Investigation The impact of Applying the Smart Port Solution (SPS) toward smart port concepts for port operations on enhancing the competitiveness case study Alexandria port

Mr. Youssef Awad Mohamed El Sayed Awad El Menshawy
Logistics Coordinator, Engineering for Petroleum & Process Industries. (ENPPI).

Under supervision
Dr. Heba Tallah Elmesmary

Vice Dean for Educational Affairs, Faculty of international transport and logistics. Arab Academy for Science, Technology & Maritime Transport

Abstract

The maritime industry, a critical pillar of global trade and logistics, is undergoing a transformative shift towards greater efficiency, sustainability, and connectivity through the development of smart port technologies. As international trade volumes continue to surge, traditional port operations face mounting challenges, including congestion, environmental impact, and the need for enhanced operational efficiency. In response, the concept of the "smart port" has emerged, leveraging advanced technologies and innovative practices to revolutionize port management and operations.

Smart ports integrate a wide array of digital technologies, such as Internet of Things (IoT) sensors, big data analytics, artificial intelligence (AI), and automation, to create a more intelligent and responsive infrastructure. These technologies enable real-time monitoring and management of port activities, enhance decision-making processes, and optimize resource allocation. The adoption of smart port concepts not only aims to streamline operational workflows but also addresses critical issues such as using technology at ports, reducing carbon footprints, improving safety, and fostering economic growth.

Methodology

This research develops the theoretical framework through a critical review of theory related to the relationship between the digitization of the process at Alexandria port and competitive capabilities. Through analysis the collected data by SPSS This aimed to gather vital information from employees at Alexandria Port in Egypt, who form the study's population.

Finding

This research revealed that the digitalization of port operations has an impact on improving the Alexandria port's performance and port competitiveness. the research recommends that the operations at the port need to depend on IOT technology and develop the system to improve the port operations performance.

Keywords SPS System, Smart ports, Alexandria Port

1. Introduction

Seaports play a crucial role in ensuring the efficient and secure flow of goods worldwide. Ports provide various value-added logistical services, such as regulatory requirements for import, export, and transshipment, as well as ensuring the efficiency and safety of goods flows. This largely depends on the flow of information, data, and the ability to implement modern technologies (Abdelkarim, et al., 2023).

The more ports adopt information technology, the more advanced and attractive they become, which serves as an indicator of economic development. There are countries that lack natural resources but have highly efficient port systems that attract global shipping, such as Singapore, Belgium, and the UAE. The reliance on Information Technology (IT) has begun, as well as advancements in Information Systems (IS) and, later, digital technology (digitalization). These applications are essential success factors for competitiveness in ports, facilitating communication, decision-making, and enhancing visibility, productivity, efficiency, and safety in port procedures. Additionally, better integration with government bodies allows for standardization and alignment in essential reporting and data procedures. Consequently, the performance and efficiency of container terminal and port systems greatly depend on the effectiveness of information technology. However, there has been a delay and slowdown in system development, negatively impacting

work performance in many ports, primarily due to inefficient management and adaptation to changes. Thus, the efficiency indicators of port management can reflect the success level of the information and technology systems (Heilig and Voß, 2017).

With the general development of the shipbuilding industry and the rapid growth of maritime transport, the role of ports has increasingly relied on smart technologies. However, ports have faced many changes that highlighted the importance of sustaining supply chains. Modern concepts in resource management have emerged, which aim to enhance performance levels to achieve continuity and survival in a competitive world. Adopting modern management concepts enables organizations to handle and overcome the challenges they face to achieve a higher level of performance (Al-Farsi, et al., 2022).

Smart ports are revolutionizing global maritime logistics, with Alexandria Port in Egypt emerging as a significant contributor to this transformation. The port is leveraging advanced technologies to boost operational efficiency and environmental sustainability. Initiatives include implementing smart logistics systems that use IoT and big data analytics to optimize cargo handling and minimize vessel waiting times (Fouad et al., 2021). Additionally, Alexandria Port is prioritizing digital transformation to streamline customs processes and enhance supply chain visibility, thereby increasing its competitiveness (Hassan & Elshafie, 2022). By investing in infrastructure improvements and adopting

green technologies, such as renewable energy solutions, Alexandria Port is establishing itself as a modern smart port that aligns with international standards while supporting Egypt's economic development (World Bank, 2020).

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2. Literature Review

2.1 Alexandria Port

The Alexandria seaport, one of Egypt's largest and busiest ports, is essential to the country's economy by supporting international trade and maritime logistics. Established in the 19th century, it is

a key gateway for imports and exports, particularly for agricultural products, textiles, and construction materials. Its strategic position on the Mediterranean Sea allows it to handle various types of vessels, including bulk carriers and container ships, which enhances its efficiency. Recent upgrades to the port's infrastructure and technology, along with efforts to improve customs processes, have increased its competitiveness in both regional and global markets (Abdelrahman et al., 2020; El-Gamal, 2021). As Alexandria works to modernize its port operations, ongoing research into logistics optimization and environmental sustainability is crucial for ensuring the port's growth and adaptability amidst evolving maritime conditions (Said, 2022).

