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Enterprise Architecture Design for Non-Container Terminal Services: A Case Study of PT Pelindo Multi Terminal (SPMT)

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Abstract: Enterprise Architecture (EA) is a framework used to align business strategy with information technology in an integrated manner. However, in non-container terminal operations, the implementation of Information Systems/Information Technology (IS/IT) is still fragmented and has not been supported by a standardized enterprise architecture, making it difficult to achieve integration and optimize business processes. To support the standardization and digitalization of non-container terminal operations, EA design is required so that the development of information systems and technology can be carried out in a structured manner and aligned with business needs. This study aims to develop an EA design as a guideline for the development of Information Systems/Information Technology (IS/IT) in non-container terminal service companies, covering loading, unloading, receiving, and delivery processes. This research uses a qualitative method through interviews and document analysis. Thematic analysis of interview transcripts and documents is conducted to identify operational needs and existing system issues. The EA design is developed using the TOGAF 10 ADM framework, starting from the Business Architecture phase to the Technology Architecture phase. The results of this study are in the form of a business, data, application, and technology architecture blueprint that supports standardization, integration, and automation of operational processes through the implementation of systems such as SCADA, the development of PTOS-M, Warehouse Management System (WMS), and the utilization of the Internet of Things (IoT). The proposed architecture is expected to improve operational efficiency, system integration, and service quality in non-container terminal operations. This design is also expected to serve as a reference for IS/IT standardization and integration, as well as to contribute to the development of EA in the context of non-container terminals. Specifically, this architecture model uniquely integrates Information Technology (IT) and Operational Technology (OT) to enable real-time operational visibility and terminal automation, while incorporating security measures across both IT and OT layers.

Keyword: Enterprise Architecture, TOGAF 10, Unloading, Loading, Receiving, Delivery

INTRODUCTION

Indonesia, as a maritime country, relies on sea transportation to support interregional connectivity, logistics, trade, and economic distribution (Destyanto et al., 2021). Ports serve as key interfaces between sea and land transportation, facilitating the flow of goods, money, and information while supporting efficient logistics and regional connectivity (Adabere et al., 2021; UNCTAD, 2021). Consequently, integrated port governance, digitalized operations, and intermodal coordination play a crucial role in improving port logistics performance by enhancing efficiency, effectiveness, and service quality (Sirajuddin et al., 2025).

As port operational complexity increases, digital transformation is a multidimensional process that integrates digital technology and strategies to improve operational performance, communication, and decision-making (Almeida, 2023). Technologies such as the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), and automation are essential for efficient logistics management (Richnák, 2022). However, limited system integration, poor data interoperability, and continued reliance on manual processes hinder operational coordination, leading to higher logistics costs, longer dwell times, and lower logistics performance in Indonesian ports (Lu & Xu, 2024; Notteboom et al., 2021; Sirajuddin et al., 2025).

Pelindo Multi Terminal (SPMT) has established its 2022–2026 IT roadmap to accelerate digital transformation and achieve operational excellence toward becoming a world-class port operator. Accordingly, Enterprise Architecture (EA) is required to provide a structured and integrated framework for information system development aligned with the organization's strategic objectives using the TOGAF ADM framework (Santika & Yulhendri, 2024).

EA aligns business processes, information systems, data, and technology to support digital transformation and organizational goals (Alghamdi, 2024). Selecting an appropriate EA framework is essential to ensure effective implementation within the organizational context (Hadjarati et al., 2025). Among existing frameworks, TOGAF ADM provides a structured approach for aligning business and IT while improving interoperability and organizational performance (Alkadrie et al., 2025; Kornyshova & Deneckère, 2022).

EA enables organizations to establish an integrated system landscape that reduces process fragmentation, improves interoperability, enhances operational effectiveness, and accelerates decision-making (Octaviani, 2025). Despite its digital transformation initiatives, SPMT has yet to develop a standardized EA to guide the integrated development of information systems and technology. Without a standardized EA, the implementation of digital transformation may result in fragmented IS/IT development, inconsistent business–IT alignment, and reduced operational integration across the organization.

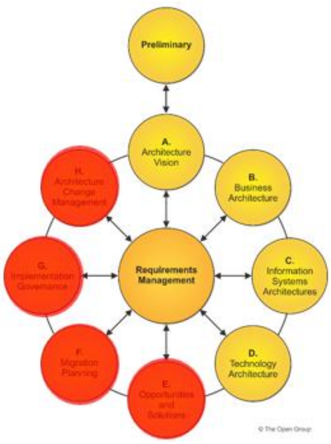
While EA has been widely applied across various sectors, limited attention has been given to cascading EA from the holding company to the subholding level to ensure strategic alignment while addressing operational requirements. This study introduces a cascading EA approach that translates the holding-level architecture into a subholding-specific architecture while preserving strategic alignment and accommodating operational requirements. Based on this gap, this study aims to design an EA for SPMT using the TOGAF ADM framework to support business alignment, operational integration, and digital transformation.

