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Artificial Intelligence Implementations Towards Shaping the Future of Digital World

ANALYZING THE IMPLEMENTATION OF TERMINAL OPERATING SYSTEM ON ENHANCING THE EFFICIENCY OF ALEXANDRIA CONTAINER TERMINAL

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ABSTRACT

Purpose: A Terminal Operating System (TOS) is essential for efficient and productive terminal operations, as it supports planning, scheduling, and equipment control. Increasingly, functions within the TOS are being automated to enhance overall performance and streamline processes. Container Terminal Operating System stands for Terminal Operating System, a computer-based system used in ports to manage and optimize various terminal operations. Therefore, this research aims at investigating and analyzing the challenges encountered during the implementation of the CTOS at Alexandria Cargo Handling and Container Company, and to propose recommendations for overcoming these challenges and improving the implementation process.

Research approach: This research will follow a deductive approach to achieve research aims and objectives through applying SWOT analysis. In addition, it will analyze the impact of implementing CTOS on theβefficiency ofβAlexandria containerβterminal during the last years from 2019 to 2023 byβusingβData EnvelopmentβAnalysis (DEA).

Research Originality: The research is consideredβthe first empirical study thatβidentifies challenges encountered during the implementation of the CTOS at Alexandria Cargo Handling and Container Company using SWOT analysis and evaluate the efficiency of the company's terminal.

Research impact: This research will determine the challenges encountered during the implementation of the CTOS at Alexandria Cargo Handling and Container Company's terminals. In addition, this research will propose procedures to measure the efficiency of container portsβwhich can be applied to other container ports using Data Envelopment Analysis (DEA) for the period from 2019 to 2023.

Practical impact: The analysis can help Alexandria Cargo Handling and Container Company's management to increase the efficiency score through identifying challenges encountered during the implementation of the TOS.

Keywords: TOS, Alexandria Container Terminal, Efficiency, DEA, Egypt.

1. INTRODUCTION

A review conducted by UNCTAD [1] revealed that shipping is the dominant mode of freight transportation, accounting for almost 90 percent of world trade, with container transportation playing an increasingly significant role due to its technical and economic advantages over traditional methods. Furthermore, a study done by Ismail [2] indicated that container terminal ports in any country are the most integral link in the maritime transport process. In addition, it reduces the delay process and provides distinct services which increase the role of ports in distributing and importing and exporting goods. Likewise, the study of Elgazzar and Ismail [3] has demonstrated that strengthening the role of ports and increasing their competitiveness has become a necessity to keep pace with the rapid changes in the economic and technological aspects.

Through strategic improvements and modern technology, container terminal ports now offer superior, integrated logistical services, setting them apart from competitors.

Along the same lines, Hafez and Elbayoumi [4] have revealed that container terminals have accelerated their efforts to provide the best services to their clients, who consist of container ship owners from global companies, by reducing the time ships spend at the port and offering high-quality services. Another study conducted by Behar and Anthony [5] has indicated that this effort is not limited to shipping companies alone but also extends to local traders (importers and exporters), who are considered the core of commercial and service activities at many container terminals worldwide. Moreover, according to Gekara and Xuan [6], the acceleration or enhancement of supply chains, along with the speed of container handling and storage efficiency, have become some of the key factors for the success of container ports and the enhancement of their competitiveness.

Therefore, costs and time are the two main factors that determine the efficiency and competitiveness of a container terminal from the customer and port users 'perspective, according to Hervás-Peralta *et al.*, [7]. As a result, many container terminals have resorted to upgrading their operational, service, and financial systems to meet customer requirements. Ali *et al.*, [9] demonstrated that Aden Container Terminal was one of the first container terminals in the Gulf of Aden and Red Sea region to begin operations in 1999, managed by the Singapore Port Authority. It was the first time a Terminal Operating System (TOS) was introduced to Yemeni seaports when PSA adopted the Computer Integrated Terminal Operating System (CITOS). This was followed by an operating system change when PSA's management of Aden Container Terminal was replaced by DP World, which then implemented the ZODIAC operating system. Currently, the management of Aden Container Terminal is working to upgrade the ZODIAC system from the current version 5.1 to the advanced version eight to keep up with global changes in container terminal services.

this research aims at investigating and analyzing the challenges encountered during the implementation of the CTOS at Alexandria Cargo Handling and Container Company, and to propose recommendations for overcoming these challenges and improving the implementation process.

2. OUTLINE OF CTOS SYSTEM

A Terminal Operating System (TOS) is the core application used by container terminals for planning, monitoring, and executing the movement of containers. It manages the transfer of containers between trucks and the yard, the yard and trucks, trucks and vessels, and vessels and trucks, utilizing heavy lifting equipment This system streamlines processes and enhances efficiency by coordinating activities such as ship loading and unloading, container stowage and storage, and yard and warehouse management, according to Hervás-Peralta *et al.*, [7].