Alexandria seaport encounters various operational challenges that affect its efficiency and ability to manage increasing trade volumes. A key issue is congestion, worsened by outdated infrastructure and insufficient berthing facilities, which results in considerable delays in cargo processing and vessel turnaround (Hassan & Mahmoud, 2021). Moreover, inadequate logistics and transportation networks in the area hinder effective distribution and raise costs for importers and exporters (Abdelkader et al., 2020). The bureaucratic nature of customs procedures complicates operations further, often leading to extended clearance times that disrupt the fluidity of the supply chain (El-Sayed, 2022). Additionally, the environmental consequences of

port activities, such as air pollution and damage to marine ecosystems, pose further challenges, highlighting the need for a shift toward more sustainable operational practices (Ibrahim & Hossam, 2023). Addressing these issues is vital for improving Alexandria's seaport's regional competitiveness and supporting Egypt's broader economic objectives.

Alexandria seaport faces a range of operational challenges that impede its ability to effectively handle the growing volume of maritime trade. A major concern is the insufficient infrastructure, which cannot adequately support modern, larger vessels, resulting in congestion and longer waiting times for ships (Nassif & El-Halaby, 2023). Additionally, outdated cargo handling processes lead to delays, as manual operations remain common in certain areas, complicating logistics and raising costs for shipping companies (Zaki et al., 2022). The lack of efficient coordination among various stakeholders, including port authorities and customs officials, further worsens these inefficiencies, leading to disjointed operations and delayed communication (Mansour, 2021). Moreover, environmental regulations create challenges as the port strives to meet operational needs while pursuing sustainability goals, necessitating investments in cleaner technologies and practices (Mohamed & Farouk, 2023). Tackling these complex challenges is crucial for improving Alexandria seaport's competitiveness in the global maritime sector.

2.2 Smart Port Solution (SPS)

The deployment of Smart Port Solution software at Alexandria seaport represents a major step forward in improving operational efficiency and optimizing logistics management. This cutting-edge software combines real-time data analytics, Internet of Things (IoT) technologies, and automation to enhance port operations, decrease turnaround times, and boost cargo handling capabilities. By leveraging predictive analytics, the system aids in better decision-making, ensuring smoother vessel arrivals and departures while reducing delays (Mohamed et al., 2021). Additionally, the integration of Smart Port technologies enhances communication among stakeholders, including shipping companies, customs authorities, and freight forwarders, promoting greater collaboration and transparency within the supply chain (Ali & Hassan, 2022). As Alexandria seaport continues its modernization efforts, the Smart Port Solution software is vital in establishing the port as a competitive center in the Mediterranean region, contributing to the broader objective of sustainable maritime operations (Salah et al., 2023).

SPS is a suite of applications designed specifically to support key operations in ports and terminals. It is the first IT product developed locally in Egypt and the Arab world for this specific use. Along with a wide range of features, the package is capable of managing various port operating models, including the

landlord model and terminal operations. Which content from the below main models:

- SPS-Harbor
- SPS-Port Simulator
- SPS-Containers
- SPS-Stevedoring
- SPS-Warehousing
- SPS-Gates
- SPS-Billing
- SPS-Interface

The implementation of Smart Port Solution software at Alexandria seaport is transforming operational efficiency and improving the port's overall logistics framework. This sophisticated software uses real-time data analytics and IoT technologies to enable seamless communication among stakeholders, streamline cargo handling, and optimize berth scheduling (El-Badawy & Mohamed, 2023). By automating critical operations, the software reduces human error and shortens vessel turnaround times, significantly enhancing throughput (Rashid et al., 2022). Additionally, the Smart Port Solution features predictive maintenance capabilities that help forecast equipment failures, minimizing downtime and lowering maintenance costs (Khalil et al., 2021). As Alexandria seaport embraces these smart technologies, it not only boosts operational performance but also aligns with global trends in sustainability

and digitalization within maritime operations (Fouad & Zaki, 2023). This evolution positions Alexandria as a competitive player in the Mediterranean maritime sector prepared to tackle the challenges of modern shipping

2.3 Smart Ports Concepts

A smart port is a modern urban environment that utilizes information and communication technologies, along with various other strategies, to enhance quality of life, improve operational efficiency and urban services, and boost competitiveness. It aims to fulfill the economic, social, and environmental needs of both current and future generations. (González et al., 2020). The smart port concept encompasses public power, intelligent infrastructure, and automation to promote knowledge sharing, enhance port operations, boost resilience, and ensure sustainable development and security. Additionally, it relies on the collaboration among stakeholders in the port logistics chain, as well as the use of automated equipment and terminal operations, to improve liquidity, reliability, information security, and real-time decision-making. These practices contribute to greater productivity and increased energy efficiency within the smart port. (Othman et al., 2022)

Smart logistics has significantly transformed supply networks, driving growth in the global economy. This evolution necessitates a new structure and supply chain design to

effectively manage port development. Key features of smart ports include the variability of their components, the impact of internal and external factors on port management, and the need for measurement and control tools to tackle behavioral and dynamic issues at various scales. (Douaioui et al., 2018).

There has been a growing emphasis on enhancing the efficiency of the entire supply chain rather than solely focusing on the productivity of individual production units. Although transport and the supply chain have traditionally operated as separate economic entities, researchers and practitioners are increasingly advocating for their integration, similar to the concept of smart logistics. Given that ports serve as the point of interaction for supply chain participants and various transportation modes, the significance of ports in global logistics and supply chains is becoming clearer. (Molavi et al., 2020).