This study contributes both practically and academically. Practically, it provides a standardized EA design that serves as a guideline for IS/IT development aligned with SPMT's business processes and strategic objectives. Academically, it extends the application of TOGAF ADM by demonstrating a cascading EA approach from the holding to the subholding level, providing a reference for future studies on enterprise-wide digital transformation.

METHOD

The research focuses on EA design for the non-container terminal operations at SPMT, covering the business processes of unloading, loading, receiving, and delivery business processes. Primary data were collected through document analysis and semi-structured interviews with key stakeholders representing both strategic and operational perspectives. The interview participants included representatives from the Holding IT Division, Subholding IT Division, Transformation Management Office (TMO), and the Operations Planning and Development Division. The data were analyzed using open coding involving coding to identify patterns and grouping them into themes. The coding results were then mapped to TOGAF phases: Preliminary and Architecture Vision (scope and objectives), Business Architecture (business processes and issues), Application and Data Architecture (system usage, integration, and data flow), and Technology Architecture (infrastructure and technology constraints). These themes were used as inputs for current state analysis, future design, and gap analysis across the TOGAF domains.

In the port and logistics sector, TOGAF ADM has been shown to facilitate the development of integrated EA that support smart port initiatives, improve interoperability among information systems, streamline operational processes, and align technology investments with business objectives (Afifah et al., 2024; Daniel et al., 2025; Hotman et al., 2024). Based on the TOGAF ADM framework, the development of EA is carried out through several stages, namely the Preliminary Phase, Architecture Vision, Business Architecture, Information Systems Architecture, and Technology Architecture, as shown in Figure 1 (The Open Group, 2022). From these stages, an initial design of EA is produced to support the subsequent implementation process.



Source : The Open Group, 2022

Figure 1. TOGAF ADM Domain

The Preliminary Phase

focuses on establishing the architecture capability, defining architecture principles, governance, scope, and preparing the organization for EA development (The Open Group, 2022). This phase identifies organizational objectives, stakeholders, digital transformation needs, and operational challenges to establish the scope, architecture principles, and requirements for EA development.

The Architecture Vision Phase

aims to define a high-level vision of the EA initiative that aligns with organizational business objectives (The Open Group, 2022). This architecture vision describes the desired future condition (architecture target) concisely and in alignment with the organization's strategy. Additionally, the architecture vision considers the needs and interests of stakeholders, as well as the business value to be achieved through EA development.

The Business Architecture Phase

is concerned with developing the baseline and target business architecture by identifying business processes, organizational functions, business services, and stakeholder requirements (The Open Group, 2022). This phase involves identifying operational inefficiencies, such as suboptimal equipment utilization and unsynchronized coordination between units, and developing a target business architecture to improve operational efficiency.

The Information Systems Architecture Phase

defines the Data Architecture and Application Architecture required to support business processes and organizational objectives (The Open Group, 2022). Information systems are designed to support data integration and real-time decision-making, resulting in an integrated architecture that enables business processes and digital transformation.

The Technology Architecture Phase

focuses on defining the technological infrastructure required to support business processes, data management, and application systems within the organization (The Open Group, 2022). This phase analyzes the current technology infrastructure, defines the target architecture, and identifies technology gaps to produce a technology architecture blueprint that supports integrated information systems.

RESULTS AND DISCUSSION

To explain the analysis process at each stage of EA design, this study presents a summary of data analysis based on the phases within the TOGAF framework. Data analysis in each TOGAF phase is conducted using information gathered from document reviews (Company Long-Term Plan, EA Holding, SOPs, and application catalogs) and stakeholder interviews to understand current conditions and organizational needs. The TOGAF ADM phases consist of the Preliminary Phase, Architecture Vision Phase, Business Architecture Phase, Information Systems Architecture Phase, and Technology Architecture Phase.

Preliminary

The resulting business architecture includes the identification of core business processes, business functions, and the relationships between integrated processes, particularly in supporting the operations of non-containerized services such as unloading, loading, receiving, and delivery. SPMT establishes three main business objectives as the foundation of the company's digital transformation. These objectives are realized through three business pillars supported by three key enablers and serve as a reference in the preparation of SPMT's IT Master Plan, the detailed explanation of which can be seen in Table 1.

Table 1. The Purpose of Digital Transformation

Transformation Purpose	Description
Enhancing Internal Business and Service Excellence	Improving the efficiency and effectiveness of internal processes through operational automation, system integration, and data-driven decision making
Breakthrough Business Expansion & Commercialization	Driving growth through the development of digital innovation in operations, market expansion, and the creation of new adaptive and value-added business models
Business Sustainability	Ensuring business continuity through the implementation of technology that supports resource efficiency, operational resilience, and adaptation to market changes

Source: Research data

The business architecture scope focuses on SPMT's core operational services, including unloading, loading, receiving, and delivery, as defined by the holding's business capability model for non-container terminal operations. The architecture principles are established to ensure that EA development aligns with business objectives and digital transformation. Business principles emphasize standardization, integration, and operational sustainability; data principles promote secure, accessible, and shareable data to support integration and decision-making; application principles focus on system integration and Single Sign-On (SSO) to improve usability; and technology principles emphasize interoperability through open standards and API-based integration.

