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Artificial Intelligence Implementations Towards Shaping the Future of Digital World

PORT INDUSTRY PERCEPTION ON THE USE OF ARTIFICIAL INTELLIGENCE. THE CASE OF GREEK PORTS

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ABSTRACT

The port industry is considered a latecomer in the Artificial Intelligence era, among others, due to the nature of port operations, the inner ort environment characteristics, the numerous players operating the port area, etc. Despite that, several actions towards adopting AI solutions in the port industry have been taken in the last few years, seeing as the next step (or the complimentary step) following port and terminal automation. AI can provide solutions and increase the efficiency of port processes, leading to reduced costs, better optimization of port operations, decreased emissions, etc., which can increase port users' satisfaction. On the other hand, AI comes with a price. Significant investments are needed to adopt AI solutions in port operations, which might prevent medium- and small-size ports from moving fast in the AI era. Also, there are significant challenges for ports related to the potential scarcity of qualified personnel and the need for port workforce transformation. Leading ports such as Rotterdam, Hamburg, and Singapore have adopted AI solutions as part of their smart-port strategy, but the applications of AI in ports are still limited. The paper tries to shed light on the issues affecting the potential of AI in the port industry by examining the perceptions of ports regarding the expectations, challenges, and pros and cons of AI in ports. Towards this, the paper proceeds with field research using a structured questionnaire in the major Greek ports operating as Societe Anonymes. The research results will provide valuable insights regarding the lack of AI adoption by the port industry that can be used to form relevant strategies and policies that will tackle the still low penetration of AI in ports.

Keywords: Artificial Intelligence, Port perceptions, Greek ports

1. INTRODUCTION

Information and Communication Technologies (ICT) are advancing, with many companies from various business sectors adopting and applying new and innovative ICT solutions to their operations, while others are also investing in further exploiting the opportunities that might arise, investing in Research and Development (R&D). The new technologies can lead to increasing performance, thus increasing competitiveness. With business sectors such as the shipping and the port industry, where competitiveness is a top priority, considering that both sectors are globalized, new technologies should be at the forefront of their business strategies. Despite that, shipping (see [1]) and the port industry show a slower pace in adopting new and innovative technologies than other business sectors. This relates to the concept of dynamic capabilities defining how the industry and employees adapt to technological changes, according to Teece *et al.* [2]. With the shipping industry facilitating 90% of global trade (International Chamber of Shipping) and ports being embedded in supply chains [3], it is obvious that new technologies can play a significant role in port efficiency and global trade efficiency for the benefit of the worldwide economy.

Contemporary technological advancements are dealing with Artificial Intelligence (AI, which has been applied in several business sectors and processes aiming at a) increasing responsiveness, b) optimizing procedures, c) reducing operating costs, and overall, d) increasing efficiency and effectiveness in a company or a business sector. AI has been used in almost any type of transport mode and system (for a review, see [4] and [5]).

The port industry is under continuous transformation due to technological advancements. Between 1980 and 2010, advancements in software and algorithms marked the emergence of new technologies, such as information management systems that tracked ships and cargo, laying the foundation for "smart ports. Although the port industry is lagging in AI applications, port initiatives are showing that the industry is taking steps toward adopting AI tools in port operations. Gupta *et al.* [6] stated that artificial intelligence (AI) has emerged as a crucial initiative in the transformation of port operations, aiming to alleviate congestion, reduce loading and unloading times, enhance operational efficiency, and address environmental issues, a view that also supported by Tiwari *et al.* [7]. Integrating AI technology into port systems enables real-time monitoring and analysis of vast amounts of data, facilitating intelligent management across various functions such as vessel scheduling, cargo handling, and port facility management [8]. Automation and robotics were widely introduced between 2010 and 2020, automating processes such as container loading and unloading with robots and autonomous vehicles, according to de la Peña Zarzuelo *et al.* [9].
It should be noted that AI applications can be extended beyond the core port activities. Port Authorities and port terminal operating companies are fostering collaboration between stakeholders, which is now a fundamental component of a contemporary port. Integration extends beyond port authorities, terminals, and users to cities, hinterlands, and supply chains.