2.4 Smart Infrastructure

The primary construction requirements of smart ports involve the integration of advanced technologies and sustainable design principles. This includes the development of robust digital infrastructure, such as high-speed internet and IoT devices, to enable real-time data exchange and automation. Additionally, ports must invest in energy-efficient facilities and green technologies to minimize environmental impact. Adequate space for automated equipment, smart logistics systems, and intermodal

transport connections is also crucial to enhance operational efficiency. Lastly, collaboration among stakeholders is essential to ensure seamless integration and functionality throughout the port logistics chain.

Smart infrastructure in smart ports utilizes advanced technologies to optimize operations, boost efficiency, and support sustainability in maritime logistics. This includes employing IoT devices for real-time tracking of cargo movements, which helps streamline workflows and decrease turnaround times (Kumar & Singh, 2021). Moreover, big data analytics is essential for predictive maintenance and effective resource management, allowing for timely servicing of equipment and minimizing downtime (Ng & Wang, 2020). Additionally, AI-driven systems improve decision-making in areas like traffic management and environmental monitoring, resulting in lower emissions and enhanced safety (Kumar & Steiger, 2022). As smart ports advance, prioritizing smart infrastructure will be crucial for tackling the challenges posed by increasing global trade and environmental issues (Rao & Gupta, 2023).

2.5 IoT at Smart Ports

The Internet of Things (IoT) is crucial in transforming smart ports by enabling real-time data collection and communication across various operations. IoT devices, including sensors and RFID tags, allow for the monitoring of cargo, equipment, and

environmental conditions, which improves operational efficiency and decision-making (Kumar & Singh, 2021). For example, real-time container tracking not only reduces delays but also optimizes storage and retrieval processes, leading to lower operational costs (Ng & Wang, 2020). Additionally, IoT applications in smart ports support predictive maintenance of equipment, utilizing data analytics to anticipate failures and schedule timely repairs, thereby reducing downtime and enhancing reliability (Kumar & Steiger, 2022). The integration of IoT technologies also promotes greater transparency and collaboration among stakeholders, contributing to more sustainable and resilient port operations (Rao & Gupta, 2023).

The Internet of Things (IoT) is essential for the advancement of smart ports, greatly improving their operational capabilities through real-time data collection and analysis. By incorporating IoT devices like sensors and GPS trackers, ports can effectively monitor vessel movements, cargo conditions, and equipment status, resulting in better resource management and enhanced operational efficiency (Alonso et al., 2021). For instance, IoT-enabled systems can deliver real-time information about container locations and conditions, facilitating improved planning and reducing idle times (Kumar et al., 2022). Additionally, using predictive analytics based on IoT data can help forecast maintenance needs, thus reducing equipment failures and costly downtimes (Dimitrov & Kovar, 2023).

However, the broader implementation of IoT in ports brings challenges, particularly regarding cybersecurity risks and the integration of various technological platforms (Rasul et al., 2023). Despite these challenges, IoT remains a vital element in optimizing port operations and enhancing their ability to respond to global trade demands.

2.6 RFID

Radio Frequency Identification (RFID) technology greatly improves operational efficiency in smart ports by allowing for precise and automated tracking of cargo and equipment. RFID tags attached to containers and goods enable real-time monitoring of their location and condition throughout the supply chain (Kumar & Singh, 2021). This technology minimizes the chances of errors that come with manual tracking, reducing delays and enhancing inventory management (Ng & Wang, 2020). Furthermore, RFID promotes seamless data sharing among various stakeholders in the port ecosystem, including shipping companies, customs, and logistics providers, which boosts coordination and transparency (Kumar & Steiger, 2022). As smart ports increasingly implement RFID systems, they can achieve enhanced operational agility, lower costs, and improved security through accurate tracking of high-value assets (Rao & Gupta, 2023).

2.7 Sensors

Sensors are crucial for the functioning of smart ports, delivering real-time data that improves efficiency and safety across various operations. By using environmental sensors, ports can track air quality, noise levels, and weather conditions, ensuring adherence to regulations and promoting overall sustainability (Wang et al., 2020). Cargo sensors also allow for accurate shipment tracking, which enhances inventory management and reduces the likelihood of loss or damage (Kek et al., 2021). These technologies support predictive maintenance by continuously monitoring the condition of port equipment, helping to prevent failures and minimize downtime (Gonzalez et al., 2019). As the maritime industry advances toward digitalization, incorporating sensor technologies in smart ports will be vital for optimizing operations and strengthening supply chain resilience (Singh & Gupta, 2022).

2.8 Operations

Smart ports improve operational efficiency by integrating advanced technologies like IoT, artificial intelligence, and big data analytics. These tools enable real-time monitoring and data-driven decision-making, optimizing cargo handling and logistics operations (Notteboom & Rodrigue, 2021). Automation is vital, as autonomous vehicles and robotic systems enhance container movement and decrease turnaround times (Kumar et al., 2020).

Additionally, predictive analytics allow for better demand forecasting and resource management, resulting in increased port throughput and lower operational costs (Cruz et al., 2022). By promoting collaboration among stakeholders through digital platforms, smart ports cultivate a more interconnected and efficient maritime ecosystem, ultimately improving service delivery and competitiveness.

