# The Impact of Smart Technology on Improving Energy Efficiency, Reducing Emissions in Egyptian Ports. Case study of Damietta port

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**المستخلص**

تُعد التجارة الخارجية عنصرًا أساسيًا في دعم اقتصادات الدول، وتلعب الموانئ البحرية دورًا محوريًا في هذا المجال، خاصة في مصر التي تتميز بموقع استراتيجي يربط بين أهم طرق الملاحة العالمية. ويُعد ميناء دمياط من الموانئ الحيوية التي تسهم في حركة التجارة الخارجية، إذ تمر عبره نحو ٩٠٪ من البضائع المصرية. إلا أنه يواجه تحديات تتعلق باستهلاك الطاقة، والانبعاثات، وكفاءة العمليات اللوجستية.

وتهدف الدراسة إلى تقييم دور التكنولوجيا الذكية في تطوير الميناء من خلال تحسين كفاءة الطاقة، وخفض الانبعاثات، وتعزيز الأداء التشغيلي. وقد أظهرت النتائج تحسنًا ملحوظًا بفضل تطبيق التطوير المستمر، بأنشاء رصيف متعدد الأغراض "تحيا مصر ١"، وتطبيق نظام Just-in-Time، واستخدام الطاقة الشمسية، والسيارات التى تعمل بالغاز الطبيعي. كما ساهم نظام النافذة الواحدة Port Single Window (PSW) في تبسيط الإجراءات وتعزيز الشفافية، في حين ساعدت المساحات الخضراء والإضاءة الشمسية في تقليل التلوث وتحسين جودة البيئة.

تؤكد هذه النتائج نجاح ميناء دمياط في التحول إلى نحو ميناء ذكي ومستدام، بما يدعم قدرته على جذب الاستثمارات ويعزز دوره الاقتصادي إقليميًا ودوليًا، رغم التحديات المحيطة.

**الكلمات المفتاحية:** الموانئ الذكية، ميناء دمياط، الاستدامة، تقليل الانبعاثات، اللوجستيات.

**Abstract**

Foreign trade is a fundamental element in bolstering national economies, with seaports playing a pivotal role in this domain, particularly in Egypt, which benefits from a strategic location connecting major global navigation routes. The Port of Damietta is a vital harbor contributing significantly to foreign trade flows, handling approximately 90% of Egyptian goods. However, it faces challenges related to energy consumption, emissions, and the efficiency of logistical operations.

This study aims to evaluate the role of smart technology in the port's development by enhancing energy efficiency, reducing emissions, and improving operational performance. The results demonstrate a notable improvement due to the implementation of continuous development initiatives, including the establishment of the multi-purpose "Tahya Misr 1" berth, the application of the Just-in-Time (JIT) system, the utilization of solar energy, and the adoption of natural gas-

powered vehicles. Furthermore, the Port Single Window (PSW) system has contributed to streamlining procedures and enhancing transparency, while green spaces and solar lighting have helped in mitigating pollution and improving environmental quality.

These findings underscore the success of the Port of Damietta in its transition towards a smart and sustainable port, which supports its capacity to attract investments and strengthens its economic role regionally and internationally, despite the surrounding challenges.

**Keywords:** Smart Ports, Port of Damietta, Sustainability, Emission Reduction, Logistics

## 1- Introduction

Ports play a crucial role in countries' national economy. As the main starting point for international trade through imports and exports, global waterways trade about 11 billion tons of goods annually, making them a vital element in strengthening the economic power of nations. Ports act as important sources of hard currency, encouraging the development of certain industries and contributing to the development of the surrounding areas. This great importance has resulted in increased regional and international competition, prompting countries to accelerate efforts to develop their ports (UNCTAD, 2023).

A recent study indicates that Egypt's distinctive geographical location makes it a central strategic point located at the intersection of the continents of Africa, Europe and Asia overlooking the Red Sea and the Mediterranean Sea associated with the Suez Canal. About12% of international shipping traffic crosses the Suez Canal," highlighting its vital importance in the global trade movement. This unique location has imposed on Egypt the need to develop its seaports to facilitate the passage of global trade and enhance its ability to counter competition with global ports (Damietta port authority, 2024).

