Artificial Intelligence in Indonesian Ports: Opportunities and Challenges

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The primary objective of this study is to ascertain the potential advantages and obstacles associated with implementing artificial intelligence (AI) within the context of Indonesian ports. The study utilises qualitative methodologies, namely conducting in-depth interviews with port managers, technicians, and operational staff. Additionally, it involves the analysis of secondary data derived from yearly port reports, case studies, and academic literature. The findings demonstrate that artificial intelligence (AI) can augment operational efficiency, boost ship traffic management, and automate container handling activities within Indonesian ports. Nevertheless, integrating artificial intelligence (AI) within Indonesian ports is currently in its nascent phase, encountering challenges about physical limitations, human capital, and regulatory frameworks. The investigation also examines using interconnected technologies, including the Internet of Things (IoT), blockchain, and augmented reality (AR), to provide additional advantages to the port sector. In summary, via a comprehensive comprehension and effective utilisation of the opportunities afforded by artificial intelligence (AI), Indonesian ports have the potential to position themselves as frontrunners in the international maritime sector.

KEY WORDS

~ Artificial intelligence
~ Automated container handling operations
~ Indonesian ports
~ Machine learning
~ Operation optimisation
~ Ship traffic management

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1. INTRODUCTION

More than 17,000 islands are in the archipelago (Berawi *et al.*, 2018). Indonesia depends on a reliable maritime transportation network to link its islands and support economic activities (Dhanistha, Wardhana and Islamiyah, 2020). The port is vital to this transportation system (Kapalidis *et al.*, 2022). Artificial intelligence (AI) has recently become recognised as a potential means of enhancing the operational effectiveness of ports due to the rapid development of information technology and the digitisation of society (Alzahrani, 2022; Gao *et al.*, 2022; Tsolakis *et al.*, 2022; Hatamlah *et al.*, 2023). The use of AI at Indonesian ports is still in its early stages, despite its enormous promise (Ship Technology, 2021). Although some significant ports may have begun testing this technology, many obstacles still need to be overcome, including infrastructure issues, human resources, and regulations (Yusriadi *et al.*, 2023). The management of ship traffic, port security, and the automation of customs procedures are only a few of the operational problems that Indonesian ports may encounter (Safuan, 2023). The need for expansion and capacity has increased due to the significant population and rapid economic growth (Utama and Berawi, 2020). With its powers, AI may be able to solve some of these problems (Blackman, 2020). Additionally, many nations have used AI in the port industry (Peng *et al.*, 2023), making it a worldwide norm that Indonesia must adhere to in order to maintain its competitiveness abroad.

What potential and difficulties in operational optimization, improved ship traffic management, and automated container handling operations can the use of artificial intelligence (AI) at Indonesian ports handle? The study aims to identify the opportunities and challenges of using AI at Indonesian ports. This study question examines the possible advantages and difficulties of implementing AI in Indonesian ports, addressing several issues, including operation optimisation, ship traffic control, and automation of container movement. Research can examine the particular AI methods and approaches that can be used in various fields and the potential obstacles to their successful application, such as a lack of knowledge, high prices, concerns about data security and privacy, and regulatory and legal challenges.

2. LITERATURE REVIEW

A subfield of computer science called artificial intelligence (AI) is devoted to developing machines that can carry out operations calling for human intelligence. It incorporates planning, reasoning, robotics, machine learning, pattern and image recognition, and natural language understanding (Alhumaid *et al.*, 2023; Gombolay *et al.*, 2023; Yusriadi *et al.*, 2023). To evaluate whether machines can "think," Alan Turing developed the "Turing Test" in the 1950s. It is when artificial intelligence (AI) first emerged. Since then, AI has seen several stages of development, from the "AI Winter" era, in which advancement was sluggish, to the present generation, in which AI integrates itself into many facets of daily life, (Lavelle, 2020; O'Regan, 2021) a subfield of AI that teaches computers how to anticipate the future or make judgments using data (Bucea-Manea-Ţoniş *et al.*, 2022). Systems for fraud detection and recommendation are two examples of applications in the (Albawwat and Frijat, 2021; Salameh and Lutfi, 2021). Machine learning is the name given to this AI (AL-Akhras *et al.*, 2023; M C and Saravanan, 2023). Deep Learning is a branch of machine learning that processes massive volumes of data and looks for patterns using artificial neural networks (Janiesch, Zschech and Heinrich, 2021; Gonwirat, Choompol and Wichapa, 2022).

Neural networks are a collection of algorithms that try to recognise patterns in data instead of Neural Networks, which are inspired by the human brain's neural networks (Skuratov *et al.*, 2020; Prabhu *et al.*, 2022). However, the inspiration from biological neural networks and artificial neural networks are not exact replicas of the human brain's networks (Wood, 2022). The sentence could be more clearly written: "Neural networks in artificial intelligence are a collection of algorithms that recognise patterns in data, and they are inspired by but not identical to the neural networks found in the human brain." They are simplified models that capture some aspects of neural processing but do not replicate the full complexity of biological neural networks. The study of natural language processing (NLP) focuses on how sound machines can comprehend, interpret, and react to

human language (Ofer, Brandes and Linial, 2021; Gu *et al.*, 2022). Robotics is the science of building machines that can carry out physical tasks in any complex (Javaid *et al.*, 2021; Ballestar *et al.*, 2022). The Expert System, a machine learning-based system, that mimics the decisions and behaviours of a subject-matter expert in a specific field, comes last (Choi and Park, 2021; Saibene, Assale and Giltri, 2021). The Supervised Learning Algorithm, a machine learning technique where models are trained using labelled datasets, is one of the techniques and technologies in AI (Abdelaal, Elemary and Youness, 2019; Uddin *et al.*, 2019; Saeheaw, 2023). Unsupervised learning is a different technique and technology that uses models to look for patterns in data without labelling them (Laha and Biswas, 2019). The final AI method and technology is Reinforcement Learning (Gupta, Ahirwal and Atulkar, 2022; Fu *et al.*, 2023), a trial-and-error learning approach (Rose *et al.*, 2014; Miles *et al.*, 2021) in which machines are rewarded for good behaviour and penalised for bad behaviour.

3. METHODOLOGY

This study aims at assessing the opportunities and challenges of implementing AI at Indonesian ports and offer suggestions for better integration. Qualitative research (Cissé and Rasmussen, 2022) focuses on understanding stakeholders' perspectives regarding AI implementation in Indonesian ports. Significant ports in Indonesia, including Tanjung Priok Port, Tanjung Perak Port, and several others, have implemented or intend to implement AI technology.

