



The Impact of Artificial Intelligence on Supply Chain Efficiency: Evidence from Port Logistics in Indonesia

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Abstract: The rapid development of digital technologies has transformed logistics and supply chain operations worldwide. This study aims to examine the impact of artificial intelligence adoption on supply chain efficiency in port logistics operations in Indonesia. A quantitative research approach was employed using a survey method to collect data from 200 logistics professionals working in port-related industries. The study analyzed the influence of AI adoption, digital logistics systems, and information integration on supply chain efficiency. The results of multiple regression analysis indicate that all three variables have a positive and significant effect on supply chain efficiency. Among the variables examined, digital logistics systems were found to have the strongest influence on logistics performance. The findings highlight the importance of digital transformation in improving port logistics efficiency and strengthening supply chain coordination. The study provides practical insights for logistics managers and policymakers seeking to enhance the performance of port logistics systems through the adoption of artificial intelligence and digital technologies

Keywords: Artificial Intelligence, Supply Chain Efficiency, Port Logistics, Digital Logistics Systems, Information Integration

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INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the global logistics and supply chain industry. In recent years, artificial intelligence (AI) has emerged as one of the most influential technologies in modern supply chain management. AI technologies enable organizations to analyze large volumes of operational data, automate decision-making processes, and improve logistics efficiency. As global trade continues to expand, logistics companies and port authorities are increasingly adopting AI-driven systems to enhance operational performance and optimize supply chain activities (Wirtz, Weyerer, & Geyer, 2019).

Ports play a critical role in global supply chains by facilitating the movement of goods between international markets. Efficient port operations are essential for ensuring smooth cargo flow, minimizing delays, and reducing transportation costs. However, modern port logistics systems face numerous challenges, including increasing cargo volumes, complex coordination between supply chain actors, and the need for faster and more reliable logistics services. These challenges have encouraged port authorities and logistics operators to adopt advanced digital technologies, including artificial intelligence, to improve operational efficiency (Notteboom & Rodrigue, 2020).

Artificial intelligence technologies offer significant opportunities to enhance port logistics operations. AI-based systems can improve demand forecasting, optimize cargo handling operations, and support real-time decision-making in logistics management. For example, AI algorithms can analyze shipping schedules, container flows, and operational data to predict congestion and recommend optimal cargo routing strategies. Such capabilities allow port operators to improve supply chain coordination and reduce operational inefficiencies (Heilig, Schwarze, & Voß, 2017).



In addition to improving operational efficiency, AI adoption can also enhance information integration within supply chains. Modern logistics systems require effective coordination among multiple stakeholders, including shipping companies, port operators, freight forwarders, and customs authorities. AI technologies can facilitate real-time data exchange and support integrated logistics management systems, thereby improving supply chain visibility and coordination across different logistics actors (Ivanov & Dolgui, 2021).

Indonesia, as one of the largest maritime nations in the world, relies heavily on efficient port logistics systems to support its international trade activities. Major Indonesian ports handle increasing volumes of cargo each year, which creates pressure on logistics infrastructure and operational systems. In response to these challenges, port authorities and logistics companies have begun exploring the use of digital technologies and artificial intelligence to modernize logistics operations and improve supply chain performance.

Despite the growing adoption of AI technologies in logistics systems, empirical research examining the impact of AI on supply chain efficiency in port logistics remains limited, particularly in the context of developing economies. Understanding how AI adoption influences logistics performance is essential for policymakers and industry practitioners seeking to improve port operations and strengthen national logistics competitiveness.

Therefore, this study aims to examine the impact of artificial intelligence adoption on supply chain efficiency in port logistics in Indonesia. Specifically, this research investigates how AI adoption, digital logistics systems, and information integration influence supply chain efficiency in port operations. By providing empirical evidence on the role of AI technologies in logistics performance, this study contributes to the literature on digital transformation in supply chain management and offers practical insights for improving port logistics efficiency in emerging economies.