The Egyptian Ministry of Transport carries out a comprehensive plan for the modernization and development of all elements of the transport system. This plan includes the improvement of transport means and networks, including roads and bridges, railways, tunnels, electric train, seaports, land and dry, logistics centers, as well as river transport. These efforts aim to meet the requirements of comprehensive development, to improve foreign trade services, promote transit trade and inland freight stations, and support tourism, industrial and commercial development. This trend aims to strengthen Egypt's position as a regional and global logistics center, thus prompting Egypt to invest in the development of its ports and enhance its competitiveness (Egyptian Ministry of transport, 2024).

Damietta Port is one of Egypt's leading seaports, its strategic location for Delta in the northeast of the Nile Delta, about 10 kilometers from the mouth of the Nile River on the Mediterranean to reach important agricultural and industrial areas in the Nile Delta and close to the main shipping routes, making it a major link between Mediterranean and Gulf markets, thereby strengthening its role as a vital logistic hub (Damietta port authority, 2024).

The port of Damietta has witnessed remarkable developments in recent years, adopting the latest technologies and mechanisms to improve its efficiency and enhance its competitiveness. One of the most important developments is the establishment of a multipurpose terminal to reduce waiting time, using the single window system, the FAL system has been activated and traded electronically on the port window. The tracksuit and departure forms were activated electronically (port development studies, 2024).

Automation systems are used to facilitate handling and storage, reduce the need for manual intervention and enhance the accuracy and speed of logistics operations (Rafaat, 2025).

As part of efforts to reduce greenhouse emissions and promote environmental sustainability the port of Damietta adopted strategies aimed at reducing the environmental impact of its operations. These strategies include the introduction of modern technologies to improve energy efficiency and reduce carbon emissions power supply, such as the delivery of electricity to ships on shore power supply and the obligation for ships to stop generators to reduce harmful emissions. Construction of 5 power plants using solar cells activation of the just in time system, conversion of approximately 11 cars to operate with natural gas clean energy equipment and advanced technologies to control ships' emissions and equipment. Waste management systems have also been developed more effectively, contributing to the preservation of the marine environment and enhancing the port's position as an example of environmental sustainability (environmental sustainability reports, 2024).

These developments are part of a comprehensive strategy aimed at improving the port's performance, enhancing its ability to meet the requirements of global trade and strengthening its role as a major logistics hub. Through these efforts, Port Damietta strives to strike a balance between economic growth and environmental conservation, enhancing its competitiveness and achieving sustainable benefits for the maritime transport industry (global port strategies, 2024).

## 2- Importance of the research

This research contributes significantly to demonstrating how smart technology and modern technologies mitigate environmental impacts, providing valuable guidance to other ports in their pursuit of the adoption and implementation of similar technologies. This in turn contributes to global efforts to improve the efficiency and sustainability of ports.

In addition, this research contributes to leading technological innovation by understanding the practical challenges and benefits associated with applying smart technology at Damietta Port. Research highlighted areas of technological improvement and innovation, proposing the latest developments in artificial intelligence that can enhance port efficiency and performance indicators.

The presentation of successful results from the implementation of smart technology can also enhance the attraction of domestic and foreign investments to Damietta port, as well as other ports seeking modernization. These results clarified the ability of smart technology to improve environmental and operational performance, making it a focus for investors and promoting development in the maritime sector.

## 3- Research Problem

Despite the vital role ports play in global trade and their environmental and technological impact, there is a lack of comprehensive understanding of how smart technology can improve energy efficiency and reduce emissions at some ports. Damietta Port adopts a range of smart technologies, but the challenge is to assess the effectiveness of these technologies in achieving their objectives of improving energy efficiency and reducing environmental impact. This research necessitates a thorough determination of the extent to which the implemented smart technologies have demonstrably improved energy utilization within the port's operations. Furthermore, it requires a robust assessment of the success of these technologies in measurably reducing emissions directly attributable to port activities.