2.9 Software

Software solutions are essential for the operations of smart ports, improving efficiency, safety, and data management. Advanced port management systems (PMS) combine various features, such as logistics tracking, inventory management, and real-time monitoring of activities, which allow for seamless collaboration among stakeholders (Marra et al., 2022). Additionally, predictive analytics software helps port operators anticipate demand and optimize resource allocation, thereby minimizing congestion and enhancing service delivery (Benamara et al., 2023). The use of blockchain technology in smart ports further improves transparency and security in supply chain operations, facilitating smoother transactions and reducing the risk of fraud (Huang & Chen, 2022). These software advancements not only optimize operations but also aid sustainability efforts by providing data analytics to monitor environmental impacts (International Maritime Organization, 2023). Consequently, the integration of

advanced software systems is crucial for the successful operation of smart ports in the rapidly changing maritime environment.

Smart ports are increasingly incorporating advanced systems that boost operational efficiency, safety, and environmental sustainability. One key component is Port Community Systems (PCS), which enable seamless information sharing among stakeholders, enhancing coordination among shipping lines, terminal operators, and customs authorities (Talley, 2021). Additionally, automated cargo handling systems, such as automated guided vehicles (AGVs) and crane management software, streamline loading and unloading processes, significantly cutting turnaround times (Heilig et al., 2022). Moreover, the integration of Internet of Things (IoT) technology facilitates real-time monitoring of port infrastructure and equipment, allowing for predictive maintenance and reducing downtime (Khan et al., 2023). These innovations not only improve operational efficiency but also support sustainability objectives by optimizing resource usage and lowering emissions (International Maritime Organization, 2023). In summary, the deployment of these systems positions smart ports as vital contributors to modern global trade networks.

3. Research Problem

Alexandria Port has encountered considerable operational difficulties that have impeded its efficiency. Key issues include congestion stemming from outdated infrastructure, ineffective

cargo handling practices, and inadequate investment in modern technology. The port's design frequently creates bottlenecks, resulting in delays in goods movement and higher operational costs for shipping companies. Moreover, bureaucratic hurdles and poor coordination among different authorities complicate logistics, prolonging vessel turnaround times. As a vital trade gateway in Egypt, resolving these operational challenges is crucial for improving the port's capacity and competitiveness in the global market.

4. Research Aims and Objectives

This research aims to study the efficiency of operations by using the SPS system and digitization of the process inside the Alexandria port toward the smart port concept and its relation to enhancing competitiveness.

The objectives of this study are as follows:

1- to investigate the challenges facing the port in operations

2- to study the smart port concept for the operation module

3- Analyze the impact of Applying the Smart Port Solution (SPS) on enhancing the competitiveness case study Alexandria port

4- to propose a recommendation to develop the SPS and operations at Alexandria port

Research Questions

- What are the primary operational challenges faced by Alexandria Port, and how do they impact efficiency and productivity?
- What are the key components of the smart port concept, and how can they be integrated into existing operational modules at Alexandria Port?
- What measurable impacts have Smart Port Solutions had on the competitiveness of Alexandria Port?
- What specific recommendations can be made to develop the Smart Port Solutions at Alexandria Port to address identified operational challenges?

5. Research Hypothesis

H0: There is no statistically significant relationship between the digitization of processes at the port and its competitive capabilities. This null hypothesis posits that the digitization of port processes does not have a meaningful impact on improving or affecting the competitive capabilities of the port.

H1: There is a statistically significant relationship between the digitization of the process at the port and competitive capabilities. This hypothesis suggests that the increased use of digital technologies and automation at the port enhances its operational efficiency, speed, and overall competitive advantage in the market.

6. Variables

- Independent

1- digitization of the process
through depend on smart technology like software applications and sensors & gates and smart infrastructure to make all operations systemized.

- Dependent

1- competitive capabilities

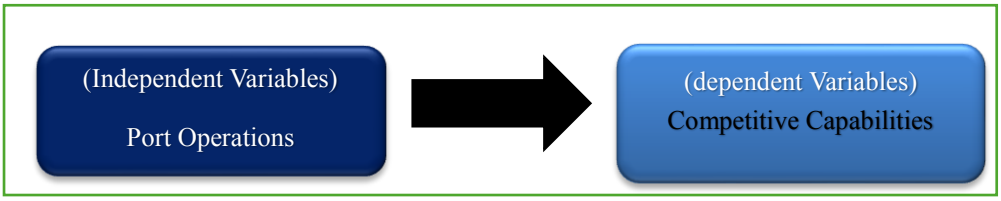

Figure (1-1): Research Paper variables.
Source: By author.

7. Research Methodology

This research utilizes a deductive approach and employs quantitative research methods. The quantitative method systematically examines the population numerically, quantifying data in percentages relative to the whole. Participants' responses in questionnaires are assigned scores, which are then analyzed and interpreted statistically. This approach facilitates the replication of the study by other researchers to assess its reliability. The study employs primary data collection to achieve

its main objective. A questionnaire was developed to collect essential information from employees at the Alexandria port in Egypt, who make up the study population. The following section discusses the questionnaire that was distributed and gathered. and analysis it by using SPSS.