Architecture Vision

The architecture vision is derived from the organization's vision, mission, business objectives, and architectural principles to define the desired future state and guide stakeholders in EA development. The translation of business strategy into architectural initiatives is performed by identifying Critical Success Factors (CSFs), business process requirements, and current organizational conditions to determine organizational capability gaps and define the target architecture. CSFs help identify the organizational priorities that are critical to achieving strategic objectives and provide a foundation for aligning business requirements with EA development and implementation (Muhaemin et al., 2024; Rouhani et al., 2019), which can be seen in Table 2.

Table 2. Strategy to Innovation

Strategy	CSF	Gap	Innovation	Code
Terminal Development by Service, Commodity, Packaging and/or Areas	Standardization of terminal services, Integration of terminals and industrial areas, Operational visibility, Integration of data and systems	- Services have not yet been differentiated based on cargo commodities and packaging types - System integration with industrial zones has not been optimized. - Operational visibility is not yet end-to-end and real-time	Terminal service catalog, End-to-end process integration, Real-time data-based planning and control	IB01
Development of Ship to Ship (STS) Handling Loading and Unloading Services	Ship operational coordination, Operational system integration, Real-time monitoring	- Standardized Ship-to-Ship (STS) handling processes have not yet been established - Operational coordination remains suboptimal and largely manual - Real-time visibility of STS operations has not yet been achieved	Standardization of the STS process, Real-time data-based scheduling, Monitoring and control of STS	IB02
Standardization, Systematization, and Operational Integration of non-container services	Process standardization, Perform-ance monitoring, Operational automation, Warehouse manage-ment efficiency	- Operational processes have not yet been standardized - Inventory management and cargo movement tracking are not yet accurate - Operational processes have not yet been automated and remain largely manual	End-to-end process integra-tion, Data-driven warehouse, Real-time monitoring and control automation	IB03

Strategy	CSF	Gap	Innovation	Code
Development of Port Infrastructure and Equipment	Equipment availability, Preventive and predictive maintenance	- Equipment utilization has not yet been optimized - Maintenance activities are not yet properly planned and have not adopted a predictive approach	Optimization of integrated equipment, Transformation of predictive maintenance	IB04

Source: Research data

Mapping Business Process Innovation to Application and Data aims to identify the correlation between business process innovations and the supporting application and data requirements (Table 3). This approach ensures that the processes of unloading, loading, receiving, and delivery are supported by integrated information systems and consistent data management.

Table 3. Innovation in Business Process to Application and Data

Code	Required Application	Required Data
IB01	Service Catalog System, Integrated Port System	Service Data, Cargo & Load Data, Tariff & Payment Data, Ship Data, Service Data, Operational Data, Stakeholders Data
IB02	STS Operation Management System, Scheduling System, Real-time Operation Dashboard	Ship Data, Cargo & Load Data, Service Data, STS Operational Data, Equipment & Utilization Data, Operational Safety Data, STS Operational Status Data (Real-time), Ship Position Data, B/M Activity Data, Operational Performance Data (KPI)
IB03	Integrated Port System, Warehouse Management System, SCADA	End-to-end operational data (unloading, loading, receiving, delivery), stacking data, cargo & load/commodity data, sensor & equipment data, real-time operational data
IB04	Equipment Management System, Predictive Maintenance System	Utilization & Equipment Data, Usage Schedule Data, Sensor & Equipment Data, Equipment Utilization Data, Downtime & Failure Data

Source: Research data

SCADA is designed to support real-time monitoring and supervisory control of port equipment and utility systems, enhancing operational integration, equipment visibility, and data-driven decision-making (Argyriou & Tsoutsos, 2024). Warehouse Management System (WMS) is designed to integrate warehouse operations with the Integrated Port System by enabling real-time inventory visibility, storage management, and cargo traceability, thereby improving receiving and delivery processes and enhancing operational efficiency in non-container terminal operations (Inutsuka et al., 2024; Khan et al., 2024)

Mapping of Applications and Data to Infrastructure is carried out to ensure that the needs of applications and data are supported by adequate technology infrastructure (Table 4). The analysis results show that the current infrastructure still has limitations in terms of scalability, reliability, and security, making it suboptimal for integrated real-time operations.