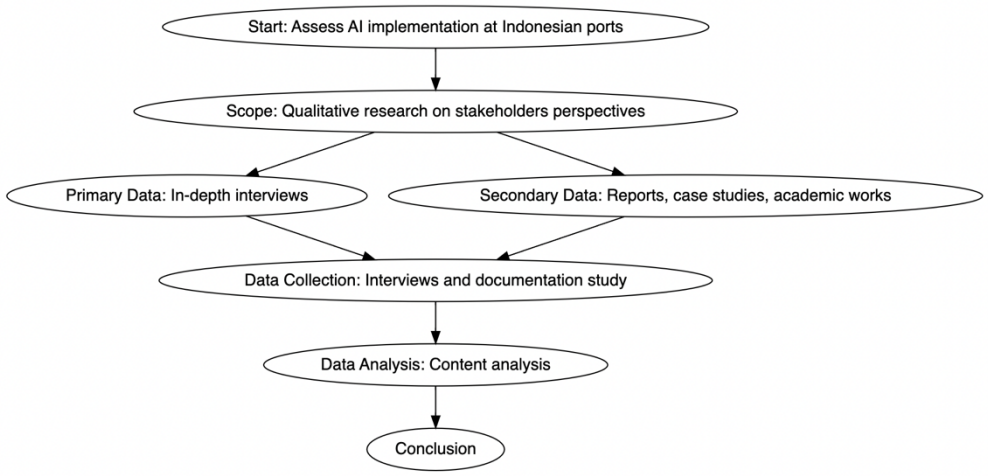

Figure 1. Flowchart

3.1. Research Design

The study adopts a qualitative research design to explore AI integration's complex dynamics and implications in port operations. This approach is suitable for obtaining detailed insights into stakeholders' attitudes, experiences, and expectations regarding AI technologies. The qualitative design facilitates an in-depth understanding of the contextual factors influencing AI adoption and its impact on port efficiency and productivity.

3.2. Data Collection Methods

3.2.1. Primary Data Collection: In-depth Interviews

Semi-structured interviews have been conducted to collect primary data. This method is chosen for its flexibility, allowing for exploring topics that emerge during the interaction with participants. The interviewees

include: a. Port Managers to understand strategic decisions regarding AI investments and implementations; b) Technicians to gather insights on the technical challenges and requirements for AI integration; and c) Operational Employees to capture the operational impacts and workforce adaptations due to AI technologies.

The interviews are designed to cover various topics, including the perceived benefits and challenges of AI, experiences with current AI technologies, and expectations for future developments.

3.2.1.1. Questionnaire Design and Validation

The questionnaire has been designed to gather insights into the perception of port stakeholders, regarding the application of AI technology. The questionnaire includes open-ended and multiple-choice questions aimed at capturing qualitative and quantitative data. The questionnaire validation process involves expert review to ensure that the questions prepared align with the research objectives and do not contain bias. In addition, a trial has been conducted with a small sample of respondents to test the clarity and relevance of the questions, ensuring that each question could be well understood by respondents and generating accurate and valuable data. The results of this trial have been used to revise the questionnaire before it was widely distributed.

3.2.1.2. Distribution and Collection

Questionnaires are distributed to port managers, technicians, and operational staff via email and face-to-face meetings. Respondents were given two weeks to complete the questionnaire, with follow-up reminders sent to ensure a high response rate. The data collected is then analysed using content analysis to identify recurring themes and patterns.

3.2.2. Secondary Data Collection: Documentation Study

Secondary data is collected from various sources to complement and validate the interview findings. These sources include a) Annual Port Reports to obtain official data on port performance and ongoing AI projects; b) Published Case Studies to incorporate experiences from other ports that have implemented similar technologies; and c) Academic Works to include theoretical perspectives and findings from previous research on AI in the port industry. All data has been collected over the last five years.

3.3. Data Analysis Method

3.3.1. Content Analysis

Content analysis is employed to systematically analyse the interview transcripts and documents. This method facilitates the identification of recurring themes, patterns, and categories that emerge from the data. The process involves several steps: a) Coding: Developing a coding scheme based on initial themes identified in the literature review and refined through iterative reading of the data; b) Categorisation: Grouping similar codes into categories that represent broader themes relevant to the research questions; c) Interpretation: Analysing the relationships between categories to conclude the integration of AI in Indonesian ports.

3.4. Ethical Considerations

Ethical approval for the study is obtained from the relevant institutional review board. Participants are informed about the purpose of the research, the voluntary nature of their involvement, and their right to withdraw at any time without penalty. Confidentiality is strictly maintained, and all data is anonymised before analysis to protect the identity of participants.

3.5. Conclusion

This methodology chapter provides a comprehensive overview of the methods used to assess the integration of AI technologies in Indonesian ports. Employing a qualitative approach, a combination of in-depth interviews and documentation studies, the research aims at offering valuable insights into the opportunities and challenges of AI implementation, contributing to strategic decision-making in the port industry.

4. RESULTS AND DISCUSSION

4.1. AI implementation in the global port sector

Artificial intelligence (AI) is being used by several of the biggest ports in the world, including Rotterdam, Los Angeles, and Singapore, to streamline various technologies, including vessel scheduling and cargo transfers (D'Amico *et al.*, 2021). Real-time maritime traffic management, optimum use of port space, and enhanced traffic planning and scheduling are all possible with AI in port management (PierNext, 2023). Ports like Los Angeles and Singapore are also working on improving vessel safety through AI (German, 2023a). Monitoring products and vehicles, automating container transfers, and managing work are additional uses of AI in the ports (AllRead, 2022). For instance, the Port of Singapore is developing its digitalPort@SG communication tool to leverage AI data analysis for Just in Time arrivals and recommend the optimum berth for a ship to dock promptly and sail on schedule (Agussurja, Kumar and Lau, 2018; German, 2023a). DigitalPort@SG represents a significant step in digitalising maritime operations, offering a streamlined, efficient, and environmentally friendly approach to port clearance and vessel management. By leveraging technology to simplify and optimise port operations, the platform supports Singapore's vision of maintaining its status as a leading international maritime centre (Jao, 2020). The Port of Los Angeles uses autonomous cranes and container trucks to transfer cargo inside the terminal (Desai *et al.*, 2016; Sinay, 2021). Other ports incorporate AI into their infrastructure, like the Port of New York and New Jersey, the Port of Hamburg, and the Port of Rotterdam (Port Technology Team, 2021; Sinay, 2021).

4.2. The current state of AI implementation in Indonesian ports

With some ports embracing AI-driven technologies to streamline their operations, AI adoption in Indonesian ports is encouraging. For instance, to digitize and streamline the processes of tug, pilot, and support vessels, the Ports of Balikpapan and Belawan have adopted Innovez One's marineM software (Iman, Amanda and Angela, 2022). The AI-powered port management information system from marineM has also been deployed by the Port of Banten to handle all aspects of managing seaport operations, such as resource planning, dispatch, and billing. These implementations have demonstrated significant operational improvements, including cost savings, reduced greenhouse gas emissions, and enhanced efficiency and competitiveness. Innovez One's marineM application represents an important step forward in digitalising port and marine services. Leveraging AI and mobile technology offers a solution that improves operational efficiency and sustainability, thereby making innovative port capabilities accessible to a broader range of ports worldwide.

