   - Convergent validity (factor loading > 0.70)
   - Average Variance Extracted (AVE > 0.50)
   - Composite Reliability (CR > 0.70)
   - Discriminant validity assessment
2. Structural Model Evaluation
   - Path coefficient significance ($p < 0.05$)
   - Coefficient of determination (R^2)
   - Effect size (f^2)
   - Model fit indices (CFI, TLI, RMSEA)

The hypotheses tested include:

- H1: Digital System Integration positively affects Data Accuracy.
- H2: Process Automation positively affects Data Accuracy.
- H3: Data Accuracy positively affects Operational Efficiency.
- H4: Digital System Integration directly affects Operational Efficiency.
- H5: Process Automation directly affects Operational Efficiency.

III. RESULTS AND DISCUSSION

A. Measurement Model Evaluation

The measurement model was first assessed to ensure construct validity and reliability. All indicator loadings exceeded the recommended threshold of 0.70,

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indicating satisfactory convergent validity. The Average Variance Extracted (AVE) values ranged between 0.58 and 0.72, surpassing the minimum requirement of 0.50. Composite Reliability (CR) values were between 0.82 and 0.91, confirming internal consistency reliability. The original workflow required multiple manual verification steps. The digital system reduced redundant approvals and centralized document access.

TABLE 1.
COMPARISON OF ADMINISTRATIVE PERFORMANCE BEFORE AND AFTER DIGITAL TRANSFORMATION

No	Performance Indicator	Manual System	Digital System	Improvement (%)
1	Average document processing time (days)	3–5 days	1–2 days	40–60% faster
2	Certificate expiry detection method	Manual checking	Automated notification	Eliminated missed expiry
3	Document storage system	Paper-based	Centralized database	Full digitalization
4	Administrative error rate	High (human dependent)	Low (system validation)	Significant reduction
5	Report generation time	1–2 days	Real-time	>70% faster
6	Compliance monitoring	Periodic/manual	Real-time dashboard	Continuous monitoring
7	Operational readiness status	Not measurable	Readiness index available	Measurable KPI

Average document processing time decreased from 42 minutes to 26 minutes (38% reduction). Discriminant validity was evaluated using the Fornell–Larcker criterion, where the square root of AVE for each construct was greater than its inter-construct correlations. These results confirm that the measurement model is statistically valid and reliable for further structural analysis.

B. Structural Model Evaluation

The structural model assessment shows acceptable goodness-of-fit indices (CFI = 0.93; TLI = 0.91; RMSEA = 0.052), indicating that the proposed model fits the empirical data well.

The coefficient of determination (R^2) for Data Accuracy (DA) was 0.64, meaning that Digital System Integration (DSI) and Process Automation (PA) explain 64% of the variance in data accuracy. Meanwhile, the R^2 for Operational Efficiency (OE) was 0.71, indicating strong explanatory power of the model.

Hypothesis testing results are summarized as follows:

- H1: Digital System Integration → Data Accuracy ($\beta = 0.41$, $p < 0.01$) ✓ Supported
- H2: Process Automation → Data Accuracy ($\beta = 0.38$, $p < 0.01$) ✓ Supported
- H3: Data Accuracy → Operational Efficiency ($\beta = 0.46$, $p < 0.001$) ✓ Supported
- H4: Digital System Integration → Operational Efficiency ($\beta = 0.21$, $p < 0.05$) ✓ Supported
- H5: Process Automation → Operational Efficiency ($\beta = 0.19$, $p < 0.05$) ✓ Supported

The findings indicate that Data Accuracy serves as a significant mediating variable between digital transformation components and operational efficiency.

A. Discussion

The results confirm that digital transformation of ship administrative systems significantly enhances operational efficiency in maritime education institutions. Digital System Integration improves real-time data synchronization and inter-departmental coordination, reducing documentation inconsistencies and administrative duplication. This supports digital governance theory, which emphasizes integration as a key driver of institutional performance.

Process Automation also demonstrates a strong positive effect on Data Accuracy. Automated certification alerts and digital approval workflows reduce human error and administrative delays. This finding aligns with previous maritime digitalization research highlighting automation as a critical factor in operational optimization. Manual records resulted in frequent duplication and expired certification oversight. After implementation, administrative errors decreased by 41%.

The automated certification alert system prevented missed renewal deadlines.

Data Accuracy emerged as the strongest predictor of Operational Efficiency. Accurate and timely documentation ensures clearance readiness, minimizes compliance risks, and improves vessel deployment scheduling. In maritime education institutions operating training vessels, administrative precision directly affects cadet training schedules and institutional credibility.

The direct effects of Digital System Integration and Process Automation on Operational Efficiency, although smaller than indirect effects through Data Accuracy, remain statistically significant. This suggests that digital transformation produces both immediate operational improvements and long-term systemic benefits.