Table 4. Application and Data to Infrastructure

Code	Required Application	Required Infrastructure
IB01	Service Catalog System, Integrated Port System	Cloud-based Platform, API Gateway, Centralized Database, Hybrid cloud, High Availability System, Enterprise Integration (API)

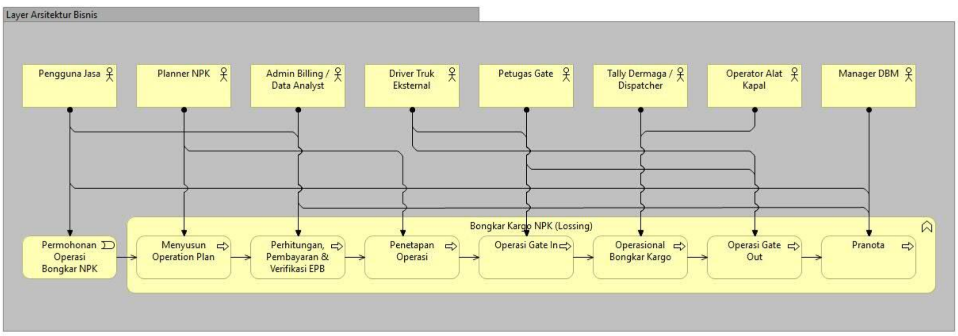
Code	Required Application	Required Infrastructure
IB02	STS Operation Management System, Scheduling System, Real-time Operation Dashboard	Edge Computing, Real-time Network, High Availability System, Cloud Computing, Enterprise Integration (API), Real-time Data Processing, BI tools, High Availability System (Server)
IB03	Integrated Port System, Warehouse Management System, SCADA	Warehouse network (WiFi/RFID), Mobile Device, Integration centralized database, Industrial Network (PLC/RTU/Switch), SCADA Server, Control Center, High Availability, DMZ
IB04	Equipment Management System, Predictive Maintenance System	Asset Management Platform, SCADA Integration, Database & Analytics Platform, Big Data Platform (data lake), AI/ML Platform, Cloud Computing

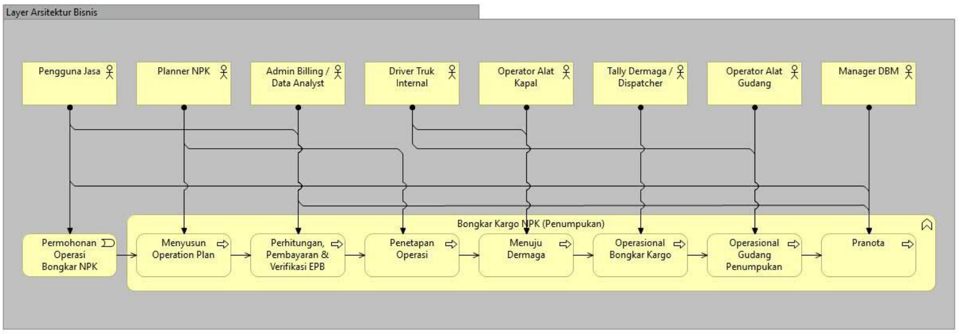
Source: Research data

The mapping from business strategy to business processes, applications, data, and technology infrastructure provides the foundation for developing the data, application, and technology architectures by translating digital transformation requirements into the applications, data, and infrastructure needed to support integrated business processes and operational performance. Accordingly, the required technology infrastructure supports integrated port operations through cloud computing, data management, system integration, industrial networks, SCADA, and security capabilities. These infrastructures enable real-time data exchange, interoperability between information technology (IT) and operational technology (OT), secure communication, and reliable operational monitoring to support digital port operations (Argyriou & Tsoutsos, 2024; Inutsuka et al., 2024; National Institute of Standards and Technology, 2023).

Business Architecture

This phase develops the target business architecture by identifying core business processes, business functions, and their relationships to support business objectives and integrated non-container terminal operations. The analysis focuses on non-container unloading operations, which include cargo transfer directly from vessels to customers or to temporary storage areas (yards or warehouses). The business process scope covers service requests, operational planning and scheduling, unloading execution, temporary storage management, and billing for completed services. The unloading business architecture can be seen in Figure 2.