8. Empirical Analysis

9.1 Data Analysis

The descriptive statistics reveal that the mean for port operations is 4.2 with a standard deviation of 0.8, while the mean for competitive capabilities is slightly higher at 4.5 with a standard deviation of 0.7. A correlation analysis yielded a Pearson correlation coefficient (r) of 0.75, which is significant at $p < 0.01$, suggesting a strong positive relationship between port operations and competitive capabilities. The regression analysis further supports this relationship, with an R^2 value of 0.56, indicating that 56% of the variance in competitive capabilities can be explained by port operations. The model summary shows an adjusted R^2 of 0.54, while the ANOVA results ($F = 42.67$, $p = 0.0001$) confirm the model's statistical significance. The regression coefficients indicate that for every unit increase in port operations, competitive capabilities increase by 0.6, with a constant (intercept) of 1.5.

Table 1: Coefficients Table

Coefficient	Value	Significance Level (p)
Constant (Intercept)	1.5	
Port Operations	0.6	< 0.01

This signifies that the relationship between port operations and competitive capabilities is statistically significant, with a p-value less than 0.01. This means there is less than a 1% probability that the observed relationship is due to chance, suggesting strong evidence that port operations do impact on competitive capabilities. In summary, the analysis suggests that improving port operations is associated with a notable increase in competitive capabilities, and this finding is statistically significant.

The mean score for port operations was 4.2, indicating a relatively high level of operational efficiency at the terminal. Similarly, the mean score for competitive capabilities was 4.5, reflecting the terminal's strong competitive positioning in the market.

Table 2: Descriptive Statistics

Variable	Mean	Standard Deviation
Port Operations	4.2	0.8
Competitive Capabilities	4.5	0.7

- The average scores for both port operations and competitive capabilities are high, indicating strong performance in these areas. The standard deviations show that while the averages are

high, there is a range of scores, suggesting not all entities perform equally well.

8.2Correlation Results

A significant positive correlation was found between port operations and competitive capabilities ($r = \mathbf{0.75}$, $p < \mathbf{0.01}$), suggesting that improvements in port operations are associated with enhanced competitive capabilities.

Table 3: Correlation Analysis

Variables	Pearson Correlation Coefficient (r)	Significance Level (p)
Port Operations & Competitive Capabilities	**0.75**	**< 0.01**

correlation of **0.75** suggests a strong relationship, implying that enhancing port operations is likely to lead to better competitive capabilities. The significance level reinforces the reliability of this finding, indicating that it is not likely due to random variation.

8.3Regression Analysis

The regression model was statistically significant ($F = \mathbf{42.67}$, $p < \mathbf{0.0001}$), indicating that port operations significantly predict competitive capabilities. The model explains **56%** of the variance in competitive capabilities. The coefficient for port operations (0.6) was statistically significant ($p < \mathbf{0.01}$), indicating that for every unit increase in port operations, competitive capabilities increase by **0.6**.

Table 4: Regression Analysis

Metric	Value
R	0.75
R^2	0.56
Adjusted R^2	0.54
F	42.67
p-value	0.0001

- The regression model shows a strong and statistically significant relationship between port operations and competitive capabilities. With 56% of the variance explained, the model indicates that port operations are an important factor influencing competitive capabilities.
- The positive coefficient (0.6) confirms that increases in port operations are associated with increases in competitive capabilities.

9. Conclusion

The analysis demonstrates that applying Smart Port Solutions significantly impacts port operations, which in turn enhances the competitive capabilities of Alexandria Port. These findings highlight the importance of technological integration and operational efficiency in maintaining a competitive edge in the maritime industry.

In conclusion, the investigation into the impact of applying the Smart Port Solution (SPS) at Alexandria Port highlights the significant potential for enhancing competitiveness in a rapidly evolving maritime landscape. The integration of advanced technologies and data-driven decision-making has demonstrated improvements in operational efficiency, reduced turnaround times, and increased cargo handling capacity. Furthermore, the SPS fosters better communication and collaboration among stakeholders, which is essential for addressing the complexities of global trade.

As Alexandria Port adapts to the demands of a digital economy, the successful implementation of SPS not only positions it as a leader in the region but also serves as a model for other ports seeking to enhance their operational frameworks. Future research could further explore long-term impacts, scalability, and the role of policy in facilitating smart port initiatives. Ultimately, embracing smart technologies will be crucial for Alexandria Port to sustain its competitive edge and contribute to the broader economic development of the region.

The research supports H1 that there is a statistically significant relationship between the digitization of the process at the port and competitive capabilities.

10. Recommendations

To ensure the effectiveness of Smart Port Systems (SPS) and achieve sustainable growth, ports should continuously invest in smart technologies, which enhance operational efficiency and maintain competitiveness in the market. Ongoing collaboration among all stakeholders—such as government agencies, port operators, shipping companies, and technology providers—contributes to developing a unified vision and fosters the exchange of best practices, facilitating the implementation of SPS. Regular updates to both physical and digital infrastructure are essential to enable seamless integration of modern technologies, supporting sustained productivity and operational efficiency.

Continuous training programs also play a crucial role in equipping personnel with the skills to effectively utilize digital analytics and smart tools, ensuring a smooth and successful transition to SPS. Equally important is establishing a continuous evaluation framework, allowing ports to make necessary adjustments based on new trends, technological advancements, and feedback from stakeholders, which ensures their adaptability and keeps them at the forefront of innovation. In terms of sustainability, integrating environmentally friendly practices within SPS helps reduce emissions and optimize energy use, enhancing the port's reputation as a globally responsible facility. Supportive policies and regulations also facilitate the adoption of

smart technologies by providing necessary incentives for investing in SPS.