4.3. AI Implementation Opportunities in Indonesian Ports

Based on the data collected and the analysis conducted, several significant opportunities can be explored in applying AI in Indonesian ports;

4.3.1. Operation Optimisation

With AI, ports can forecast ship arrivals more accurately, reduce wait times, and ease congestion. AI can significantly improve port ship traffic management (Karsavran and Erdik, 2021). By leveraging machine learning

and data analysis techniques, ports can become more effective in predicting ship arrivals, which can help shorten waiting times and minimise congestion (Chatterjee and Cho, 2022). It can lead to more efficient port operations and better utilisation of resources (Foster and Rhoden, 2020). AI and machine learning can help understand and predict traffic volumes, enabling the simulation of alternative solutions to smooth flows and reduce congestion in port cities. With the aid of AI and machine learning, it is possible to simulate alternative methods to streamline flows and relieve congestion in port towns (Lehmacher *et al.*, 2022).

AI has the potential to significantly automate container movement in ports, resulting in quicker loading and unloading procedures, shorter loading times, and increased port capacity. AI can accelerate loading and unloading procedures, shorten loading times, and increase port capacity. Artificial intelligence (AI) technologies can automate spreaders while handling large-size containers, decreasing vehicle downtime during loading and unloading operations, and boosting container terminal efficiency (Shchemelev, Zub and Ezhov, 2023). The makespan for loading and unloading containers in container terminals can be reduced, along with truck wait times and operating costs, using AI-based optimisation algorithms. With simultaneous loading and unloading activities taken into account, AI algorithms can arrange yard vehicles in subterranean container logistics systems, increasing efficiency and cutting overall handling time (Lehmacher *et al.*, 2022; Gao *et al.*, 2023).

The application of artificial intelligence (AI) technology in port management can improve operational efficiency, ship traffic management, and container handling automation. These findings align with research conducted by Karim et al. (2023), which highlighted the benefits of using machine learning in automated container handling at ports. Their research shows that the trained AI model can identify and handle container prototypes with more than 98% accuracy, significantly reducing human labour requirements and handling time. Implementing AI and machine learning in this context improves operational efficiency, reduces costs, and improves port operational safety. Therefore, the integration of AI technology, as proposed in this study and supported by the findings of Karim et al. (2023), provides a clear picture of the potential for digital transformation in the port industry (Karim *et al.*, 2023).

Artificial Intelligence (AI) is revolutionising port operations worldwide, including in Indonesia, by optimising maritime logistics and management. This transformation is crucial for enhancing efficiency, reducing congestion, and promoting sustainability in ports, vital global supply chain nodes. In collaboration with the Port of Long Beach, Los Angeles, the busiest port in the Western hemisphere, AI tools like the Port Optimiser are utilised. This cloud-based application facilitates information sharing among shipping companies, terminal operators, and other stakeholders, enhancing cargo flow and predicting future cargo volumes through machine learning. The Maritime and Port Authority of Singapore has also tested AI technology for collision risk detection and introduced a Next Generation Vessel Traffic Management System (German, 2023b). Adopting AI in Indonesian ports could address challenges such as vessel traffic management, logistics distribution flow management, and operational optimisation. Implementing AI in port operations globally and potentially in Indonesia signifies a shift towards more efficient, sustainable, and safer maritime logistics. AI can significantly reduce operational costs, waiting times, and environmental impact by automating and optimising berth planning, vessel scheduling, and cargo handling processes. As the maritime industry continues to evolve, integrating AI technologies in ports worldwide, including Indonesia, will be crucial for maintaining competitiveness and meeting the demands of global trade.

4.3.2. Security and Surveillance

AI systems can recognise suspicious activities in the port area and notify the security staff. Artificial intelligence (AI) technology can automatically alert security personnel to suspicious activity in port areas. Using machine learning and data analysis techniques, AI can detect irregularities in various port operations, including network traffic, container handling, and ship movements. Dynamic anomaly detection in the marine sector can

be done using AI-based statistical tools like iGroup learning and iDetect, which offer early warnings of abnormalities and assess their hazards to the monitored vessels (Cai *et al.*, 2018).

In ports, AI can monitor the water and air quality to make sure environmental criteria are being maintained. AI may monitor the air and water quality in ports, ensuring that environmental regulations are followed and a robust ecosystem is maintained. Artificial intelligence (AI) can analyse several environmental indicators and spot potential problems in real time by utilising machine learning and data analysis tools. Data on air quality, including PM2.5 and PM10 concentrations, can be analysed using AI-based approaches to find trends or outliers in air pollution levels. It can assist port authorities in reducing air pollution and guarantee adherence to air quality regulations (Schreiber *et al.*, 2022). Data on water quality, including critical physicochemical factors, can be analysed using AI to identify possible problems with water contamination. It can assist port authorities in taking the necessary steps to preserve water quality and save aquatic ecosystems (Yudina *et al.*, 2021). Data on organotin pollution in harbours, which can hurt marine life, can be analysed using artificial intelligence (AI). Port authorities can take the necessary action to decrease pollution and safeguard marine habitats by monitoring organotin levels (da Costa *et al.*, 2017). With Artificial Intelligence (AI), it is possible to determine the isotopic composition of CO2 in the air. It can be used as a non-intrusive marker to track environmental pollution in cultural heritage sites, like historic monuments near ports (Pironti *et al.*, 2022).

The Port of Rotterdam, one of the world's leading ports, has effectively integrated AI into its security operations. This integration includes developing advanced surveillance and monitoring systems that utilise pattern recognition to analyse real-time images and videos, automatically identifying activities within the port. Additionally, AI is crucial in threat detection at the Port of Rotterdam. AI algorithms analyse data from various sources, such as motion sensors and X-ray scanners, to identify potential threats and alert security operators in real time. This comprehensive approach to port security, facilitated by AI, enables the Port of Rotterdam to respond more efficiently to crises and manage security incidents effectively (Prosertek, 2022a). AI applications in Indonesian ports for security and surveillance, such as the New Makassar Container Port in Indonesia, have taken steps towards becoming a smart port, indirectly related to enhancing security measures. The port has implemented an international standard security and safety surveillance system, supervised using CCTV directly connected to the security room and control tower. Additionally, installing sensors at the gate and integrating document inspection, contribute towards the port's security infrastructure (Azisah, Asdar and Paotonan, 2023).

4.3.3. Data-driven Decision Making

Ports may use AI to make decisions based on past data and precise predictions, increasing operational effectiveness and resource management. AI tremendously impacts data-driven decision-making for ports, enhancing resource management and operational effectiveness. AI can assist port authorities in making informed decisions on various port operations-related issues by analysing previous data and producing precise predictions. The reliability and usefulness of network resource use can be increased using AI-based techniques to predict network traffic in cellular networks, such as residual neural networks (Bolakhrif *et al.*, 2022). By examining previous maintenance logs and current sensor data, AI can be used to create models for electrical systems, such as subsea blowout preventers, that can forecast when they will fail. It can assist port authorities in streamlining repair plans and decreasing downtime (Eldred *et al.*, 2023).