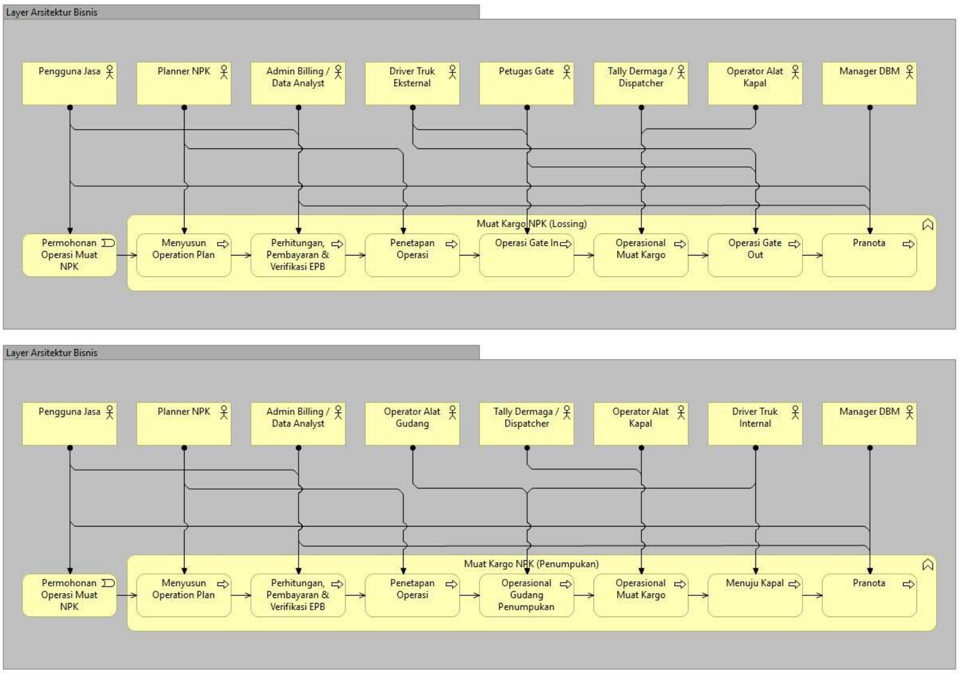




Source: Research data

Figure 2. Business Architecture for Unloading Services (Lossing & Stacking)

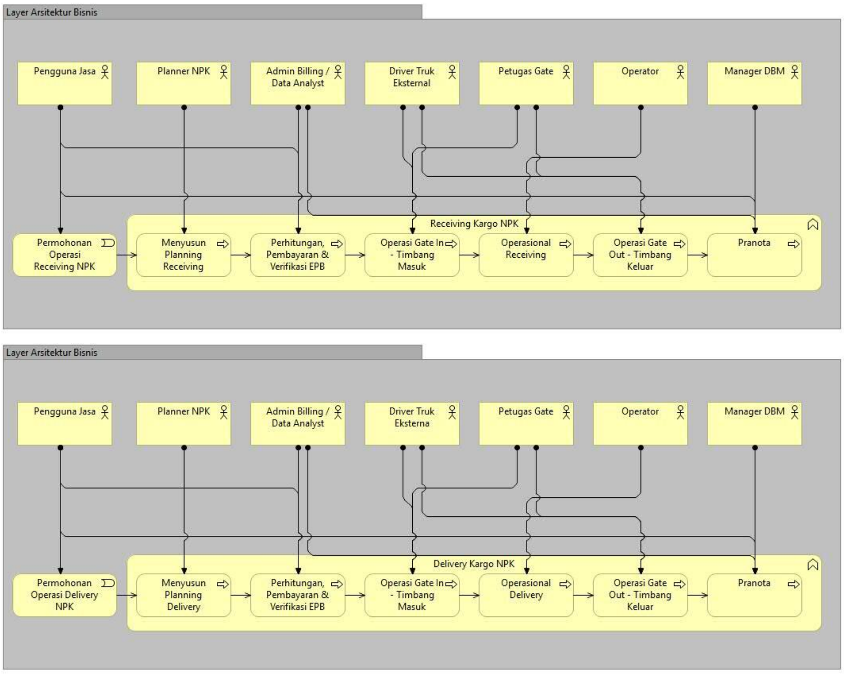
Non-container loading operations include direct loading of cargo from customers to vessels and loading from temporary storage areas (yards or warehouses) to vessels. The business process covers service requests, operational planning and scheduling, loading execution, and billing for completed services. The loading business architecture can be seen in Figure 3.



Source: Research data

Figure 3. Business Architecture for Loading Services (Lossing & Stacking)

Receiving operations involve the receipt and handling of cargo within the port area before loading onto vessels. The business process covers service requests, operational planning, cargo receiving, and billing for completed services. The business architecture of receiving and delivery can be seen in Figure 4.



Source: Research data

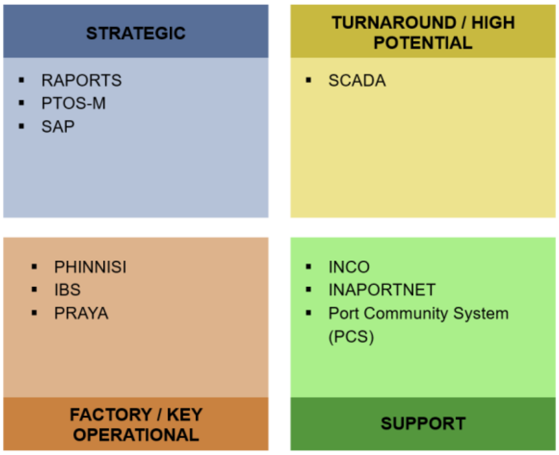
Figure 4. Business Architecture of Receiving and Delivery Services

Information Systems Architecture

This phase develops the target data and application architectures to support business objectives through integrated, adaptive, and data-driven business processes. The application architecture for loading and unloading operations enables the management of cargo handling, cargo tracking, equipment allocation, and stacking location assignment. Integrated with the Pelindo Terminal Operating System (PTOS-M) and operational equipment, the architecture improves data accuracy and supports planning, scheduling, and operational recording. For unloading and loading operations, SCADA enables real-time monitoring and control of cranes, pumps, conveyors, and flow meters through PTOS-M (Argyriou & Tsoutsos, 2024). Operational data are integrated with the WMS to automate cargo recording and movement (Inutsuka et al., 2024; Khan et al., 2024). Furthermore, AI-based analytics improve operational efficiency, resource utilization, and data-driven decision-making .