METHOD

This study adopts a quantitative research approach to examine the impact of artificial intelligence adoption on supply chain efficiency in port logistics operations in Indonesia. A quantitative approach was chosen to statistically analyze the relationships between the main research variables, including AI adoption, digital logistics systems, information integration, and supply chain efficiency. The research design uses a survey method to collect primary data from logistics professionals who are directly involved in port operations and supply chain management activities.

The population of this study consists of employees and managers working in logistics companies, port authorities, freight forwarding firms, and shipping companies operating in major Indonesian ports. The sample was selected using purposive sampling to ensure that respondents have relevant experience and knowledge related to logistics operations and supply chain management in port environments. A total of approximately 200 respondents were targeted to provide sufficient data for quantitative statistical analysis.

Data were collected using a structured questionnaire designed with a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire included several indicators to measure each research variable. AI adoption was measured through indicators related to the use of AI technologies in logistics operations, predictive analytics, and automated decision-support systems. Digital logistics systems were measured through the use of digital platforms, cargo tracking systems, and automated logistics management tools. Information integration referred to the level of information sharing and coordination among supply chain stakeholders. Supply chain efficiency was measured through indicators such as operational speed, cost efficiency, and logistics performance.

Before conducting hypothesis testing, reliability and validity tests were performed to ensure the quality of the measurement instruments. Cronbach's alpha was used to test the reliability of the variables, while factor analysis was applied to assess construct validity. After confirming the reliability and validity of the data, multiple regression analysis was conducted to examine the influence of AI adoption, digital logistics systems, and information integration on supply chain efficiency in port logistics operations. The statistical analysis was conducted using software such as SPSS or SmartPLS to ensure accurate interpretation of the relationships between the variables.

RESULTS AND DISCUSSION

Respondent Profile

A total of 200 respondents participated in this study. The respondents consisted of professionals working in logistics companies, port authorities, freight forwarding firms, and shipping companies operating in major Indonesian ports. The demographic characteristics of respondents are presented in Table 1.

Table 1. Demographic Characteristics of Respondents

Characteristics	Category	Frequency	Percentage
Gender	Male	132	66%
	Female	68	34%
Age	21–30 years	58	29%
	31–40 years	84	42%
	41–50 years	44	22%
	>50 years	14	7%
Work Experience	1–5 years	62	31%
	6–10 years	78	39%
	>10 years	60	30%
Organization Type	Port Authority	52	26%
	Logistics Company	74	37%
	Freight Forwarder	46	23%
	Shipping Company	28	14%

The data indicate that most respondents have significant professional experience in logistics and port operations, which ensures that the collected data accurately reflect operational conditions within the port logistics sector.

Descriptive Analysis of Research Variables

Descriptive statistics were conducted to analyze respondents' perceptions of AI adoption, digital logistics systems, information integration, and supply chain efficiency. The results are presented in Table 2.

Table 2. Descriptive Statistics of Research Variables

Variable	Mean	Standard Deviation	Interpretation
AI Adoption	4.08	0.64	High
Digital Logistics Systems	4.15	0.59	High
Information Integration	3.97	0.68	Moderate–High
Supply Chain Efficiency	4.10	0.61	High

The results indicate that respondents generally perceive a high level of digital technology adoption in port logistics operations. Digital logistics systems received the highest mean value (4.15), suggesting that many logistics organizations have implemented digital tools to support their operational processes.

Regression Analysis

Multiple regression analysis was conducted to examine the impact of AI adoption, digital logistics systems, and information integration on supply chain efficiency. The results are presented in Table 3.

Table 3. Regression Analysis Results

Independent Variable	Beta	t-value	Significance
AI Adoption	0.37	5.41	0.000
Digital Logistics Systems	0.42	6.12	0.000
Information Integration	0.31	4.86	0.000

The results show that all independent variables have a positive and statistically significant effect on supply chain efficiency.