The Port of Rotterdam, one of the world's largest and most advanced ports, has implemented AI to enhance data-driven decision-making. The port uses a digital twin to simulate and analyse operations, which helps in optimising cargo handling and vessel scheduling. By leveraging big data analytics and AI, the Port of Rotterdam can process vast amounts of data from various sources, such as IoT devices, weather stations, and vessel tracking systems, to make informed decisions that improve efficiency and safety (ABU GHAZALEH, 2023). The concept of a Port Management Integrated Digitisation System (PMIDS) has been explored to revolutionise port operations in Indonesia. PMIDS includes AI, which can automate various aspects of port

operations, such as cargo handling, vessel scheduling, and traffic management. AI algorithms in PMIDS analyse large amounts of data to identify patterns and make predictions, enabling port managers to optimise resource utilisation and enhance operational efficiency (Diah Kusumawati, Karmanis and Karjono, 2023).

4.3.4. Proactive Maintenance

AI can predict port equipment and infrastructure failures, enabling maintenance before severe damage occurs. AI can significantly contribute to the proactive maintenance of port infrastructure and equipment by foreseeing potential breakdowns beforehand and helping maintenance to be carried out before serious harm occurs. AI systems can forecast equipment breakdowns and assist port authorities in optimising maintenance schedules, lowering downtime, and extending the lifespan of equipment by examining past maintenance records and real-time sensor data. In district heating networks, AI-based techniques can anticipate issues and organise corrective actions (Langroudi and Weidlich, 2020). Effective predictive maintenance is possible with the application of AI to track the health of machines in industrial IoT systems and predict component breakdown (Hafeez, Xu and Mcardle, 2021). By examining vibration data and developing monitoring systems, AI algorithms can recognise and foresee the deterioration of rotating equipment in factories, such as those in the automobile industry (Kim, 2023).

Goa Shipyard Limited (GSL), an Indian shipbuilding company, has implemented an AI-driven Condition Monitoring System (CMS) for predictive ship maintenance. This system continuously monitors onboard equipment, allowing for maintenance decisions based on the actual condition of the equipment, rather than on a fixed maintenance schedule. The CMS uses machine learning algorithms to analyse sensor data, predict system failures or fatigue, and provide at least a 72-hour warning. This enables timely onboard repairs or the procurement of new parts, thus preventing unnecessary downtime and enhancing the efficiency of maintenance operations (Kumar, 2021). Indonesian ports could benefit from similar AI systems to those used by GSL for predictive maintenance. By adopting such technologies, Indonesian ports could improve the reliability and longevity of their equipment, reduce maintenance costs, and minimise operational disruptions.

4.3.5. Reduced Operating Costs

AI-powered process automation can save money by reducing the requirement for manual labour in particular procedures. Lower operational expenses can be achieved by using AI in ports by automating specific operations and removing the need for manual work in certain jobs. AI can enhance maritime traffic management by correctly anticipating ship arrivals, optimising vessel routing and synchronisation, and easing congestion (Khullar *et al.*, 2021; Abaza *et al.*, 2022; Hummes *et al.*, 2023). It may result in more effective port operations and greater resource utilisation, ultimately lowering costs. Automation of container handling procedures by AI can shorten wait times, increase port capacity, and accelerate loading and unloading (Khullar *et al.*, 2021). Ports can reduce labour expenses and improve overall efficiency by automating certain activities. Using AI, port infrastructure and equipment breakdowns can be predicted, allowing for maintenance before serious harm is done (Vasta *et al.*, 2023). It can assist ports in reducing downtime, enhancing equipment lifespan, and optimising maintenance schedules, all of which will save maintenance costs. Ports can improve operational effectiveness and resource management using AI to make decisions based on historical data and precise predictions (Abaza *et al.*, 2022; Hummes *et al.*, 2023). Ports can optimise resource allocation and cut costs by making better decisions.

The Port of Los Angeles, one of the busiest ports in the Western Hemisphere, utilises AI through the Port Optimiser™ tool. This cloud-based application facilitates better planning and allocation of resources, especially during cargo booms, by providing real-time data sharing among shipping companies, terminal operators, and other stakeholders. The tool improves forecasts over time and issues volume updates for the next six months every month, optimising container and vehicle movements, managing capacity constraints, and

enhancing security. This AI implementation contributes towards significant cost reductions and operational efficiency improvements (Iman, Amanda and Angela, 2022). In Indonesia, the maritime sector is rapidly embracing digitalisation and automation to drive competitiveness and enhance operational efficiency. Although specific AI applications are not detailed, the general trend towards digital transformation in Indonesian ports includes creating integrated systems, reducing bureaucracy, enabling remote and anytime monitoring, prioritising automation, and ensuring safety from crime and technical issues. These elements of digitisation are aimed at significantly reducing costs and increasing the competitiveness of ports in Indonesia. The transition towards digitisation and automation is accelerating, particularly in the last couple of years, indicating a growing adoption of AI and other technologies to optimise port operations and reduce operating costs (Iman, Amanda and Angela, 2022).

4.3.6. Service Quality Improvement

Ports can provide clients with faster and more dependable service by automating the loading and unloading procedures and improving predictions of ship arrival. By automating loading and unloading procedures and offering more precise forecasts of ship arrival, AI can significantly raise the quality of port services. As a result, customers benefit from quicker and more dependable service. Ship arrivals can be predicted more correctly using AI-based models than traditional techniques, such as the Long Short-Term Memory (LSTM) model (Yoon *et al.*, 2023). Port administrations can better plan and manage their resources, which will result in more effective operations and higher-quality services by increasing the accuracy of ship arrival projections.

Ports 4.0 refers to the digital transformation of port operations by integrating advanced technologies, including AI, to improve efficiency, safety, sustainability, and service quality. Technologies such as the Internet of Things (IoT), blockchain, automation, robotics, and AI are employed to optimise various port operations. For instance, AI improves decision-making processes, optimises shipping routes, enhances inventory management, and improves customer service quality. Automating inventory management processes and optimising shipping routes can reduce errors and improve delivery times, positively impacting service quality (Prosertek, 2022b). In Indonesia, the maritime sector is undergoing rapid digitalisation and automation to enhance operational efficiency and competitiveness. While specific AI applications are not detailed, the general trend towards digital transformation includes creating integrated systems, reducing bureaucracy, enabling remote and anytime monitoring, and prioritising automation. These elements of digitisation are aimed at improving the quality of services by making port operations more efficient and reliable. The transition towards digitisation and automation has accelerated, particularly in the last few years. This indicates a growing adoption of AI and other technologies to optimise port operations and improve service quality (Iman, Amanda and Angela, 2022).