## 4- Research Aim and Objectives

The research aims to explore the regional and global challenges facing Damietta Port in its efforts to become a smart port and identify opportunities for further improvement and investment.

**Objectives:**

1- Identification of smart technologies and marine innovations developed at Damietta Port

2- Assess the impact of smart technologies implemented at Damietta Port on energy efficiency, emission reduction and port performance.

3- Demonstrate the dual impact of these technologies on both environmental sustainability and economic performance and increased competitiveness.

## 5- Research Methodology

This research methodology relies on using a descriptive reviews approach by past literature and reports on smart technologies and digital transformation in seaports. This orientation helped build a knowledge base to understand the impact of these smart technologies in improving energy efficiency and reducing emissions. A case study focused on Damietta port development was then used, focusing on the port's smart technology to improve environmental and economic performance. The study reviews the impact of these applications on energy efficiency and emission reduction. Data collected through personal interviews of experts and academics in the management of ports and environmental technologies in Egyptian ports. The meta-audits were intended to assess the expected impact of new technologies on improving the port's operational and environmental performance. Using this integrated methodology, we were able to obtain comprehensive insights into the impact of smart technologies and digital transformation in improving energy efficiency and reducing emissions at Damietta Port.

## 6- Research Questions

1- Which specific smart technologies and innovations adopted at Damietta Port have had the most significant impact on improving energy efficiency and reducing emissions?

2- What regional and global challenges has Damietta Port faced in its efforts to become a smart port, and what opportunities exist for further enhancement and investment?

3- How can the advancements at Damietta Port serve as a model for similar initiatives in other Egyptian and regional ports, and what broader implications can be drawn for maritime logistics and environmental sustainability?

## 7- The Smart Port Concept

The concept of smart ports envisages transforming traditional ports into advanced and integrated systems where environmental impact, operational efficiency and energy consumption is carefully managed. The overarching goal is to develop ports into smart sustainable cities (SSC) within global supply chains. According to the International Telecommunication Union (ITU, 2015, p. 8), a sustainable smart city is defined as "an innovative city that uses information and communication technologies and other means to improve the quality of life, improve the efficiency of urban processes and services, and enhance competitiveness, while ensuring that the needs of current and future generations alike are met in economic, social and environmental terms".

Thus, if the port applies the requirements of the smart port, if some important indications are measured within the port such as the productivity and capacity consumed by ships, while waiting on the dock as well as the waiting time of ships on the dock, its impact for some indicators relating to the three dimensions of the sustainability supply chain, such as average wages for workers belonging to the social dimension of supply chain sustainability, the amount of emissions generated, the number of vessels that frequent the port, the length of their stay in the pier (environmental dimension), the sustainability supply chain and the world-wide arrangement of ports to demonstrate the efficiency of operations within the port, this "economic dimension" of supply chain sustainability (Heba, et al., 2019).

## 8- Smart Port Model

The Smart Port Model represents a comprehensive approach to transforming traditional seaports into highly efficient, technologically advanced, and environmentally sustainable hubs. This model integrates a variety of innovative technologies and strategies to optimize port operations and enhance their role within global supply chains. The core components of the Smart Port Model include (NASA MORE Conference, 2021).

Advanced Technological Integration:

- Incorporation of Internet of Things (IOT) devices, sensors, and data analytics to monitor and manage port activities in real time. This includes automated cargo handling, predictive maintenance, and enhanced safety measures.
- Sustainability Focus:
- Adoption of green technologies and practices aimed at reducing the environmental footprint. This involves utilizing renewable energy sources, implementing energy-efficient systems, and optimizing resource usage.