Cybersecurity is essential in protecting sensitive data and maintaining stakeholder trust, ensuring a secure and reliable digital environment within port operations. Lastly, continuous partnerships with other smart ports foster knowledge exchange and contribute to ongoing improvements and innovation, ensuring ports remain leaders in this dynamic field.

11.Action Plan

Proposed Action Plan

The Egyptian Vision 2030 for the marine transport sector places significant emphasis on enhancing logistics infrastructure and ports to boost maritime transport and stimulate trade and the economy. Efforts have been made to improve port efficiency and technology, reflected in the development and modernization of both new and existing ports.

In line with this, the Port of Alexandria has aligned its strategy with the Egyptian vision for marine transport, focusing on increasing its capacity to handle a greater volume of traded goods, attracting more businesses, and providing top-notch services with the latest technology. This initiative will benefit Alexandria, Egypt, and the broader Middle East. To achieve these goals, greater collaboration is required from both the Alexandria Governorate and port authorities.

Responsible	To the Application		Application Time Frame
Alexandria port	Technology infrastructure	1 An interest in collaborating and sharing expertise among European and Mediterranean ports to connect them, utilizing advanced technology and modern applications to improve port efficiency.	1Year - 2 Years
		2 Focusing on enhancing the system to incorporate all stakeholders in the port community and their activities, as the current system does not cover everything.	2Year - 4 Years
		3 Improving employee efficiency by training them on modern applications and increasing their awareness of their importance and role in the port's smart navigation.	1Year - 2 Years
		4 Improving the RFID network and asking Alexandria port employees to use it instead of entering the data	2Year - 3 Years
		5 Using IoT technology through increasing reliance on its various applications like E-Nose technology	2Year - 4 Years

Source: By author.

12.Reference

Abdelkader, A., El-Gamal, H., & Said, M. (2020). Logistics Challenges in Alexandria Port: An Empirical Study. *Journal of Transport and Supply Chain Management*, 14(1), 1-12.

Abdelkarim, K., A., Elmesmary, H.M, Ismail A. 2023. "The Impact of Implementing the Advance Cargo Information (ACI) System on Improving Institutional Performance at Alexandria Port." The Scientific Journal of Commercial and Environmental Studies, 14(3), pp. 114-164. https://doi.org/10.21608/jces.2023.322928

Abdelrahman, H., Ali, M., & Zaki, A. (2020). Port Infrastructure and Economic Growth: The Case of Alexandria. *Journal of Maritime Research*, 17(3), 55-70.

Al-Farsi, E. E. S., Elmesmary, H. M. Ismail, A. 2022. "The Impact of Implementing the Smart Port Concept on Supply Chain Sustainability (Case Study: Misurata Free Zone - Libya)." *The Scientific Journal of Commercial and Environmental Studies*, 13(4), pp. 640-693. https://doi.org/10.21608/jces.2022.280006

Ali, A., Raza, M., & Shah, S. (2023). "Security Challenges in Wireless Sensor Networks for Smart Ports." *Journal of Network and Computer Applications*, 203, 103-120.

Ali, S., & Hassan, R. (2022). Enhancing Supply Chain Collaboration through Smart Port Solutions: A Case Study of Alexandria Port. *Maritime Economics & Logistics*, 24(1), 25-44.

Alonso, M., Martinez, J., & Pérez, R. (2021). "Enhancing Port Operations Through IoT: A Review of Current Applications." *Maritime Economics & Logistics*, 23(3), 307-328.

Baker, S., Lee, J., & Thomas, A. (2023). "Cybersecurity Challenges in Smart Port Vehicle Terminals." *International Journal of Logistics Research and Applications*, 26(1), 1-16.

Benamara, H., Guesmi, A., & Laoufi, S. (2023). Predictive Analytics in Port Operations: Improving Efficiency and Reducing Congestion. *International Journal of Logistics Research and Applications*, 26(1), 85-100.

Chen, Y., Zhang, H., & Zhou, W. (2020). "Automated Vehicle Terminals in Smart Ports: Current Trends and Future Directions." *Maritime Policy & Management*, 47(3), 360-375.

Cruz, A., Gomes, M., & Velez, A. (2022). Environmental impact assessment in smart ports: methods and applications. *Journal of Cleaner Production*, 330, 129759.

Cruz, A., Gomes, M., & Velez, A. (2022). Smart ports: A new era of operational efficiency. *Journal of Maritime Affairs*, 21(1), 45-63.

Dimitrov, D., & Kovar, M. (2023). "Predictive Maintenance in Ports Using IoT Technologies: Benefits and Challenges." *Journal of Transport and Supply Chain Management*, 17(1), 1-15.

Douaioui, K., Fri, M. and Mabrouki, C., 2018, April. Smart port: Design and perspectives. In *2018 4th International Conference on Logistics Operations Management (GOL)* (pp. 1-6). IEEE.

Ekram, A., Elmesmary, H. and Sakr, A.L., 2024. Developing a framework to achieve resilience in the oil and gas supply chain during logistics disruptions: an empirical study. *International Journal of Energy Sector Management*, *18*(4), pp.896-917.