4.4. Challenges of AI Implementation in Indonesian Ports

The implementation of AI in ports does offer several great opportunities, but various challenges need to be faced, especially in the Indonesian context:

4.4.1. Infrastructure and Hardware Investment

Indonesian ports range in terms of how ready their infrastructure is. Modern hardware and an advanced information technology infrastructure are needed for AI applications. A substantial investment may be required to purchase technology such as servers, sensors, cameras, and AI-compatible robotics. The essential technology and infrastructure must be bought to implement AI successfully in Indonesian ports. High-performance servers are necessary for hosting AI applications and services and processing and analysing the massive volumes of data produced by AI algorithms. Various sensors, including environmental, vibration, and GPS sensors, are needed to gather data from many areas of port operations. These sensors offer the data that

AI algorithms' analysis and decision-making capabilities rely on. AI-compatible cameras can be utilised for various applications, including environmental monitoring, anomaly detection, visual surveillance, and anomaly detection in port areas.

4.4.2. Lack of AI-Trained Manpower

Even though Indonesian academia and businesses are becoming more interested in AI, there is still a need for more workers who have received specialised training in this area. Training and capacity building are essential for ports to fully utilise AI. The lack of AI-trained personnel may make using AI in Indonesian ports difficult. Ports can work with universities and other educational organisations to develop specific training courses and programmes in AI and related fields. It could contribute towards developing a workforce with the necessary skills to create, maintain, and improve AI systems at ports. Ports might fund in-house training programmes to upskill their current personnel in AI technologies. It could fill the gap between the skill sets currently held by personnel and what is needed for AI-driven port operations. Ports can collaborate with AI businesses and technology suppliers to gain access to their resources and expertise. Through these collaborations, ports may more efficiently implement AI solutions and train their staff in the newest AI techniques. The Indonesian government may significantly advance AI education and training by providing funds, incentives, and policy support. It may offer a favourable environment for the nation's skilled AI workforce.

4.4.3. Data Security and Privacy Issues

The amount of data gathered and analysed will grow with the deployment of AI in ports. It raises questions about privacy and security, especially when working with sensitive or personal data. It is essential to ensure that data is safely stored and that only authorised individuals can access it. Ports can use robust access control strategies, encryption, and secure storage options to protect data from unauthorised access and potential breaches. Especially when using confidential or sensitive information, ports should establish clear standards and guidelines. It entails specifying the reason for data gathering, limiting its use to those reasons, and ensuring that it is not inadvertently used. Data sharing with third parties, such as suppliers of AI technology or other stakeholders, should be governed by stringent rules established by ports. It entails ensuring that contracts for data exchange are in place and that third parties follow the same data security and privacy standards as the Port. The General Data Protection Regulation (GDPR) (Taylor, 2019) in the European Union is one example of a significant data protection law that ports should ensure their AI-driven operations abide by. It entails putting suitable data protection measures in place, conducting frequent audits, and upholding openness regarding data processing activities. The best data security and privacy practices should be taught to employees by ports. It involves training staff members on the value of data protection, the dangers that could result from data breaches, and the precautions they can take to protect sensitive data.

4.4.4. Integration with Existing Port Information Systems

Integrating AI technology with Indonesia's current port information systems can be challenging, especially if those systems need to be updated or made compatible with the most recent AI-based solutions. These difficulties must be overcome to fully utilise AI in optimising port operations, increasing efficiency, and lowering costs. Ports should thoroughly evaluate their current information systems to find any potential problems with AI technologies. Based on this evaluation, ports can modernise or replace obsolete systems with AI-compatible alternatives. Ports can use Application Programming Interfaces (APIs) and other data integration technologies to enable a smooth data transfer between their current plans and AI-based solutions. It can make sure that AI algorithms have access to the information they need to analyse and make decisions. It can be necessary for some circumstances to create specialised AI solutions that are made to integrate with already-existing port information systems. It may entail collaborating closely with suppliers of AI technology to customise their offerings to the particular demands and specifications of the Port. Ports can start with trial projects or

specific areas of operation before integrating AI with their current information systems. It can aid in identifying potential problems and difficulties early, allowing for changes and adjustments before a full-scale implementation. Ports can collaborate with other ports, tech companies, and industry stakeholders to share best practices and knowledge about integrating artificial intelligence (AI) into current information systems. It can help ports exchange experiences and develop better methods for incorporating AI into their daily operations.

4.4.5. Aspects of Government Regulations and Policies

Applying AI in public sectors such as ports may require revision or introduction of new government regulations and policies. It is to ensure that the use of AI complies with ethical, safety, and fairness standards. In addition, licensing processes and bureaucracy can also present barriers to adopting this new technology. AI applications in the public sector should abide by ethical standards, including accountability, openness, and justice (Blasimme and Vayena, 2020). To ensure ethical AI adoption, governments may need to create policies and rules that address these moral issues. Safety and security considerations should be considered while developing and implementing AI systems, especially when working with sensitive data or essential infrastructure (Blasimme and Vayena, 2020). The public sector's use of AI may need the government's establishment of safety and security guidelines. AI systems should be made without prejudice and discrimination to ensure everyone is treated equally and fairly (Blasimme and Vayena, 2020). Governments should create laws that cover fairness and equality in AI applications. The volume of data ports received and the process will exponentially expand with AI, generating questions regarding data storage, access, and utilisation (Martinez-Martin *et al.*, 2020). Governments may need to create data protection and privacy rules to overcome these issues. Implementing AI in the public sector can require new licensing procedures and overcoming administrative obstacles. Governments may need to streamline these procedures to encourage deploying AI technologies in public sector organisations (Khurshid *et al.*, 2020).

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The conclusion of this study confirms that artificial intelligence has significant potential to optimise port operations in Indonesia. Despite various challenges, such as the need for better infrastructure, HR training, and the development of a supportive regulatory framework, AI offers multiple advantages that can improve the efficiency, safety, and quality of port services. With the right strategy, Indonesian ports can overcome these barriers and leverage AI to compete globally.

5.2. Recommendations

Investing in modernising infrastructure and technology in Indonesia's port sector and procuring AI-compatible hardware, such as high-performance servers, is necessary to strengthen infrastructure and technology. In addition, training and capacity-building programmes should be enhanced to prepare a skilled workforce to manage AI solutions. It is also essential to revise regulations that support AI implementation, focusing on ethics, security, and data privacy. Collaboration with academic institutions and researchers needs to be enhanced to access the latest innovations in AI. Further studies are required to evaluate the social impact of automation brought by AI and develop better data security strategies. With these steps, it is expected that Indonesian ports can implement AI solutions effectively and responsibly.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abaza, H. et al. 2022, Industrializing residential construction using artificial intelligent (AI) robotics, in Volume 2B: Advanced Manufacturing, American Society of Mechanical Engineers. Available at: http://dx.doi.org/10.1115/IMECE2022-96675.

Abdelaal, H. M., Elemary, B. R. & Youness, H. A. 2019, Classification of Hadith according to its content based on supervised learning algorithms, IEEE Access, 7, pp. 152379–152387. Available at: http://dx.doi.org/10.1109/ACCESS.2019.2948159.

Abu Ghazaleh, M. 2023, Smartening up ports digitalization with artificial intelligence (AI): A study of artificial intelligence business drivers of smart port digitalization, Management and Economics Review, 8(1), pp. 78–97. Available at: http://dx.doi.org/10.24818/mer/2023.02-06.