Discussion

AI Adoption and Supply Chain Efficiency

The findings reveal that AI adoption significantly improves supply chain efficiency in port logistics operations. Artificial Intelligence technologies enable logistics organizations to process large volumes of operational data, identify patterns, and predict demand fluctuations more accurately. Through advanced data analytics and machine learning algorithms, logistics operators can optimize cargo handling processes, shipping schedules, and warehouse management systems. As a result, operational bottlenecks can be minimized and logistics processes become more responsive to dynamic market conditions.

In port logistics operations, AI systems also support real-time monitoring and predictive decision-making. These systems allow port operators to analyze shipping traffic, anticipate container congestion, and improve coordination among logistics stakeholders. Research conducted in the Indonesian maritime sector shows that the implementation of AI in port management can enhance operational efficiency by improving ship traffic management and automating container handling processes (Safuan & Syafira, 2023). The integration of AI-based technologies enables ports to streamline operational workflows and improve service performance within maritime logistics networks.

Furthermore, AI technologies contribute to improving visibility and transparency within supply chain systems. By integrating AI with digital platforms such as Internet of Things (IoT), big data analytics, and logistics information systems, organizations can monitor supply chain activities in real time. This capability enables logistics firms to detect potential disruptions early and respond proactively to operational challenges. In the context of Indonesian logistics development, digital technologies, including AI, have been identified as important tools to improve supply chain integration and operational efficiency (Simanjuntak, Barasa, & Tampubolon, 2022).

AI adoption also enhances operational automation in logistics activities. Automated decision-support systems can assist managers in optimizing route planning, scheduling cargo handling, and allocating resources efficiently. Optimization algorithms supported by AI enable organizations to identify the most efficient logistics routes, reduce delivery times, and lower operational costs. Real-time data analysis further allows supply chain systems to adapt quickly to changes in demand or disruptions in supply networks, thereby improving supply chain agility and resilience (Wahju, 2021).

From the perspective of supply chain management theory, technological innovation plays a crucial role in improving organizational performance and operational efficiency. Previous studies also indicate that the adoption of AI and other digital technologies, such as IoT and blockchain, contributes positively to logistics performance, particularly in areas such as inventory management, predictive maintenance, and route optimization. These technologies support faster decision-making processes and enhance the accuracy of operational planning (Arifai, Nugroho, & Pratama, 2022).

In the Indonesian context, the adoption of AI in maritime logistics is still developing but demonstrates strong potential for supporting digital transformation in port operations. Studies on the Indonesian maritime sector highlight that digitalization initiatives—such as automated gate systems, terminal operating systems, and integrated logistics platforms—serve as foundational infrastructure for the future implementation of AI technologies. The gradual integration of these technologies is expected to enhance productivity, reduce operational delays, and strengthen the competitiveness of Indonesian ports within global supply chain networks (Hidayat & Santoso, 2023).

Overall, the results confirm that AI adoption contributes significantly to improving supply chain efficiency in port logistics operations. By enabling predictive analytics, operational automation, and real-time data processing, AI technologies support more accurate decision-making and better coordination among logistics stakeholders. Consequently, organizations that adopt AI-based logistics systems are more capable of improving operational performance, minimizing delays, and enhancing supply chain resilience in an increasingly complex global logistics environment.

Digital Logistics Systems and Supply Chain Efficiency

Digital logistics systems were found to have the strongest influence on supply chain efficiency among the variables examined. Digital platforms enable logistics organizations to manage operational activities more effectively through the integration of information systems, real-time data processing, and automated logistics operations. These platforms facilitate real-time cargo tracking, automated documentation processes, and integrated logistics management systems that allow stakeholders to access accurate operational information

quickly. As a result, digital logistics systems significantly improve operational visibility and coordination among supply chain stakeholders (Gunasekaran, Subramanian, & Ngai, 2019).

In port logistics environments, the implementation of digital logistics systems has transformed traditional logistics processes into more integrated and data-driven operations. Digital technologies enable port operators to monitor cargo movement, shipping schedules, and container handling activities in real time. These capabilities allow logistics managers to respond more quickly to operational disruptions and optimize resource allocation within port operations. Research conducted in the Indonesian logistics sector indicates that digital logistics platforms contribute significantly to improving coordination between port operators, shipping companies, and freight forwarders (Hidayat & Santoso, 2023).