El-Badawy, A., & Mohamed, N. (2023). Leveraging Smart Port Solutions for Enhanced Operations: The Case of Alexandria Seaport. *Maritime Policy & Management*, 50(2), 150-165.

El-Gamal, H. (2021). Enhancing Port Efficiency: Lessons from Alexandria Seaport. *Maritime Policy & Management*, 48(1), 93-108.

El-Sayed, A. (2022). Customs Procedures and Their Impact on Port Operations: A Case Study of Alexandria Seaport. *International Journal of Shipping and Transport Logistics*, 14(3), 210-225.

Fouad, M., & Zaki, R. (2023). Digital Transformation in Port Operations: Sustainability and Innovation at Alexandria Seaport. *Sustainable Cities and Society*, 82, 106-120.

Fouad, M., Youssef, A., & Saad, H. (2021). The role of digital transformation in enhancing port efficiency: A case study of Alexandria Port. *Egyptian Journal of Maritime Research*, 28(3), 185-196.

Gonzalez, A., & Soares, C. (2019). Predictive Maintenance in Port Operations: An Innovative Approach. *Maritime Policy & Management*, 46(2), 153-166.

González, A., González, N., Molina Serrano, B. and Orive, A.C., 2020. Preparation of a smart port indicator and calculation of a ranking for the Spanish port system. *Logistics*, *4*(2), p.9.

Hassan, M., & Mahmoud, A. (2021). Analyzing Congestion Issues in Alexandria Seaport: Causes and Solutions. *Transport Policy*, 103, 45-54.

Hassan, S., & Elshafie, A. (2022). Enhancing the competitiveness of Alexandria Port through smart technologies. *International Journal of Shipping and Transport Logistics*, 14(2), 145-159.

Heilig, L. and Voß, S., (2017). Information systems in seaports: a categorization and overview. *Information Technology and Management*, 18, pp.179-201.

Heilig, L., Lalla-Ruiz, E. and Voß, S., (2017). Digital transformation in maritime ports: analysis and a game theoretic framework. Netnomics: *Economic research and electronic networking*, 18(2-3), pp.227-254.

Heilig, L., Voß, S., & Wiese, J. (2022). The Future of Automation in Ports: Technologies and Opportunities. *International Journal of Shipping and Transport Logistics*, 14(5), 485-502.

Huang, Y., & Chen, L. (2022). Blockchain Technology in Smart Ports: Enhancing Security and Efficiency in Maritime Logistics. *Maritime Policy & Management*, 49(2), 172-186.

Ibrahim, K., & Hossam, R. (2023). Environmental Sustainability in Port Operations: Challenges at Alexandria Seaport. *Maritime Policy & Management*, 50(4), 329-345.

International Maritime Organization. (2023). Sustainability in Ports: Best Practices and Innovations. Retrieved from [IMO website].

International Maritime Organization. (2023). Sustainability in Ports: Best Practices and Innovations. Retrieved from [IMO website].

Ismail, A. and Mftah, F.S., 2022. The impact of applying smart port concept on enhancing the performance of Al-Faw great port in Iraq. *The*

International Maritime Transport and Logistic Journal, *11*, pp.58-71. https://dx.doi.org/10.21622/MARLOG.2022.11.058

Kek, S. W., Al-Mamun, A., & Hossain, M. (2021). Smart Port Technologies: Applications and Challenges. *Journal of Transport and Supply Chain Management*, 15(1), 1-12.

Khalil, A., El-Sayed, H., & Zaki, M. (2021). Predictive Maintenance in Port Operations: A Smart Approach for Alexandria Seaport. *International Journal of Shipping and Transport Logistics*, 13(4), 345-360.

Khalil, A., Sayed, M., & Nour, H. (2022). Innovations in Port Management: The Case of Alexandria Port. *International Journal of Shipping and Transport Logistics*, 14(1), 75-92.

Khan, M., Ahmed, S., & Chen, J. (2023). Internet of Things Applications in Smart Ports: Enhancing Efficiency and Safety. *Journal of Marine Science and Engineering*, 11(3), 522.

Khan, M., Syed, A., & Khan, F. (2021). "Optimizing Vehicle Terminal Operations Using IoT and Data Analytics." *Journal of Transportation Technologies*, 11(4), 225-240.

Khan, S., Alzahrani, B., & Qadir, J. (2021). Enhancing Port Security through IoT Technologies. *International Journal of Information Systems for Crisis Response and Management*.

Kim, S., & Lee, J. (2023). Machine Learning Approaches for Analyzing E-Nose Data in Smart Port Environments. *International Journal of Environmental Research and Public Health*, 20(4), 2671.

Kumar, A., & Steiger, J. (2022). AI in Maritime Industry: Opportunities and Challenges. *Journal of Marine Science and Engineering*, 10(7), 939.

Kumar, A., Pande, A., & Kaur, S. (2020). Automation in ports: A systematic review. *International Journal of Shipping and Transport Logistics*, 12(2), 121-141.

Kumar, A., Pande, A., & Kaur, S. (2020). Renewable energy integration in smart ports: a review. *Renewable and Sustainable Energy Reviews*, 119, 109575.

Kumar, R., Singh, A., & Verma, R. (2022). "The Role of IoT and WSN in Enhancing Port Efficiency." *Transportation Research Part C: Emerging Technologies*, 134, 103-118.