Agussurja, L., Kumar, A. & Lau, H. C. 2018, Resource-constrained scheduling for maritime traffic management, Proceedings of the AAAI Conference on Artificial Intelligence, 32(1). Available at: http://dx.doi.org/10.1609/aaai.v32i1.12086.

Al-Akhras, M. et al. 2023, Botnet attacks detection in IoT environment using machine learning techniques, International Journal of Data and Network Science, 7(4), pp. 1683–1706. Available at: http://dx.doi.org/10.5267/j.ijdns.2023.7.021.

Albawwat, I. & Frijat, Y. A. 2021, An analysis of auditors' perceptions towards artificial intelligence and its contribution to audit quality, Accounting, 7(4), pp. 755–762. Available at: http://dx.doi.org/10.5267/j.ac.2021.2.009.

Alhumaid, K. et al. 2023, The adoption of artificial intelligence applications in education, International Journal of Data and Network Science, 7(1), pp. 457–466. Available at: http://dx.doi.org/10.5267/j.ijdns.2022.8.013.

AllRead 2022, How do ports use artificial intelligence, AllRead Machine Learning Technologies. Available at: https://www.allread.ai/en/how-ports-use-artificial-intelligence/.

Alzahrani, S. M. 2022, Implementing green port strategies in Saudi ports to achieve environmental sustainability, Malmö, Sweden. Available at: https://commons.wmu.se/cgi/viewcontent.cgi?article=3129&context=all_dissertations.

Azisah, N., Asdar, M. & Paotonan, C. 2023, Fulfillment of smart port criteria for the existing terminal 2 of the new Makassar container port, Journal of Ocean Science and Technology Innovation, 4(2), pp. 67–76.

Ballestar, M. T. et al. 2022, Why is your company not robotic? The technology and human capital needed by firms to become robotic, Journal of Business Research, 142, pp. 328–343. Available at: http://dx.doi.org/10.1016/j.jbusres.2021.12.061.

Berawi, M. A. et al. 2018, Prioritizing airport development plan to optimize financial feasibility, Aviation, 22(3), pp. 115–128. Available at: http://dx.doi.org/10.3846/aviation.2018.6589.

Blackman, R. 2020, A practical guide to building ethical AI, Harvard Business Review Digital Articles, Harvard Business Publishing. Available at: https://hbr.org/2020/10/a-practical-guide-to-building-ethical-ai.

Blasimme, A. & Vayena, E. 2020, The ethics of AI in biomedical research, patient care, and public health, in Dubber, M. D., Pasquale, F. & Das, S. (eds), The Oxford Handbook of Ethics of AI, Oxford University Press, pp. 702–718. Available at: http://dx.doi.org/10.1093/oxfordhb/9780190067397.013.45.

Bolakhrif, A. et al. 2022, AI-assisted network traffic prediction without warm-up periods, in 2022 IEEE 95th Vehicular Technology Conference: (VTC2022-Spring), IEEE, pp. 1–6. Available at: http://dx.doi.org/10.1109/VTC2022-Spring54318.2022.9860997.

Bucea-Manea-Ţoniş, R. et al. 2022, Artificial intelligence potential in higher education institutions enhanced learning environment in Romania and Serbia, Sustainability, 14(10), p. 5842. Available at: http://dx.doi.org/10.3390/su14105842.

Cai, C. et al. 2018, iGroup learning and iDetect for dynamic anomaly detection with applications in maritime threat detection, in 2018 IEEE International Symposium on Technologies for Homeland Security (HST), IEEE, pp. 1–6. Available at: http://dx.doi.org/10.1109/THS.2018.8574162.

Chatterjee, I. & Cho, G. 2022, Development of a machine learning-based framework for predicting vessel size based on container capacity, Applied Sciences, 12(19), p. 9999. Available at: http://dx.doi.org/10.3390/app12199999.

Choi, H. & Park, S. 2021, A survey of machine learning-based system performance optimization techniques, Applied Sciences, 11(7), p. 3235. Available at: http://dx.doi.org/10.3390/app11073235.

Cissé, A. & Rasmussen, A. 2022, Qualitative methods, in Comprehensive Clinical Psychology, Elsevier, pp. 91–103. Available at: http://dx.doi.org/10.1016/B978-0-12-818697-8.00216-8.

D'Amico, G. et al. 2021, Smart and sustainable logistics of port cities: A framework for comprehending enabling factors, domains and goals, Sustainable Cities and Society, 69, p. 102801. Available at: http://dx.doi.org/10.1016/j.scs.2021.102801.

da Costa, M. B. et al. 2017, A temporal and spatial monitoring of organotin pollution in a harborside region of Brazil by imposex and ecological quality ratio using Leucozonia nassa, Environmental Monitoring and Assessment, 189(12), p. 650. Available at: http://dx.doi.org/10.1007/s10661-017-6367-7.

Desai, M. et al. 2016, Evaluation and design of a foundation system for automated stacking cranes at the Port of Los Angeles, Berths 144-145 automated terminal, in Geotechnical and Structural Engineering Congress 2016, Reston, VA: American Society of Civil Engineers, pp. 1078–1091. Available at: http://dx.doi.org/10.1061/9780784479742.091.

Dhanistha, W. L., Wardhana, W. & Islamiyah, M. 2020, Maritime weather predictor design based neural network and ANFIS to an increase in accuracy in the Java Sea, Journal of Engineering and Applied Sciences, 15(7), pp. 1724–1727. Available at: http://dx.doi.org/10.36478/jeasci.2020.1724.1727.

Diah Kusumawati, E., Karmanis & Karjono 2023, Review of port management integrated digitization system: A pathway to efficient and sustainable port operations, Maritime Technology and Society, 2(3), pp. 1–7. Available at: http://dx.doi.org/10.20956/zl.v2i3.18678.

Eldred, M. E. et al. 2023, Leveraging AI for inventory management and accurate forecast – An industrial field study, in Day 1 Tue, January 17, 2023, SPE. Available at: http://dx.doi.org/10.2118/214457-MS.

Foster, M. N. & Rhoden, S. L. N. H. 2020, The integration of automation and artificial intelligence into the logistics sector, Worldwide Hospitality and Tourism Themes, 12(1), pp. 56–68. Available at: http://dx.doi.org/10.1108/WHATT-10-2019-0070.

Fu, G. et al. 2023, To reduce maximum tardiness by Seru production: Model, cooperative algorithm combining reinforcement learning and insights, International Journal of Industrial Engineering Computations, 14(1), pp. 65–82. Available at: http://dx.doi.org/10.5267/j.ijiec.2022.10.002.

Gao, J. et al. 2022, Understanding data governance requirements in IoT adoption for smart ports – A gap analysis, Maritime Policy & Management, pp. 1–14. Available at: http://dx.doi.org/10.1080/03088839.2022.2155318.