- **Operational Efficiency:**
- Streamlined processes through automation and digitalization to enhance throughput, reduce turnaround times, and improve overall efficiency. This encompasses the use of AI for logistics optimization, automated port equipment, and smart traffic management systems.
- Enhanced Connectivity:
- Development of robust communication infrastructure to ensure seamless integration with global supply chains and facilitate real-time information exchange among port stakeholders.
- Resilience and Adaptability:
- Designing infrastructure and systems to withstand and adapt to changing conditions, such as climate impacts or technological advancements. This includes resilient infrastructure and flexible operational strategies.
- Stakeholder Collaboration:
- Engaging various stakeholders, including port authorities, shipping companies, local communities, and technology providers, to align initiatives with broader economic, social, and environmental goals.

**8-1 Characteristics of a Smart Port**

A Smart Port is defined by several key characteristics that enhance its efficiency, sustainability, and overall functionality:

- Real-Time Data Monitoring: Continuous tracking of port operations through a network of sensors and data systems, providing actionable insights for decision-making and operational adjustments.
- Automation and Robotics: Use of automated systems for cargo handling, vessel traffic management, and port logistics to reduce human intervention and increase efficiency.
- Energy Efficiency: Implementation of energy-saving technologies and practices, such as electric or hybrid vehicles, energy-efficient lighting, and optimized energy consumption strategies.
- Environmental Stewardship: Measures to minimize environmental impact, including pollution control systems, waste management solutions, and initiatives to enhance air and water quality.
- Smart Infrastructure: Modernized port infrastructure designed to accommodate advanced technologies and support scalable and adaptable operations.
- Integrated IT Systems: Advanced IT solutions for managing port operations, including port community systems (PCS), and integrated logistics platforms that facilitate coordination among various stakeholders.
- Security and Safety Enhancements: Advanced security measures, including surveillance systems, cybersecurity protocols, and automated safety systems to protect assets and personnel.
- User-Centric Services: Services and facilities designed to enhance the experience for users, including improved customer service, user-friendly interfaces, and efficient processes for cargo handling and documentation (Basma et al.,2023)

**9- Development at Damietta Port**

The Port of Damietta Authority has launched a comprehensive development plan aimed at transforming the port into a smart sustainable port based on smart technology and emission reduction. This development included upgrading infrastructure and technology to enhance operational efficiency, environmental sustainability, and economic competitiveness (International Association of Ports and Harbors (IAPH), 2021).

The development strategy focused on introducing advanced technologies and improving operational processes, and integrating sustainability measures to meet the growing needs of global trade, details of the new techniques implemented are as follows:

**9-1 "Tahya Masr 1" multi-purpose container terminal**

The multipurpose container terminal at Damietta Port is one of the most prominent infrastructure projects aimed at enhancing the port's capabilities in dealing with the movement of containers and miscellaneous goods. The terminal runs 681 meters, 17 meters deep, enabling it to accommodate large vessels and greatly enhance the port's operational capability. The objective of the container terminal is:

Increased capacity: The terminal provides the ability to handle a larger volume of containers and miscellaneous goods, enhancing Damietta Port's ability to meet global and domestic trade needs more efficiently.

Reduce waiting time: The dock design enables large depth of ships to dock without delay, reducing the waiting time of ships and enhancing the speed of handling operations.

Improved operational efficiency: the terminal provides state-of-the-art port equipment such as cranes and advanced logistics tools, which contributes to improving the speed and efficiency of container loading, unloading and intelligent tracking operations to enhance the accuracy and efficiency of port operations.

Reducing emissions: By reducing ship waiting time and enhancing fast handling operations, the terminal contributes to reducing emissions from the operation of ship generators during the waiting period. This is in line with recent environmental trends in reducing adverse impacts on the environment, improved logistical performance: the terminal contributes to improved cargo flow and reduced congestion at the port, enhanced efficiency of logistics operations and helped facilitate trade movement (European Commission, 2022).

Modern infrastructure: The terminal features a design that conforms to the latest global infrastructure standards, including docks capable of accommodating the latest types of ships, and modern navigation techniques.

Tahya Misr Container Terminal (l) Multipurpose Port Damietta Authority is an important step towards development.