Integrating Artificial Intelligence (AI) in port operations offers significant advantages, improving efficiency and streamlining processes. One key benefit is the reduced cargo handling time, which enhances service quality and customer satisfaction. AI's ability to process large amounts of data quickly helps optimize management decisions, enabling fast and accurate responses to changing conditions within the port environment [10] [11]. AI also plays a crucial role in increasing automation and supply chain visibility. By transforming digital operations in ports, terminals, and vessels, AI is helping to redefine cross-border trade, making shipping operations more efficient and transparent. Specifically, AI optimizes berth scheduling, particularly at bulk terminals, and automates the loading and unloading of rolling cargo, improving time management, energy consumption, and space utilization [12] [13].
AI also has significant potential to reduce emissions within the maritime industry. By employing advanced fuel optimization techniques, AI can analyze real-time data such as weather conditions, sea currents, ship speed, and engine performance. This allows AI systems to determine the most fuel-efficient routes and adjust a vessel's speed to optimize fuel consumption while ensuring timely arrivals. This adaptive approach reduces fuel consumption and minimizes greenhouse gas emissions, aligning with broader sustainability goals. AI-driven route optimization is revolutionizing energy efficiency in maritime operations, utilizing advanced algorithms to identify the most efficient routes for vessels, as supported by Durlik *et al.* [14].

Despite AI's benefits in the port industry, its adoption varies between ports. It can be observed that large ports and nodes in the global sea transport networks have been moving forward with the application of AI-based solutions. Many leading global ports, such as Rotterdam, Hamburg, and Singapore, have embraced the smart port strategy through extensive digitization efforts. This involves leveraging Artificial Intelligence (AI), the Internet of Things (IoT), and automation to enhance efficiency, optimize operations, and improve environmental sustainability. The port of Los Angeles (USA) is using the Port Optimizer portal, which entails AI, while the port of Rotterdam (The Netherlands) is working towards utilizing the potential of AI on nautical safety, asset life cycle, operations optimization, and energy management systems. Hutchinson Ports uses modern AI in the company's new Terminal Operating System (TOS) to maximize productivity.

The AI applications are observed mainly in container ports/terminals where productivity, efficiency, and effectiveness are more important compared with other types of ports/terminals (for example, dry and liquid bulk ports/terminals). AI applications are spotted on ports of international interest. This might be related to the cost of developing and applying AI solutions in port operations. AI application in ports might also relate to the host country's investments in new technologies and whether the host country is technologically advanced.

The paper aims to contribute to the academic literature and the relevant discussions in the port industry regarding the applicability of AI in ports. It does so through field research with the use of a questionnaire aimed at professionals in the port industry with varying levels of experience and expertise in information and Communication Technologies (ICT), such as IT Managers and managers from the upper management level of Greek ports, with the goal being to analyze the perspectives of Greek ports and their intentions in adopting AI as well as identifying areas where AI applications will provide significant added value to ports. The paper is organized as follows. Section 2 provides an overview of the existing literature regarding AI potential in the port industry. Section 3 presents the methodological framework of the current research. Section 4 analyses the field research results, while Section 5 discusses the results and their use in developing relevant port policies and strategies and proposes steps for further research.

2. LITERATURE REVIEW

Artificial intelligence is at its initial stage in the port industry. AI is gaining attention with automation of port operations showing increasing penetration, especially in container ports and terminals, due to potential reductions in operating costs (OPEX). It aims to minimize workforce requirements further, increase safety, and promote environmental sustainability. The efficiencies produced by port automation processes are coupled with AI's capacity to predict vessel arrival times, facilitating better rescheduling in disruptions and enhancing overall operational agility [15].
In summary, as stated by Wang *et al.* [16], AI technology is an interdisciplinary and integrated technology that blends human-computer interaction, deep learning, and intelligent decision-making systems to support various industries. AI improves port efficiency through better exploitation of automation and optimization and promotes environmental sustainability and economic gains, positioning it as a vital technology for the future of port operations.

Adopting AI in ports faces several significant challenges, primarily related to high financial costs and workforce transformation. When investing in AI technology, two types of costs must be taken into account:
1. **Fixed Costs**: These cover developing systems, sensors, data transmission, and other infrastructure requirements.
2. **Marginal Costs**: These are associated with the digitalization of each cargo unit (for example, a container), including system maintenance, data storage, and other ongoing operational expenses, which increase with port throughput.