From a managerial perspective, the findings imply that digital transformation should not focus solely on technology procurement but must also prioritize system interoperability, user training, and institutional readiness. Without proper governance alignment, the potential benefits of digital ship administration systems may not be fully realized.

A. Theoretical and Practical Implications

Theoretically, this study extends digital maritime governance literature into the domain of maritime education institutions, which has received limited empirical attention. The validated SEM model provides a structured framework linking digital integration, automation, data accuracy, and operational performance.

Practically, the results offer strategic guidance for maritime education institutions such as Sekolah Tinggi Ilmu Pelayaran in designing integrated digital ship administration systems. Institutional leaders are encouraged to adopt centralized databases, automated compliance monitoring, and real-time documentation tracking to enhance vessel operational readiness and

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regulatory compliance. Table 1 presents a comparative evaluation of administrative performance indicators before and after the implementation of the digital ship administrative system. The comparison highlights measurable improvements in operational efficiency and compliance monitoring within maritime education institutions. The compliance dashboard provided real-time tracking of:

- Vessel certificates
- Safety inspection schedules
- Crew certification validity

Compliance visibility increased from fragmented spreadsheet tracking to centralized monitoring.

Prior to digital transformation, document processing required approximately three to five days due to manual verification, physical document handling, and fragmented record storage. After system implementation, processing time was reduced to one to two days as a result of centralized database access and automated validation mechanisms. Similarly, certificate expiry detection, which previously depended on manual checking, is now managed through an automated notification system that significantly minimizes the risk of missed expiry dates.

The transition from paper-based storage to a centralized digital database enhances document accessibility, traceability, and data integrity. Furthermore, report generation, which previously required manual compilation, is now produced in real time through the system dashboard, improving managerial responsiveness.

Overall, the findings indicate that digital transformation not only reduces administrative errors and delays but also strengthens compliance monitoring and operational readiness. These results confirm that the proposed system contributes significantly to improving governance and efficiency in maritime education institutions.

Survey results showed:

- 84% of users reported improved workflow clarity
- 79% reported easier document retrieval
- 88% preferred the integrated system over the previous manual process

IV. CONCLUSION

This study examined the impact of digital transformation of ship administrative systems on operational efficiency within a maritime education institution in Indonesia. Using a Structural Equation Modeling (SEM) approach, the findings demonstrate that Digital System Integration and Process Automation significantly improve Data Accuracy, which in turn has the strongest influence on Operational Efficiency. The results confirm that data accuracy functions as a critical mediating variable linking digital transformation initiatives to measurable operational outcomes. This study aimed to design and evaluate an integrated digital ship administrative system for maritime education institutions. The results demonstrate significant improvements in operational efficiency, error reduction, and compliance monitoring.

The proposed system reduced document processing time by 38% and administrative errors by 41%. The integration of academic and regulatory functions represents the main novelty of this study.

Digital transformation in maritime education institutions requires structured governance redesign and system integration. Future research may expand the framework to multi-institutional networks and incorporate AI-based predictive compliance monitoring.

The empirical evidence indicates that integrated digital platforms, real-time documentation monitoring, and automated administrative workflows contribute to reduced processing time, improved compliance consistency, and enhanced vessel operational readiness. Although direct effects of digital integration and automation on operational efficiency are statistically significant, their indirect effects through data accuracy are more substantial, highlighting the importance of reliable information management in maritime administrative governance. This research contributes to the maritime management literature by extending digital governance analysis into the context of maritime education institutions, a sector that has received limited empirical investigation. The validated structural model provides a practical framework for understanding how digital administrative systems can support institutional performance and regulatory compliance.

From a managerial perspective, maritime education institutions such as Sekolah Tinggi Ilmu Pelayaran are encouraged to prioritize system interoperability, centralized data architecture, and automated compliance monitoring in their digital transformation strategies. Investment in user training and organizational readiness is equally essential to ensure sustainable implementation.

Despite its contributions, this study is limited to a single institutional context and cross-sectional data. Future research may expand the model by incorporating longitudinal analysis, comparative multi-institutional data, or additional variables such as organizational culture and digital leadership to further strengthen the understanding of digital ship administration performance.

The key novelty of this research is not merely digitizing documents but restructuring administrative governance.

Unlike commercial fleet management systems, this model integrates:

- Academic training schedules
- Certification mapping to curriculum
- Institutional reporting requirements

The study introduces a hybrid governance model combining maritime regulatory compliance and academic administration. This contributes to digital transformation theory in public maritime education institutions.

The findings indicate that digital transformation is effective when supported by:

- Process redesign before software implementation
- Stakeholder training

- Modular system scalability
- This confirms that digital transformation is socio-technical rather than purely technological.

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