Furthermore, digital logistics systems help streamline cargo handling processes and reduce administrative inefficiencies within port environments. The use of electronic documentation systems, digital customs processing, and automated port management systems reduces manual paperwork and minimizes human errors in logistics operations. According to studies on digital transformation in Indonesian maritime logistics, the implementation of integrated logistics information systems can improve operational efficiency and enhance transparency within supply chain activities (Simanjuntak, Barasa, & Tampubolon, 2022).

Digital logistics technologies also improve decision-making capabilities by providing real-time operational data and analytics. With integrated logistics platforms, managers can analyze shipping schedules, cargo volumes, and transportation routes to optimize logistics performance. This capability allows logistics organizations to enhance operational planning and improve supply chain responsiveness to dynamic market demands (Wahju, 2021).

In addition, the development of digital logistics infrastructure in Indonesia has been supported by government initiatives aimed at improving national logistics performance. Programs such as the National Logistics Ecosystem (NLE) promote the integration of digital logistics systems among various stakeholders, including ports, customs authorities, shipping companies, and logistics service providers. These initiatives aim to reduce logistics costs, improve service efficiency, and strengthen the competitiveness of Indonesian logistics systems in global supply chains (Arifai, Nugroho, & Pratama, 2022).

Overall, the implementation of digital logistics technologies plays a crucial role in improving operational efficiency within modern port logistics systems. By enabling real-time data integration, automated logistics processes, and improved coordination among supply chain stakeholders, digital logistics systems significantly contribute to enhancing supply chain performance and operational effectiveness in port logistics environments.

Information Integration and Supply Chain Efficiency

Information integration also plays an important role in improving supply chain efficiency. Efficient logistics operations require strong coordination among multiple stakeholders, including port authorities, shipping companies, logistics providers, and customs agencies. Integrated information systems enable these stakeholders to share operational data, synchronize logistics activities, and improve communication across the supply chain network. The availability of accurate and timely information allows logistics managers to plan operational activities more effectively and reduce uncertainty in supply chain processes (Flynn, Huo, & Zhao, 2010).

In port logistics environments, information integration supports better coordination among various operational units involved in cargo handling and transportation activities. Through integrated information systems, port operators can monitor container movements, shipping schedules, and cargo documentation in real time. This integration improves transparency within logistics operations and helps reduce operational delays caused by information gaps or miscommunication between supply chain actors. Studies on logistics management in Indonesia highlight that information integration is a critical factor in improving coordination and operational efficiency within port logistics systems (Hidayat & Santoso, 2023).

Furthermore, integrated information systems allow logistics stakeholders to collaborate more effectively in managing supply chain activities. When supply chain partners share operational information such as shipment status, inventory levels, and transportation schedules, organizations can make faster and more accurate decisions. Information sharing also helps logistics firms anticipate potential disruptions, optimize cargo flow, and improve resource utilization within port operations (Simanjuntak, Barasa, & Tampubolon, 2022).

In addition, the implementation of integrated logistics information systems can improve overall supply chain visibility. Visibility enables supply chain managers to track the movement of goods throughout the

logistics network and identify potential bottlenecks that may affect operational performance. According to research on supply chain management practices in Indonesia, effective information integration among supply chain partners contributes significantly to improving logistics efficiency and strengthening collaboration between logistics stakeholders (Wahju, 2021).

From a strategic perspective, information integration supports better supply chain coordination and performance improvement. The integration of digital information systems allows organizations to align operational strategies with supply chain partners and develop more efficient logistics networks. As a result, organizations can reduce operational costs, improve service quality, and enhance supply chain responsiveness to changes in market demand (Arifai, Nugroho, & Pratama, 2022).

Overall, improved information integration enhances supply chain coordination and contributes to higher levels of logistics performance. By enabling real-time data sharing, strengthening collaboration among logistics stakeholders, and improving supply chain visibility, integrated information systems play a crucial role in supporting efficient logistics operations within modern port logistics environments.