Hub ports must carefully evaluate the balance between fixed and marginal costs, as large-scale AI investments in automating operations, such as smart terminals, can strain short-term profitability. As waiting times for vessels decrease through the adoption of AI tools, energy consumption fees also decrease, offering long-term savings. However, AI implementation may demand large upfront investments and time, and while service quality improves, it may come at the expense of short-term profits [11].
For feeder ports, although benefiting from short-term profits, its impact on service quality is limited, making long-term planning critical [11]. Moreover, ports acting as feeder nodes in the sea transport network do not have the financial capacity to implement large-scale investments required to implement and operate AI solutions. Measures such as transfer payments, loan support, or financial leasing may be useful to support AI adoption in hub ports and facilitate its eventual expansion to

feeder ports. The financial support can come through mechanisms like Public-Private Partnerships (PPP) or Engineering, Procurement, and Construction (EPC) models that could alleviate cost pressures, promoting AI adoption in both hub and feeder ports [15]. Additionally, the lack of qualified personnel poses another obstacle, requiring significant investment in workforce re-training to operate AI systems effectively. In conclusion, port management must take into these challenges vis-à-vis the potential long-term benefits in the decision-making process for the development and/or implementation of AI in port operations.

Artificial intelligence is gradually being applied in the port industry, with the ports of international interest pioneers in relevant developments and investments. Whether AI will be broadly used in every aspect of port operations and management, irrespective of port six, is something to be seen. Several technological developments have been welcomed with enthusiasm by the port industry, but so far, the applications are limited, and things are moving slower (see, for example, the blockchain technology application in the port industry). The paper will add to the discussion regarding the potential of AI in the port industry through field research on IT experts from the Greek port industry and port managers from the upper management levels (C.E.O.s, C.O.Os).

3. METHODOLOGICAL FRAMEWORK

The paper aims to identify the penetration of Artificial Intelligence in the Greek port industry and to exploit their perception regarding the potential of AI. Towards this, a questionnaire has been developed with 17 questions in total, grouped into five categories: a) General information (the profile of the expert), b) Awareness and Use of AI, c) Benefits and Challenges of AI, d) Future Prospects and e) Potential Applications of AI. The questionnaire was developed online using Google Forms and the majority of questions were multiple-choice questions or evaluation questions based on a 5-point Likert scale. The target group was the CEOs, COOs, and IT experts from the major Greek ports operating as Sociate Anonymes, which are 13. It must be noted, though, that out of the 13 Port Authorities operating as Societe Anonymes, six PAs (46,15%) do not have an ICT-related department in their organization structure, six have an ICT Department, and one Port Authority has an IT Directorate in its organization structure. Despite the various general reforms that the Greek port system, and the Port Authorities S.A. in particular, went through (for details, see [17]), several Port Authorities are not paying the proper attention to ICT developments. This might be because several Port Authorities are understaffed, so allocating human resources in scarcity to an ICT department is not a priority.

Based on the above, the target group comprised 23 experts invited to participate in the research by completing the questionnaire. The field research ran from the 20th of December 2024 to the 20th of January 2025, while two reminders were sent on the 10th and the 20th day of this period. In total, 16 experts responded, formatting a Response Rate (RR) of 69,56%. The data collected have been analyzed to highlight the main conclusions regarding the application of AI in Greek ports.

4. RESEARCH RESULTS

4.1. Respondents profile

The first part of the questionnaire analyses the respondents' profiles regarding their position in the Port Authority and their experience in years. Figure 1 shows the respondents' role in the Port Authority, and Figure 2 shows their expertise in the ICT domain

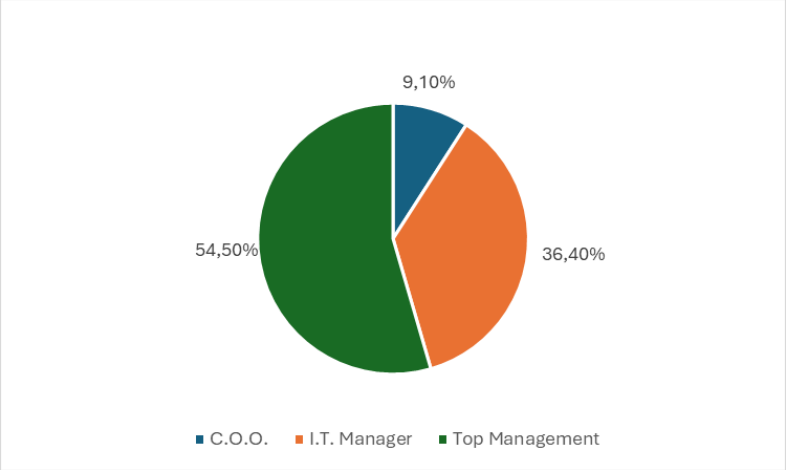

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Figure 1: *Job position of respondents*