The application architecture for receiving and delivery digitalizes cargo receiving and delivery by enabling real-time monitoring of cargo movement from storage areas to gate-out. The receiving module manages service requests, document verification, vehicle monitoring, and cargo placement, whereas the delivery module manages cargo retrieval from storage areas. Both modules are integrated with PTOS-M, the gate system, and payment services to ensure data synchronization, operational validation, and real-time cargo traceability (Inutsuka et al., 2024).

The proposed applications were classified using the McFarlan Strategic Grid to determine their strategic role in supporting current operations and future business objectives. The resulting application portfolio, shown in Figure 5, provides a basis for prioritizing application development and implementation.



Source: Research data

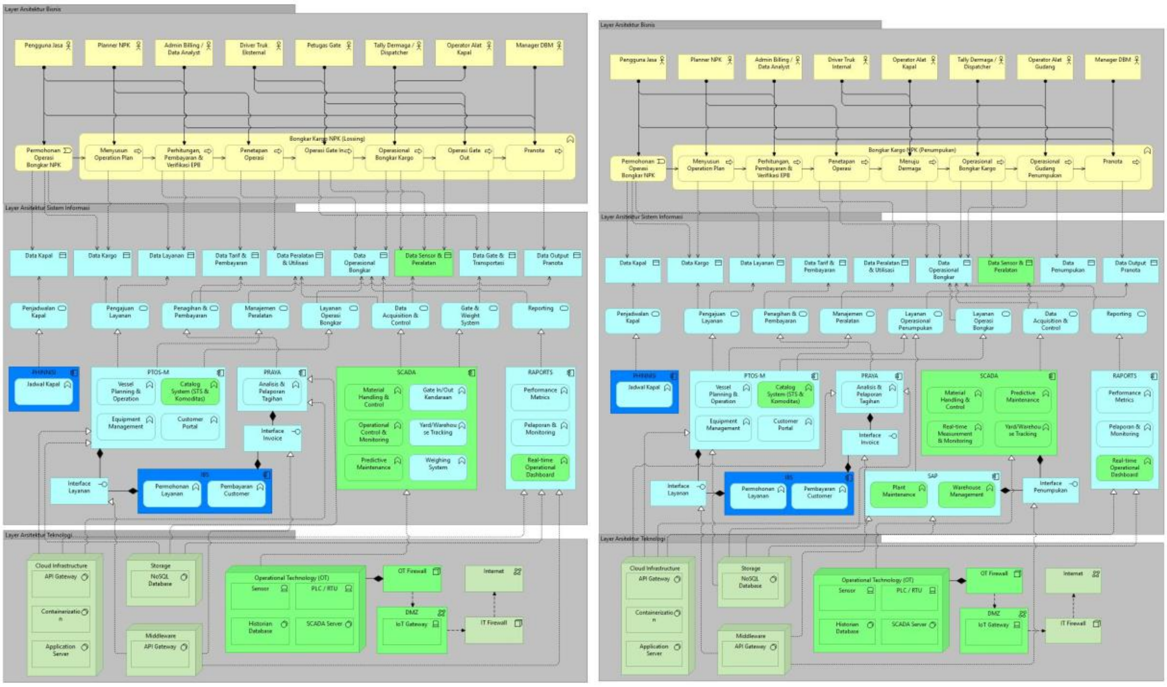
Figure 5. Application Portfolio

Technology Architecture

This phase develops the Technology Architecture based on the business and information systems architectures to establish a target technology environment aligned with the organization's business objectives. The proposed architecture provides an integrated, automated, and data-driven technology foundation to enhance the efficiency of non-container terminal operations, including unloading, loading, receiving, and delivery. It enables real-time planning, operational control, and monitoring of cargo and vessel movements through integrated digital technologies.