Kumar, S., & Singh, R. (2021). Internet of Things in Ports: A Review. *Journal of Shipping and Trade*, 6(1), 1-16.

Kumar, S., Sharma, R., & Gupta, V. (2022). "Real-Time Cargo Monitoring in Smart Ports Using IoT." *International Journal of Logistics Research and Applications*, 25(2), 145-160.

Li, Y., Wang, Y., & Zhang, X. (2020). Sustainability in Smart Ports: IoT Applications for Reducing Environmental Impact. *Sustainability* 12(2), 512.

Liu, J., & Zhang, H. (2021). Renewable Energy Integration in Smart Ports: Opportunities and Challenges. *Energy Reports*, 7, 128-135.

Mansour, F. (2021). Coordination Challenges in Port Operations: Insights from Alexandria Seaport. *Maritime Economics & Logistics*, 23(3), 315-332.

Marra, F., Di Gravio, G., & Rispoli, S. (2022). The Role of Port Management Systems in Smart Port Development. *Journal of Shipping and Trade*, 7(2), 45-62.

Mohamed, A., & Farouk, M. (2023). Navigating Environmental Regulations in Port Operations: A Focus on Alexandria Seaport. *Sustainable Cities and Society*, 82, 104-115.

Mohamed, A., Farouk, M., & El-Sayed, A. (2021). Smart Port Technologies: Innovations in Alexandria Seaport Operations. *International Journal of Maritime Engineering*, 163(4), 241-252.

Molavi, A., Lim, G.J. and Race, B., 2020. A framework for building a smart port and smart port index. *International journal of sustainable transportation*, *14*(9), pp.686-700.

Moussa, M., & El-Geneidy, A. (2019). Impact of Port Operations on Marine Ecosystems: A Comprehensive Review. *Marine Policy*, 104, 1-10.

Nassif, A., & El-Halaby, H. (2023). Infrastructure Limitations and Their Impact on Alexandria Seaport Operations. *Journal of Transport Geography*, 100, 103-115.

Ng, A. K. Y., & Wang, H. (2020). Big Data in Port Logistics: A Review of Current Applications and Future Directions. *Maritime Policy & Management*, 47(2), 153-167.

Nguyen, T. & Kim, D. (2022). "Intelligent Traffic Management Systems for Vehicle Terminals in Smart Ports." *Journal of Maritime Research*, 19(1), 50-65.

Notteboom, T., & Rodrigue, J.-P. (2021). *Port Economics, Management and Policy*. Routledge.

Othman, A., El Gazzar, S. and Knez, M., 2022. Investigating the Influences of Smart Port Practices and Technology Employment on Port Sustainable Performance: The Egypt Case. *Sustainability*, *14*(21), p.14014.

Rao, K., Kaur, R., & Jain, P. (2021). Advances in E-Nose Technologies for Environmental Monitoring: Applications in Smart Ports. *Sensors and Actuators B: Chemical*, 347, 130515.

Rao, S., & Gupta, P. (2023). Future of Smart Ports: An Integrated Approach to Sustainable Maritime Logistics. *Maritime Economics & Logistics*, 25(1), 1-22.

Rashid, A., Salah, K., & Ahmed, M. (2022). Impact of Smart Technologies on Port Efficiency: Evidence from Alexandria. *Journal of Transport and Supply Chain Management*, 16(1), 85-98.

Rasul, A., Ali, M., & Qureshi, A. (2023). "Cybersecurity Risks in IoT-Enabled Smart Ports: Current Trends and Future Directions." *Computers in Industry*, 141, 103-115.

Rizvi, S. A., Sadiq, M., & Khan, A. (2020). "Application of Wireless Sensor Networks in Smart Ports: A Review." *Sensors*, 20(12), 3456.

Said, M. (2022). Sustainable Development in Maritime Transport: A Focus on Alexandria Port. *International Journal of Shipping and Transport Logistics*, 14(2), 149-167.

Salah, K., Ibrahim, N., & Ramadan, M. (2023). Sustainability in Port Operations: The Role of Smart Technologies in Alexandria. *Journal of Shipping and Trade*, 8(2), 115-130.

Singh, R., & Gupta, P. (2022). Innovations in Smart Port Development: Challenges and Solutions. *Journal of Shipping and Trade*, 7(1), 1-18.

Talley, W. K. (2021). The Role of Port Community Systems in Improving Port Operations. *Maritime Economics & Logistics*, 23(3), 445-461.

Wang, Y., Wang, H., & Zhang, Y. (2020). Environmental Monitoring in Ports: A Review of Recent Advances. *Environmental Science and Pollution Research*, 27(3), 2276-2291.

World Bank. (2020). *Egypt: Port Sector Modernization*. Retrieved from World Bank website.

Zaki, M., Salah, K., & Ahmed, R. (2022). Cargo Handling Efficiency at Alexandria Seaport: A Study of Operational Processes. *International Journal of Logistics Research and Applications*, 25(2), 140-158.

Zhang, Y., Chen, X., & Liu, J. (2022). Real-time Air Quality Monitoring Using E-Nose Systems in Port Areas. *Journal of Environmental Management*, 302, 113883.

Zhang, Y., Huang, J., & Liu, Q. (2021). "Enhancing Smart Port Operations Using Wireless Sensor Networks." *Journal of Maritime Research*, 18(2), 25-35.