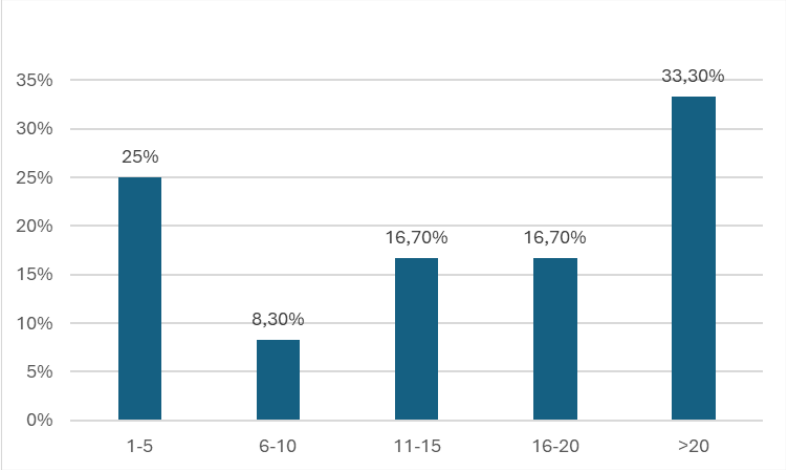

Figure 2: *Respondents' experience (in years)*

Most respondents work at the Port Authority's top management levels, while more than one-third are IT managers in PAs. Fifty percent of respondents have more than 16 years of experience. Based on the above, the sample has qualitative elements that reinforce the reliability of the results.

4.2. Awareness and Use of Artificial Intelligence

Among the respondents, 87% were well aware of using Artificial Intelligence in ports, even though only 20% of the Port Authorities they represented in the sample already used AI in their operations. This shows that Greek port experts are following AI usage in the global port industry even though Greek ports are lagging. This can be attributed to the fact that most of the Greek Port Authority operate small to medium-sized ports with small revenues, which impose investment constraints. Figure 3 presents the channels through which the respondents keep up with the AI developments. 41,7% of the respondents said that they follow the developments of AI applications in the port industry by participating in related conferences and seminars. One-third of the sample answered that the information comes mainly from port industry publications and reports. Another 16,7% is being updated through relevant workshops, and the remaining 8,3% responded that they keep up with the AI developments in the port industry through their network of colleagues and professionals in Greece and abroad.

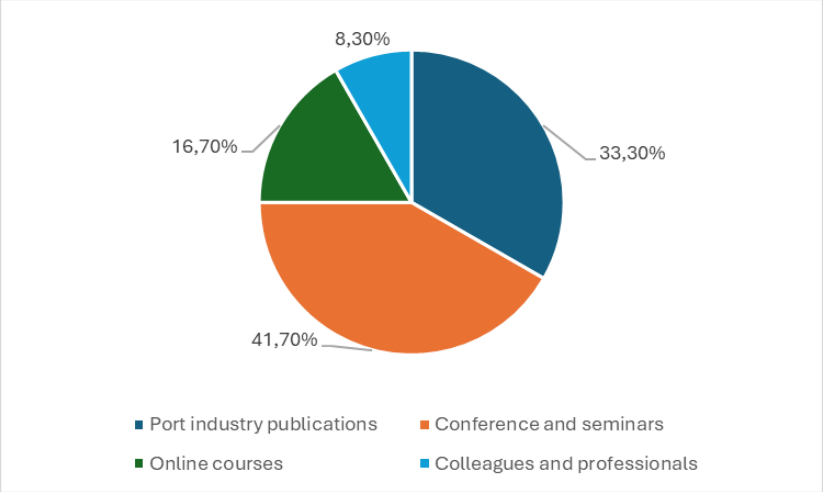

Figure 3: How the respondents are keeping up with AI developments in the port industry

Table 1 shows the respondents' perceptions on how AI can be used in the port industry to increase efficiency and effectiveness.