Gao, Y. et al. 2023, Scheduling of yard truck considering loading and unloading simultaneously in an underground container logistics system, Transportation Research Record: Journal of the Transportation Research Board, 2677(2), pp. 246–263. Available at: http://dx.doi.org/10.1177/03611981211047834.

German, K. 2023a, How the world's largest ports are using AI to keep the global supply chain humming, techfinitive.com. Available at: https://www.techfinitive.com/features/how-the-worlds-largest-ports-are-using-ai-to-keep-the-global-supply-chain-humming/.

German, K. 2023b, How the world's largest ports are using AI to keep the global supply chain humming, techfinitive.com. Available at: https://www.techfinitive.com/features/how-the-worlds-largest-ports-are-using-ai-to-keep-the-global-supply-chain-humming/ (Accessed: 12 February 2024).

Gombolay, G. Y. et al. 2023, Review of machine learning and artificial intelligence (ML/AI) for the pediatric neurologist, Pediatric Neurology, 141, pp. 42–51. Available at: http://dx.doi.org/10.1016/j.pediatrneurol.2023.01.004.

Gonwirat, S., Choompol, A. & Wichapa, N. 2022, A combined deep learning model based on the ideal distance weighting method for fake news detection, International Journal of Data and Network Science, 6(2), pp. 347–354. Available at: http://dx.doi.org/10.5267/j.ijdns.2022.1.003.

Gu, Y. et al. 2022, Domain-specific language model pretraining for biomedical natural language processing, ACM Transactions on Computing for Healthcare, 3(1), pp. 1–23. Available at: http://dx.doi.org/10.1145/3458754.

Gupta, N., Ahirwal, M. K. & Atulkar, M. 2022, Simulation and modeling of human decision-making process through reinforcement learning based computational model involving past experiences, Decision Science Letters, 11(4), pp. 366–378. Available at: http://dx.doi.org/10.5267/j.dsl.2022.9.001.

Hafeez, T., Xu, L. & McArdle, G. 2021, Edge intelligence for data handling and predictive maintenance in IIOT, IEEE Access, 9, pp. 49355–49371. Available at: http://dx.doi.org/10.1109/ACCESS.2021.3069137.

Hatamlah, H. et al. 2023, The role of artificial intelligence in supply chain analytics during the pandemic, Uncertain Supply Chain Management, 11(3), pp. 1175–1186. Available at: http://dx.doi.org/10.5267/j.uscm.2023.4.005.

Hummes, O. et al. 2023, Executing the digital well plan - enhancing process automation, in Day 3 Tue, February 21, 2023, SPE. Available at: http://dx.doi.org/10.2118/213726-MS.

Iman, N., Amanda, M. T. & Angela, J. 2022, Digital transformation for maritime logistics capabilities improvement: Cases in Indonesia, Marine Economics and Management, 5(2), pp. 188–212. Available at: http://dx.doi.org/10.1108/MAEM-01-2022-0002.

Janiesch, C., Zschech, P. & Heinrich, K. 2021, Machine learning and deep learning, Electronic Markets, 31(3), pp. 685–695. Available at: http://dx.doi.org/10.1007/s12525-021-00475-2.

Jao, F. C. 2020, Digital port ecosystem, sustainableworldports.org. Available at: https://sustainableworldports.org/project/mpa-singapore-digital-port-ecosystem/ (Accessed: 14 February 2024).

Javaid, M. et al. 2021, Substantial capabilities of robotics in enhancing industry 4.0 implementation, Cognitive Robotics, 1, pp. 58–75. Available at: http://dx.doi.org/10.1016/j.cogr.2021.06.001.

Kapalidis, C. et al. 2022, A vulnerability centric system of systems analysis on the maritime transportation sector most valuable assets: Recommendations for port facilities and ships, Journal of Marine Science and Engineering, 10(10), p. 1486. Available at: http://dx.doi.org/10.3390/jmse10101486.

Karim, M. M. et al. 2023, Automated handling of port containers using machine learning, SSRN Electronic Journal, (December), pp. 1–7. Available at: http://dx.doi.org/10.2139/ssrn.4446335.

Karsavran, Y. & Erdik, T. 2021, Artificial intelligence based prediction of seawater level: A case study for Bosphorus Strait, International Journal of Mathematical, Engineering and Management Sciences, 6(5), pp. 1242–1254. Available at: http://dx.doi.org/10.33889/IJMEMS.2021.6.5.075.

Khullar, A. et al. 2021, Experiences with the introduction of AI-based tools for moderation automation of voice-based participatory media forum, in India HCI 2021, New York, NY, USA: ACM, pp. 30–39. Available at: http://dx.doi.org/10.1145/3506469.3506473.

Khurshid, M. M. et al. 2020, Modeling of open government data for public sector organizations using the potential theories and determinants—a systematic review, Informatics, 7(3), p. 24. Available at: http://dx.doi.org/10.3390/informatics7030024.

Kim, D. H. 2023, Developing equipment condition prediction and monitoring system using deep learning models in automotive production factory, in SAE Technical Papers. Available at: http://dx.doi.org/10.4271/2023-01-0093.

Kumar, A. 2021, Ai & maritime - enabling predictive maintenance, linkedin.com. Available at: https://www.linkedin.com/pulse/ai-maritime-enabling-predictive-maintenance-anish-kumar/ (Accessed: 15 February 2024).

Laha, S. & Biswas, S. 2019, A hybrid unsupervised learning and multi-criteria decision making approach for performance evaluation of Indian banks, Accounting, 5(4), pp. 169–184. Available at: http://dx.doi.org/10.5267/j.ac.2018.11.001.

Langroudi, P. P. & Weidlich, I. 2020, Applicable predictive maintenance diagnosis methods in service-life prediction of district heating pipes, Environmental and Climate Technologies, 24(3), pp. 294–304. Available at: http://dx.doi.org/10.2478/rtuect-2020-0104.

Lavelle, S. 2020, The machine with a human face: From artificial intelligence to artificial sentience, in Lecture Notes in Business Information Processing, pp. 63–75. Available at: http://dx.doi.org/10.1007/978-3-030-49165-9_6.

Lehmacher, W. et al. 2022, Reducing port city congestion through data analysis, simulation, and artificial intelligence to improve the well-being of citizens, Journal of Mega Infrastructure & Sustainable Development, 2(sup1), pp. 65–82. Available at: http://dx.doi.org/10.1080/24724718.2022.2133524.

M C, P. & Saravanan, P. 2023, Crop insurance premium recommendation system using artificial intelligence techniques, International Journal of Professional Business Review, 8(4), p. e01270. Available at: http://dx.doi.org/10.26668/businessreview/2023.v8i4.1270.

Martinez-Martin, N. et al. 2020, Ethics of digital mental health during COVID-19: Crisis and opportunities, JMIR Mental Health, 7(12), p. e23776. Available at: http://dx.doi.org/10.2196/23776.

Miles, J. T. et al. 2021, A machine learning approach for detecting vicarious trial and error behaviors, Frontiers in Neuroscience, 15. Available at: http://dx.doi.org/10.3389/fnins.2021.676779.