**9-2 Activation of Just in Time system at Damietta Port**

The Port Authority of Damietta is improving the efficiency of port operations and mitigating environmental impacts through the application of the "Just in Time" (JIT) system, which relies on

ship tracking techniques such as global positioning system (GPS) and marine traffic management systems or Vessel Traffic Services (VTS): -

These techniques allow accurate monitoring of ships' movement and analysis of their data, helping to accurately predict their arrival dates and coordinate their arrival timings to avoid congestion at the port. By improving arrival timings and reducing ship staying time in the waiting area, the need to operate ship generators is reduced, reducing fuel consumption and emissions of harmful pollutants, contributing to improved air quality and reduced environmental impacts. Through this strategy, Damietta Port enhances its operational efficiency and achieves higher environmental sustainability (Damietta Port Authority, 2024).

**9-2-1 Types of VTS:**

- Port VTS: These are localized systems within ports or harbors to manage vessels arriving at or departing from the port, ensuring safe docking, loading, and unloading processes.
- Coastal VTS: Used along busy coastal areas to monitor and manage the flow of vessels along major shipping routes, preventing accidents and improving safety for ships navigating near shorelines.
- River and Inland VTS: Implemented on rivers and inland waterways to monitor and control vessel traffic in areas that are often narrower and more complex than coastal waters, ensuring safe passage for all types of vessels.
- Area VTS: Covering a broader maritime area, these systems are used to manage vessel movements in congested regions that span large geographical areas, like busy straits or sea lanes (Terry Hughes et al.,2019)

**9-2-2 Marine Traffic Management System:**

Vessel tracking: Global positioning technologies and maritime traffic management systems are used to monitor and analyses ships' traffic. This allows accurate forecasting of ships' arrival dates and coordinated arrival dates so that they arrive on time to avoid congestion.

Data Analysis: Through cooperation with shipping and joint planning companies, ship arrival schedules are improved based on loading and unloading schedules. Data analysis is also used to improve handling timing and reduce unnecessary downtime.

Automation Systems: Technologies used in JIT include advanced automation systems in container loading and unloading processes, which accelerates procedures and reduces human errors.

Emission reduction: Reducing generator operation means reducing vessel waiting time and reducing the need to operate generators freely, resulting in lower fuel consumption and reducing harmful emissions such as nitrogen oxides and sulfates, the number of pollutants emitted into the air from generators is reduced, contributing to improved air quality in the port area.

**9-3 Onshore Power Supply (OPS):**

An integrated infrastructure for supplying ships with electricity from land. OPS has been developed, reducing the need to operate ship generators and reducing harmful emissions in accordance with annex VI of the MARBOL Convention 73/78 which aims to reduce air pollution

from ships where the system obliges ships to decommissioning their generators while in port in compliance with international environmental standards.

This system reduces the emissions of nitrogen oxides and sulfates, which contributes to the improvement of air quality in the port area, advanced electric charging stations have been installed in the port docks to supply ships with electricity while they are present, requiring appropriate infrastructure such as high voltage cables and electrical transformers.

The system includes intelligent energy management to ensure the balance of load and energy saving in an efficient and sustainable manner, as well as the development of customized delivery components that conform to the specifications of different vessels to ensure the smooth and safe supply of electricity to ships.

Using measurement and surveillance technology to track energy consumption and record data needed to ensure optimal operation of the system, using clean and renewable sources of energy to generate electricity supplied to ships, such as solar or wind energy, thereby enhancing the port's environmental sustainability, as well as developing advanced cooling and heating systems to help ships maintain appropriate operating conditions during road power connections(International Maritime Organization (IMO), 2020).

**9-3-1 Training and rehabilitation of the crew**

Ships and crew should be provided with training program on how to properly use OPS to ensure compatibility with environmental requirements, and enhance awareness among operators on the importance of adhering to OPS requirements and environmental impacts of generator operation, as it contributes to reducing fossil fuel vessels, significantly reducing energy consumption and improve the port's energy efficiency.