Table 1: Port and port-related activities in which AI could be used,

Security and surveillance	**90,90%**
Port equipment maintenance management	**81,80%**
Real-time tracking	**72,70%**
Environmental monitoring	**72,70%**
Berth allocation	**72,70%**
Cargo handling	**63,60%**
Ship scheduling	**63,60%**
Warehouse management	**54,50%**
AI-driven customer services	**54,50%**
Data management	**54,50%**
Financial management	**45,50%**
Customs procedures	**27,30%**
Procurements	**9,10%**

Most respondents indicated that security and surveillance are the main domains in which AI can be applied in ports, followed by port equipment maintenance through better programming and identifying potential damages. In third place, respondents selected three activities: berth allocation, real-time tracking, and monitoring of the port's environmental performance. According to the significant benefits in port efficiency and safety.

As mentioned above, only 20% of the respondents work for a Port Authority implementing AI in port operations. According to the answers, these applications are related to three tasks: a) security and surveillance, b) financial management, and c) warehouse management. Compared with other ports worldwide, AI applications in Greek ports are limited, and the applications do not focus on core port activities.

4.3. Artificial Intelligence Benefits and Challenges

In this part of the questionnaire, respondents were asked to express their perceptions of how beneficial AI could be for the port industry and the challenges towards AI implementation in ports. Respondents were asked to rate whether AI could benefit the port industry on a scale of 1-5, with 5

being the top-rated selection. Based on the responses, 81,8% of the sample gave the highest rating while the remaining 18,2% gave a rate of 4. Thus, the respondents expect that AI could be a significant added value for the port industry that can create substantial benefits for the wider port community. Figure 4 presents the respondents' views regarding the main benefits they expect from using AI in the port industry.

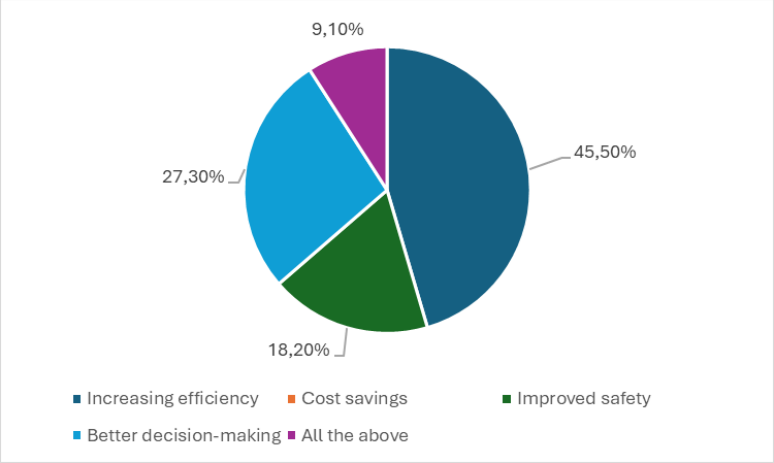

Figure 4: How the respondents are keeping up with AI developments in the port industry

According to 45,5% of the respondents, the main benefit of using artificial intelligence in the port industry will be increasing efficiency. AI could also improve decision-making processes (27,3%) and port safety (18,2%). Despite the expected benefits of AI, the experts identified some main challenges related to using AI in the port industry, as shown in Figure 5.

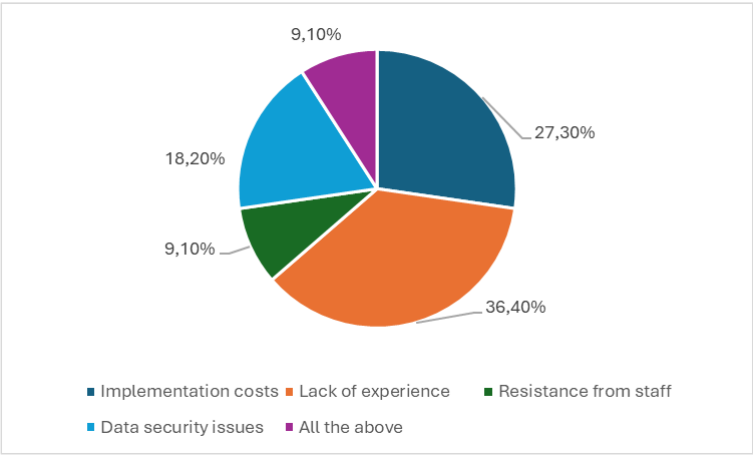

Figure 5: Challenges towards the implementation of AI in the port industry

The data collected shows that 36,4% of the sample identified a major challenge for AI implementation in the port industry as a lack of experience, as AI is a relatively new technology, while in some ports, the employees lack the proper training. The cost of implementing AI technology in ports is the second most important challenge, with 27,3%, while in the third place, there are issues related to data security (18,2%). These challenges, with a particular emphasis on the high initial investment costs and the need for specialized workforce training, could cause delays in the widespread adoption of AI.