O'Regan, G. 2021, History of artificial intelligence, in A Brief History of Computing, Cham: Springer International Publishing, pp. 295–319. Available at: http://dx.doi.org/10.1007/978-3-030-66599-9_22.

Ofer, D., Brandes, N. & Linial, M. 2021, The language of proteins: NLP, machine learning & protein sequences, Computational and Structural Biotechnology Journal, 19, pp. 1750–1758. Available at: http://dx.doi.org/10.1016/j.csbj.2021.03.022.

Peng, W. et al. 2023, A deep learning approach for port congestion estimation and prediction, Maritime Policy & Management, 50(7), pp. 835–860. Available at: http://dx.doi.org/10.1080/03088839.2022.2057608.

PierNext 2023, Will AI take over port management?, Port de Barcelona. Available at: https://piernext.portdebarcelona.cat/en/technology/will-ai-take-over-port-management/ (Accessed: 9 September 2023).

Pironti, C. et al. 2022, New analytical approach to monitoring air quality in historical monuments through the isotopic ratio of CO2, Environmental Science and Pollution Research, 29(20), pp. 29385–29390. Available at: http://dx.doi.org/10.1007/s11356-020-12215-8.

Port Technology Team 2021, How can ports use artificial intelligence?, Port Technology. Available at: https://www.porttechnology.org/news/how-can-ports-use-artificial-intelligence/ (Accessed: 9 September 2023).

Prabhu, S. et al. 2022, Resolving-power domination number of probabilistic neural networks, Journal of Intelligent & Fuzzy Systems, 43(5), pp. 6253–6263. Available at: http://dx.doi.org/10.3233/JIFS-220218.

Prosertek 2022a, How artificial intelligence is transforming port security, prosertek.com. Available at: https://prosertek.com/blog/artificial-intelligence-transforming-port-security/ (Accessed: 15 February 2024).

Prosertek 2022b, Ports 4.0: How technology is transforming port operations, prosertek.com. Available at: https://prosertek.com/blog/ports-4-0-how-technology-is-transforming-port-operations/ (Accessed: 15 February 2024).

Rose, L. et al. 2014, Self-organization in decentralized networks: A trial and error learning approach, IEEE Transactions on Wireless Communications, 13(1), pp. 268–279. Available at: http://dx.doi.org/10.1109/TWC.2013.112613.130405.

Saeheaw, T. 2023, Comparison of different supervised machine learning algorithms for bead geometry prediction in GMAW process, Engineering Solid Mechanics, 11(2), pp. 175–190. Available at: http://dx.doi.org/10.5267/j.esm.2022.12.003.

Safuan, S. 2023, Application of digital technology in Indonesian ports and contribute to lowering national logistics costs, Jurnal Manajemen Transportasi & Logistik (JMTRANSLOG), 9(3), p. 211. Available at: http://dx.doi.org/10.54324/j.mtl.v9i3.738.

Saibene, A., Assale, M. & Giltri, M. 2021, Expert systems: Definitions, advantages and issues in medical field applications, Expert Systems with Applications, 177, p. 114900. Available at: http://dx.doi.org/10.1016/j.eswa.2021.114900.

Salameh, R. S. & Lutfi, K. M. 2021, The role of artificial intelligence on limiting Jordanian commercial banks cybercrimes, Accounting, 7(5), pp. 1147–1156. Available at: http://dx.doi.org/10.5267/j.ac.2021.2.024.

Schreiber, S. G. et al. 2022, Statistical tools for water quality assessment and monitoring in river ecosystems – a scoping review and recommendations for data analysis, Water Quality Research Journal, 57(1), pp. 40–57. Available at: http://dx.doi.org/10.2166/wqrj.2022.028.

Shchemelev, V. L., Zub, I. V. & Ezhov, Y. E. 2023, Automation of spreader operation in handling large size containers at ship's list and trim, Vestnik of Astrakhan State Technical University. Series: Marine Engineering and Technologies, 2023(2), pp. 101–107. Available at: http://dx.doi.org/10.24143/2073-1574-2023-2-101-107.

Ship Technology 2021, Two Indonesian ports opt for Innovez One's AI-driven tech, ship-technology.com. Available at: https://www.ship-technology.com/news/indonesian-ports-innovez-one/?cf-view (Accessed: 9 September 2023).

Sinay 2021, What is artificial intelligence in smart port operations?, SINAY SAS. Available at: https://sinay.ai/en/what-is-artificial-intelligence-in-smart-port-operations/ (Accessed: 9 September 2023).

Skuratov, V. et al. 2020, Creation of a neural network algorithm for automated collection and analysis of statistics of exchange quotes graphics, EUREKA: Physics and Engineering, 3(3), pp. 22–29. Available at: http://dx.doi.org/10.21303/2461-4262.2020.001238.

Taylor, C. R. 2019, Editorial: Artificial intelligence, customized communications, privacy, and the General Data Protection Regulation (GDPR), International Journal of Advertising, 38(5), pp. 649–650. Available at: http://dx.doi.org/10.1080/02650487.2019.1618032.

Tsolakis, N. et al. 2022, Towards AI driven environmental sustainability: an application of automated logistics in container port terminals, International Journal of Production Research, 60(14), pp. 4508–4528. Available at: http://dx.doi.org/10.1080/00207543.2021.1914355.

Uddin, S. et al. 2019, Comparing different supervised machine learning algorithms for disease prediction, BMC Medical Informatics and Decision Making, 19(1), p. 281. Available at: http://dx.doi.org/10.1186/s12911-019-1004-8.

Utama, D. P. & Berawi, M. A. 2020, Increasing terminal capacity based on adaptive port planning case study at Cigading Port, Indonesia, IOP Conference Series: Materials Science and Engineering, 830(2), p. 022059. Available at: http://dx.doi.org/10.1088/1757-899X/830/2/022059.

Vasta, S. et al. 2023, Automated prototype for Bombyx mori cocoon sorting attempts to improve silk quality and production efficiency through multi-step approach and machine learning algorithms, Sensors, 23(2), p. 868. Available at: http://dx.doi.org/10.3390/s23020868.

Wood, T. 2022, How similar are neural networks to our brains?, fastdatascience.com. Available at: https://fastdatascience.com/how-similar-are-neural-networks-to-our-brains/ (Accessed: 14 February 2024).

Yoon, J.-H. et al. 2023, Enhancing container vessel arrival time prediction through past voyage route modeling: A case study of Busan New Port, Journal of Marine Science and Engineering, 11(6), p. 1234. Available at: http://dx.doi.org/10.3390/jmse11061234.

Yudina, E. et al. 2021, Optimization of water quality monitoring networks using metaheuristic approaches: Moscow region use case, Water, 13(7), p. 888. Available at: http://dx.doi.org/10.3390/w13070888.

Yusriadi, Y. et al. 2023, Implementation of artificial intelligence in Indonesia, International Journal of Data and Network Science, 7(1), pp. 283–294. Available at: http://dx.doi.org/10.5267/j.ijdns.2022.10.005.