**9-4 Construction of five solar power plants at Damietta port**

As part of Damietta Port's strategy to promote environmental sustainability and reduce environmental impacts, an important step has been taken with the establishment of five solar power plants. This project aims to reduce dependence on traditional energy sources such as fossil fuels, which contribute to the consumption of natural resources and release of harmful pollutants. Solar panels will be installed in strategic locations across the port, which will contribute to reducing fuel consumption and reducing harmful emissions such as nitrogen oxides and sulfate. This shift to solar not only enhances energy efficiency but also contributes to improved air quality in the port area and achieves environmental goals for sustainable development (IRENA, 2021).

**9-5 Conversion of cars to operate natural gas to reduce emissions**

As part of the development and work to reduce greenhouse gas emissions, emphasis is placed on converting a number of cars into Damietta Port to operate with natural gas rather than conventional fuel, through this conversion, significant reductions in harmful emissions are expected, contributing to improved air quality and reducing the environmental impact of the port's activities (Damietta Port Authority, 2024).

**9-6 Application of single port window system (PSW)**

The only port window - PSW is a regulatory and technical framework aimed at streamlining and standardizing procedures to deal with various stakeholders inside and outside the port, facilitating the flow of information and reducing bureaucracy. This system allows customers to send all required documents and information through one platform, improve efficiency and reduce time and costs associated with the procedures, PSW has many standards including: -

Data Integration: Through a unified and centralized platform, all documents and information related to port operations, such as customs licenses, shipping data and vessel information, can be provided and managed.

The system also coordinates with various systems, such as the Marine Traffic Management System and the Financial System, providing an integrated and smooth customer experience, and by standardizing order and information processing processes, PSW reduces the need to deal with several different destinations, saving time and effort and contributing to accelerated removal and approval procedures, improving the speed of ship and cargo flow within the port (UNCTAD, 2021).

Enhancing transparency: The system provides a mechanism for tracking the status of requests and transactions in a transparent manner, facilitating verification of procedures and enhancing transparency. Documents and approvals are exchanged electronically, reducing the use of paper and the speed of procedures.

Through the application of the single port window system, Port Damietta seeks to improve operational efficiency and simplify procedures, enhance performance effectiveness and achieve a better customer experience, to keep pace with the development globally and locally within the ports of the Arab Republic of Egypt.

**10-Energy efficiency and emission reduction measures in Damietta Port**

Environmental pollution management at Damietta Port is an essential part of the port's sustainable development strategies, which aim to balance operational efficiency and environmental protection. Port management seeks to develop environmental mechanisms that reduce negative impacts and support sustainability by addressing dust, light, noise and waste pollution. Strategies also include the promotion of green spaces, reflecting a deep commitment to preserving environmental quality and enhancing the port's role as a major trading and shipping hub in the region (Damietta Port Authority, 2024).

Increasing Green Spaces: Damietta Port expands its green space, a procedure aimed at reducing dust pollution. These spaces contribute to improving air quality and reducing the effects of dust on the environment and people's health.

Solid waste management: Solid waste is collected from ships and other activities at the port in specific areas to ensure proper disposal and keep the environment clean. This waste is transported to the Farascore dump, where it is processed in accordance with approved waste management

practices. In addition, hazardous wastes are delivered to Public Environmental Protection Authority -accredited contractors with environmental licenses required to handle such wastes.

Solar Lighting System: A solar-powered lighting system has been applied in the port, significantly reducing light pollution. The initiative supports the use of renewable energy sources and mitigates the environmental impact associated with traditional lighting systems.

Monitoring noise levels: Decibel measurements are used to monitor noise levels within the port, ensuring compliance with established legal limits. This strategy requires port companies to conduct environmental assessments of noise from their equipment, as well as periodic maintenance to ensure compliance with international standards.

## 11- Regional and global challenges for Damietta Port

Damietta's efforts to become a smart port face several regional and global challenges, including:

- Adaptation to global environmental standards, financial pressures to finance new technologies and economic volatility affecting infrastructure investments. Advances in smart technologies also require appropriate technical skills and training for employees.
- Investing in sustainable technologies: Damietta Port can benefit from investing in new technology such as artificial intelligence and dual cohesion to predict and address any challenges facing the port by proactively developing technical solutions to improve logistics and cope with crises.
- The port can seek funding from green project investment funds or international grants to support sustainability projects.