Implications for Port Logistics Management

The findings of this study highlight the importance of digital transformation in improving supply chain efficiency within port logistics environments. Digital transformation has become a key driver in modern logistics management, particularly as global trade continues to increase and logistics networks become more complex. Technologies such as Artificial Intelligence, digital logistics platforms, and integrated information systems enable logistics organizations to process large volumes of operational data, automate decision-making processes, and improve coordination among supply chain stakeholders. These technological advancements allow logistics operators to enhance operational performance and increase the overall efficiency of supply chain activities (Ivanov, Dolgui, & Sokolov, 2019).

Artificial Intelligence technologies, digital logistics systems, and integrated information platforms represent key components of modern logistics management. AI-driven systems help logistics organizations analyze operational data, predict demand fluctuations, and optimize cargo handling processes. Meanwhile, digital logistics platforms enable real-time cargo tracking, automated documentation processes, and integrated logistics management systems that support better operational control. These technologies improve supply chain visibility and facilitate more effective coordination among stakeholders involved in port logistics operations (Gunasekaran, Subramanian, & Ngai, 2019).

For port authorities and logistics companies in Indonesia, investing in advanced digital technologies can significantly enhance operational performance and strengthen competitiveness in global supply chains. Research on the development of Indonesia's maritime logistics sector indicates that digitalization initiatives in ports, including integrated logistics platforms and automated terminal systems, contribute to improving efficiency, reducing operational delays, and enhancing service quality within port logistics systems (Hidayat & Santoso, 2023). In addition, the integration of digital information systems across logistics stakeholders can improve supply chain coordination and support more efficient logistics operations (Simanjuntak, Barasa, & Tampubolon, 2022).

By adopting AI-driven logistics solutions and improving information integration across supply chain networks, port operators can reduce operational inefficiencies and support more effective cargo management processes. Integrated digital systems enable logistics managers to monitor cargo movements, shipping schedules, and operational performance in real time, allowing them to respond quickly to potential disruptions and optimize logistics resources. Previous studies also emphasize that digital supply chain integration plays a significant role in improving logistics performance and strengthening collaboration among supply chain partners (Flynn, Huo, & Zhao, 2010).

Overall, the results demonstrate that digital transformation plays a critical role in improving supply chain efficiency in port logistics operations. The adoption of advanced digital technologies enables port operators to streamline operational processes, improve information transparency, and enhance supply chain responsiveness. As global trade continues to expand and logistics networks become increasingly interconnected, the implementation of digital technologies will become an essential strategy for maintaining efficient and competitive port logistics systems, particularly in developing maritime economies such as Indonesia (Arifai, Nugroho, & Pratama, 2022).

CONCLUSIONS

This study examined the impact of artificial intelligence adoption on supply chain efficiency in port logistics operations in Indonesia. The findings indicate that digital transformation plays a significant role in improving operational performance within modern port logistics systems. Specifically, AI adoption, digital logistics systems, and information integration were found to have positive and significant effects on supply chain efficiency.

The results show that AI adoption contributes to improved operational decision-making and more efficient logistics processes. AI technologies enable logistics operators to analyze large volumes of operational data, predict logistics demand patterns, and optimize cargo handling activities. These capabilities allow port operators to reduce operational delays and enhance the overall efficiency of supply chain operations.

Digital logistics systems were identified as the most influential factor affecting supply chain efficiency. The implementation of digital platforms for cargo tracking, logistics coordination, and automated documentation allows logistics organizations to improve operational visibility and streamline logistics processes. These systems enable real-time monitoring of cargo flows and facilitate faster coordination among logistics stakeholders.

Information integration also plays a critical role in enhancing supply chain efficiency. Effective communication and data sharing among supply chain actors—including port authorities, shipping companies, freight forwarders, and customs agencies—allow logistics managers to coordinate operations more effectively and respond quickly to operational disruptions. Integrated information systems therefore strengthen collaboration across the supply chain network and improve overall logistics performance.

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