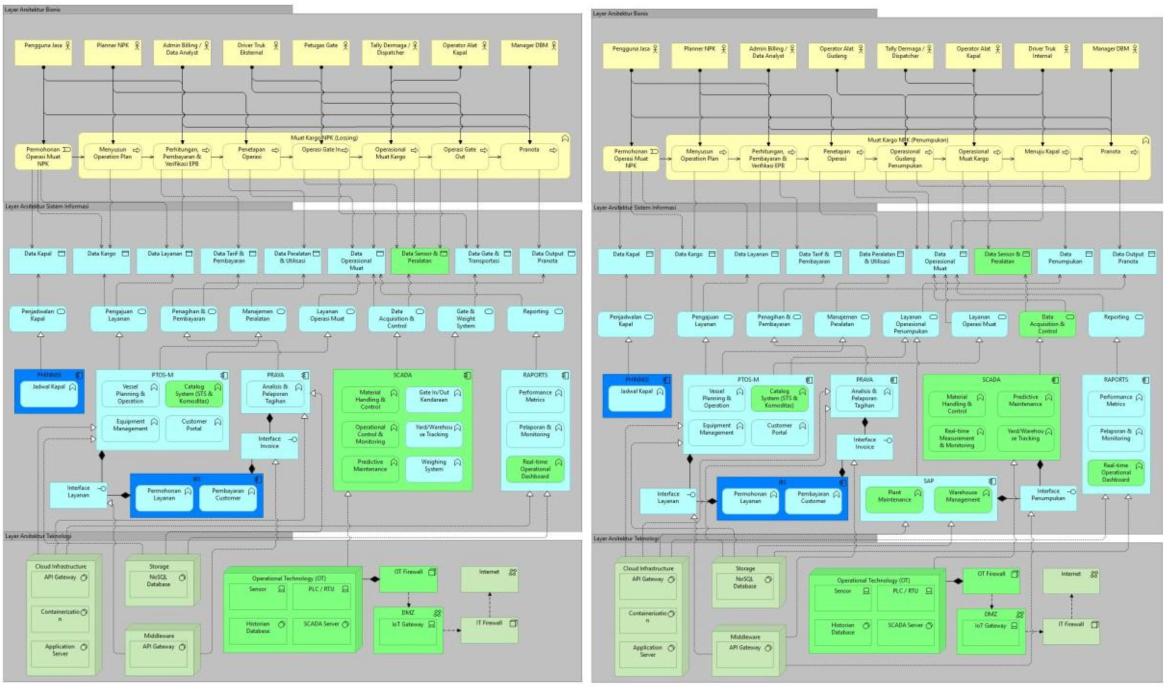
The implementation of technology at the subholding level strengthens the technology architecture of non-container ports through system virtualization, enhancing efficiency, availability, and centralized management. Data integration is facilitated by middleware solutions such as Kepware, enabling secure and real-time interoperability between Operational Technology (OT) and Information Technology (IT) systems while supporting industrial communication and network segmentation (Argyriou & Tsoutsos, 2024; National Institute of Standards and Technology, 2023). Furthermore, analytics platforms such as Power BI and Tableau are utilized to support performance monitoring, data visualization, and data-driven decision-making through integrated operational data.

Figures 6–8 illustrate the target Technology Architecture supporting the Information Systems Architecture for the unloading, loading, receiving, and delivery processes. The architecture depicts the integration of applications, data, operational technology (OT), and supporting infrastructure to enable real-time operations, secure IT–OT interoperability, and data-driven decision-making across non-container terminal operations.