4.4. Future Prospects of Artificial Intelligence in the Port Industry

All the respondents believed that Artificial Intelligence would play a significant role in the medium to long term (5-10 years). This is related to the developments in every domain of AI. Introducing AI solutions to our daily lives (see, for example, the ChatGTP) makes people more familiar with this

technology, thus affecting perceptions regarding the evolution of AI adoption in our working lives and environment.
The necessity of AI for ports was unveiled by asking the respondents whether they intend to invest in or recommend investing in AI solutions for their ports. Most of the respondents (90,9%) gave a positive answer.
The answers in this questionnaire section indicate port professionals' confidence in AI's potential to modernize and develop the port sector.

4.5. Applications of Artificial Intelligence in the Port Industry

In the last part of the questionnaire, the participants were asked to evaluate the existing AI applications in the port industry and to express their views on the potential areas of port operations where AI could be more beneficial. Regarding evaluating the current AI implementations and their effect in improving a port's efficiency and cost reduction, from a scale of 1-5, where 5 strongly agree and one strongly disagree, the respondents gave a moderate rate of 3,27. This means that the existing benefits of AI applications in port efficiency improvement and cost reductions are not the expected ones.
Figure 6 shows the experts' responses regarding the areas in which AI applications could be most beneficial for ports.

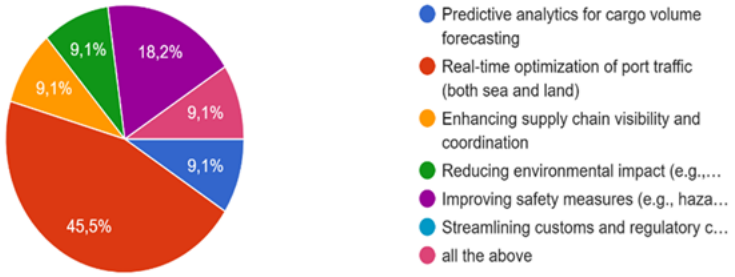

***Figure 6**: Challenges towards the implementation of AI in the port industry*

According to the data collected, 45,5% of the sample selected real-time optimization of port traffic as the top area for AI applications. The second most preferred area is improvements in port safety, with 18,2%. Real-time optimization, both from the sea and land perspective, can reduce the congestion problems observed in many ports worldwide, which can explain this selection by the sample.

5. CONCLUSIONS

Although Artificial Intelligence is considered a technology with enormous potential to improve port operations, its adoption is still in the early stages in Greek ports. Challenges such as implementation costs and the lack of specialized personnel remain key limiting factors. At the same time, the high percentage of professionals recognizing the importance of AI for the future indicates the need for strategic investments and training.
International experience shows that ports adopting AI, such as those in Rotterdam, Hamburg, and Singapore, enjoy increased efficiency and a reduced environmental footprint. AI can reduce loading and unloading delays, improve vessel management, and enhance security. The challenge for Greek ports is to balance the costs and benefits of the technology.

The questionnaire's findings confirmed the literature review results, as common trends and conclusions were observed. Participants recognized the importance of AI in improving efficiency and safety in port operations, aligning with the insights provided in the literature review. Moreover, the economic and technological constraints reported in the questionnaire, such as high implementation costs and the need for specialized workforce training, are consistent with the challenges documented

in previous studies. The optimism professionals expressed regarding AI's role in the coming years reflects the literature's emphasis on AI's contribution to ports' future development and modernization. This alignment between the questionnaire results and the literature strengthens the validity of the study's conclusions.
Based on the research, the papers propose further exploitation of AI-related solutions for core port operations and the direction of relevant investments towards this scope. The goal should be to invest in areas like cargo management and security, where AI can offer significant benefits.

Training and skill development are other fields in which the paper proposes the development of initiatives. Strengthening workforce expertise in AI is necessary to use the technology effectively. Also, developing strategic partnerships with technology companies can reduce implementation costs and accelerate the transition to digitization. Finally, the pilot implementation of AI applications can help assess AI performance and tailor applications to the needs of Greek ports. With these steps, Greek ports can successfully integrate AI, making them more efficient, sustainable, and competitive globally. The Greek port reform program, which is under development in Greece and aims to attract private investments in the Greek port industry, might be an opportunity to further exploit AI potential in Greek ports.

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