## 12- Results

The development of the port of Damietta has shown several positive results that reflect the effectiveness of the strategies implemented to enhance operational efficiency and environmental sustainability. The establishment of the multi-purpose terminal "Tahya Egypt 1" at the port of Damietta has greatly enhanced the port's capacity and efficiency, enabled faster handling of containers and reduced waiting times for ships. Advanced equipment and logistics tools improved container loading, unloading and tracking, reducing congestion. The environmental impact has been reduced by the implementation of Just in Time (JIT), reducing fuel consumption and harmful emissions, along with the Earth power supply system and renewable energy sources such as solar energy. In addition, the transition to natural gas-powered vehicles has reduced emissions. The introduction of the Single Window System (PSW) has streamlined processes, reduced bureaucracy, enhanced transparency, improved operational efficiency and customer experience.

The expansion of green spaces in Damietta port improved air quality by reducing dust pollution, benefiting public health. The solar-powered lighting system has reduced light pollution and supported the use of renewable energy. These efforts reflect the port's commitment to enhancing operational performance while prioritizing environmental sustainability and a successful balance between economic growth and environmental stewardship.

Consequently, it can be asserted that the three dimensions of sustainability are being achieved through the application of smart sustainable port requirements. The environmental dimension is addressed via innovative technologies that reduce emissions and increase energy efficiency, while the social dimension contributes to the improvement of working conditions and social equity by providing a safer and more sustainable working environment. The economic dimension is realized through enhanced operational efficiency and increased port competitiveness, which contributes to long-term sustainable economic growth.

## 13- Conclusion

Damietta Port's comprehensive development plan represents significant progress towards transforming it into a smart and sustainable port. Through strategic improvements and integration of advanced technologies, the port aims to enhance its operational efficiency, environmental sustainability and economic competitiveness. Key initiatives such as the "Tahya Egypt 1" multipurpose container plant, the operationalization of Just in Time (JIT), the implementation of the onshore power supply (OPS), and the construction of solar power plants are pivotal in achieving these objectives.

The development of green spaces, the transition to natural gas, and the application of the single port window system further confirms the port's dedication to reducing environmental impacts and enhancing operational effectiveness.

The Port of Damietta's development efforts are aimed not only at meeting the growing demands of world trade, but also at setting a standard for port sustainability and efficiency. Sustained investment in innovative technologies and the introduction of artificial intelligence and sustainable practices will be critical in maintaining the port's competitive advantage and contributing positively to local and global environmental goals. Through these initiatives, Damietta Port is preparing to strengthen its role as a major trading and shipping hub, demonstrating a proactive approach to addressing environmental challenges and promoting sustainable development.

## 14- Recommendations

Assessing the long-term impact Future research should focus on long-term assessments of the impact of smart port initiatives in Damietta Port. This could include a detailed analysis of the ongoing environmental benefits, operational efficiencies and economic impacts of technologies implemented over a long period.

1- To study a comparison between Damietta Port and other smart ports globally, by examining many smart port applications, researchers can identify best practices, common challenges and innovative solutions that can enhance Damietta Port strategies.

2- Stakeholder engagement: Further research should be undertaken to explore the role of stakeholder engagement in the successful implementation of smart port initiatives. Understanding the views and participation of various stakeholders, including communities, port authorities and technology providers, can help maximize cooperation and address potential challenges.

3- Investigating the impact of emerging technologies, such as advanced AI algorithms, supply chain management blockchain and next-generation renewable energy solutions, on smart port operations can provide new ways to enhance port efficiency and sustainability.
4- Economic impact studies to assess financial benefits and cost-effectiveness of smart port investments, including investment return and economic impact analyses, can guide future investments and policy decisions.
5- Study climate resilience, which focuses on the climate resilience of smart ports, to take proactive action in the face of extreme weather events and sea level rise.

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