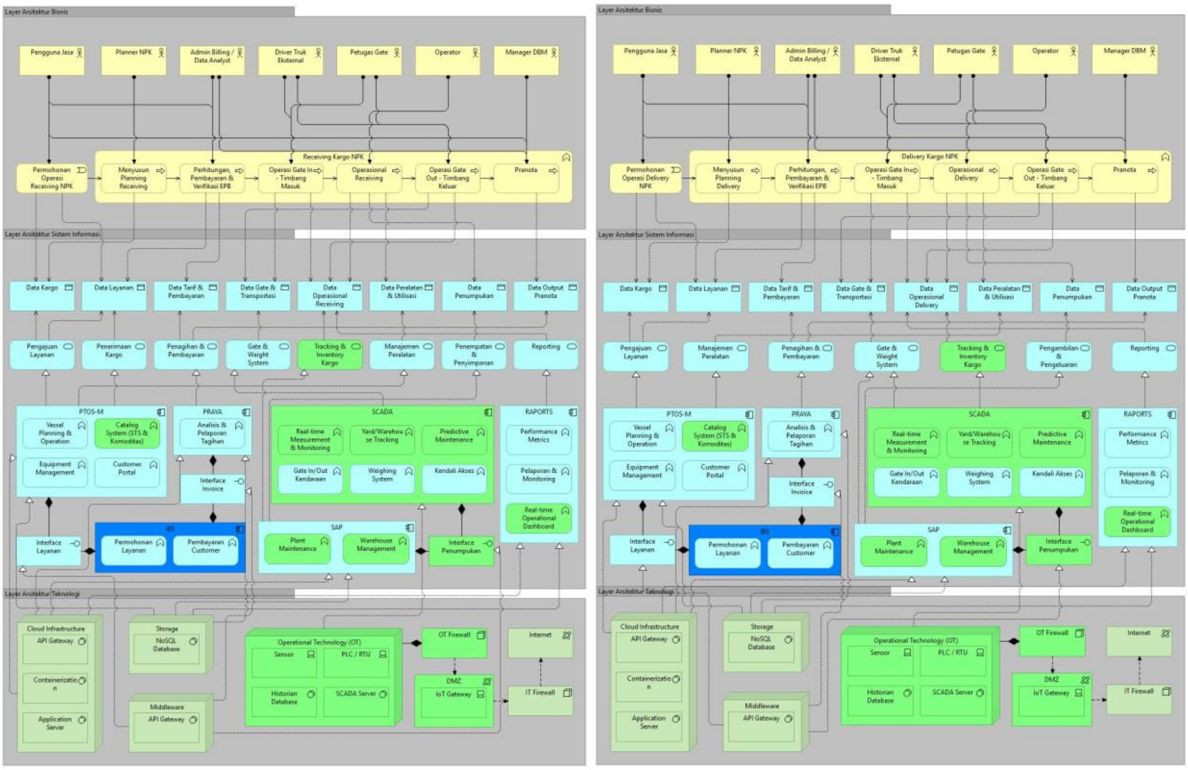
Source: Research data

Figure 6. Technology Architecture for Unloading Services (Lossing & Stacking)



Source: Research data

Figure 7. Technology Architecture for Loading Services (Lossing & Stacking)



Source: Research data

Figure 8. Technology Architecture for Receiving and Delivery Services

Impact Analysis

In this study, TOGAF serves as the methodological framework for the development of EA to support digital transformation at SPMT. An analysis of the impacts of this research on the organization and academia is presented in Tables 5 and 6.

Table 5. Analysis of the Research Impact on the Organization

TOGAF Phase	Results	Impact on the Organization
Preliminary	- The purpose of SPMT digital transformation - Scope of architecture - Architecture principles	- IT investment priorities are more focused and aligned with business strategy - Improvement of service efficiency and integration of operational processes - Strengthening governance and system integration
Architecture Vision	- Architecture vision - Digital transformation needs - Stakeholder identification	- Alignment of system development with organization strategy - Priority of digital solutions that support operations - Enhancement of business and IT collaboration
Business Architecture	- Documentation of main business processes - Analysis of target business processes	- Supporting the standardization and improvement of operational processes - Serving as the basis for system integration and process automation
Information System Architecture	- Data architecture artifacts - Application mapping and application architecture	- Improvement of data quality and integration - Reduction of application redundancy and ease of system integration
Technology Architecture	- Technology Architecture Target	- Improved technology security and performance - Optimization of infrastructure and real-time OT–IT integration - Supporting operational analytics and monitoring

Source: Research data

Table 6. Analysis of the Research Impact on Academia

Theoretical Framework	Results	Impact on the Academic
TOGAF ADM	Enterprise Architecture design from the Preliminary phase to the Technology Architecture	Providing empirical evidence of the end-to-end application of TOGAF ADM in the context of non-container terminals, which is still limited in the literature
Enterprise Architecture	Target architecture model	Developing an understanding of applying EA as a tool for digital transformation planning in port organizations
IT/IS Strategic Planning	Mapping business strategy to innovation, innovation to data and applications, and data and applications to infrastructure	Strengthening the concept of IT/IS strategic planning through tiered mapping from business strategy to innovation, then to data and application needs, all the way to technology infrastructure in the context of EA.
Cascading EA from the Holding to the Subholding	Adapting the strategic needs of the Holding (Pelindo) to the operational	Providing empirical evidence of the implementation of cascading EA in the holding–subholding organizational structure in the port sector

Source: Research data

The proposed Enterprise Architecture (EA) provides both organizational and academic contributions. From an organizational perspective, the EA serves as a blueprint for supporting the digital transformation of non-container terminal operations through the integration and standardization of business processes, information systems, and technology infrastructure. The architecture enables the development of integrated operational systems, real-time monitoring capabilities, predictive maintenance, and IT–OT integration, which are expected to improve operational efficiency, governance, and visibility. From an academic perspective, this study provides empirical evidence of the application of TOGAF ADM, EA, strategic IS/IT planning, and EA cascading within a holding–subholding structure in the context of non-container terminals. The findings contribute to the growing body of knowledge on EA implementation in the port industry and demonstrate its role in supporting digital transformation initiatives.

CONCLUSION

This study developed an Enterprise Architecture (EA) for a non-container terminal service company using the TOGAF ADM framework to support digital transformation and align information technology initiatives with business strategy. The proposed EA adopts a cascading approach by translating the holding-level architecture into a subholding-specific architecture while preserving strategic alignment and addressing operational requirements. The resulting EA blueprint encompasses the Business, Data, Application, and Technology Architecture domains and provides a structured guideline for IS/IT development in unloading, loading, receiving, and delivery operations.

The proposed architecture integrates Operational Technology (OT) and Information Technology (IT), including SCADA, WMS, the Terminal Operating System (TOS), and IoT, to enable operational integration, automation, and data-driven decision-making. It provides a foundation for improving operational efficiency, strengthening process and data integration, reducing application redundancy, and optimizing real-time IT–OT interoperability. Nevertheless, the proposed architecture remains conceptual and has not yet been implemented or evaluated in an operational environment. Future research should validate the proposed architecture through practical implementation and assess its impact on operational performance and digital transformation within non-container terminal operations.

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