A Container Terminal Operating System (CTOS) is a comprehensive software platform designed to manage and optimize the various operations within a container terminal [12]. CTOS Operating System covers the operational aspect of the CTOS, which includes Terminal Monitoring and Control: Overseeing and managing terminal operations in real-time. Handling operations related to different terminal areas such as gates, yards, ships, dangerous goods (DG), refrigerated containers (Reefer),

rail, and container freight stations (CFS). EDI/Web IP Services: managing Electronic Data Interchange (EDI) and Internet Protocol (IP) services for communication and data exchange.

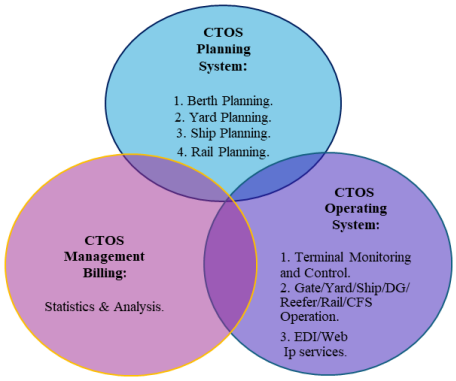

Figure 1. Outline of the CATOS System. Source: Gekara and Nguyen, 2020.

CTOS Management Billing; involves the management and billing functions within the CTOS: Statistics & Analysis: Collecting data and performing analysis to inform decision-making and improve terminal efficiency.

3. LITERATURE REVIEW:

A substantial body of research has been devoted to the study and development of Terminal Operating Systems (TOS) due to their critical role in optimizing port terminal operations. Numerous papers have explored various aspects of TOS, including its impact on operational efficiency, cost reduction, and overall productivity. These studies have consistently highlighted the importance of TOS in streamlining processes such as berth planning, yard management, and resource allocation, thereby enhancing the competitiveness and effectiveness of port operations.

Quoc and Thanh [10] indicated that a Terminal Operating System (TOS) is the main application used by container terminals to plan, monitor, and execute container movements. Furthermore, a study by Inutsuka *et al.*, [11] stated that TOS manages the transfer of containers between trucks, the yard, and vessels using heavy lifting equipment, streamlining operations like ship loading and unloading, container stowage, and yard management. In addition, Gaete *et al.*, [12] clarified that a Container Terminal Operating System (CTOS) is a comprehensive software platform that optimizes operations within a container terminal. These terminals are key points in the supply chain, facilitating container transfers between ships, trucks, and trains. Likewise, Chhetri *et al.*, [13] mentioned that the CTOS enhances efficiency by managing container handling, storage, and movement. Its key functions include planning systems for berth, yard, ship, and rail logistics within the terminal.

Additionally, according to a study by Zhang *et al.*, [14], Terminal Operating System is the core application used by container terminals for planning, monitoring, and executing container movements. Weerasinghe *et al*., [15] pointed out that this includes managing the transfer of containers from truck to yard, truck to vessel, vessel to truck, and yard to truck using heavy lifting equipment. In this context, a TOS has been proposed to enhance the efficiency of port terminal operators and consists of six main modules: yard planning, vessel planning, berth planning, resource planning, interface module, and communications, according to a study conducted by Min *et al.*, [16]". In fact, to improve port productivity, safety, and sustainability, the smart port initiative promotes the integration of information and communication technology. Therefore, Hervás-Peralta *et al.*, [17] affirmed that implementing a TOS is essential for elevating port operations to a higher level of efficiency and sophistication.

Thus, Inutsuka *et al.*, [18] asserted that the Integrated ITOS aims to improve the efficiency of container terminal operations. Finally, it is revealed in a study done by Inutsuka *et al.*, [19] that TOS enhances security, productivity, and sustainability. In fact, they stated that TOS provides a suite of applications

designed to collect, manage, store, analyze, and distribute information from various activities within container terminals [20].

It can be concluded that a Terminal Operating System (TOS) is the most critical planning and management component to consider for the optimization of inland and port terminals. No previous studies has analyzed the TOS that has been applied in Alexandria container terminal science 2022 from adding this new system till the end of the year 2024. The next figure 2. Shows research gap and research contribution.

Many researchers regard DEA as the most effective approach for quantifying a set of essential performance indicators. DEA stands out as the optimal tool for assessing efficiency due to its non-parametric nature, enabling it to accommodate multiple outputs without necessitating prior assumptions about the relationships between inputs and outputs [24, 25, 26]. This technique proves particularly valuable in addressing the measurement of port efficiency. DEA has been used in several earlier studies. DEA is the most important approach to measure efficiency [27, 28, 29, 30].

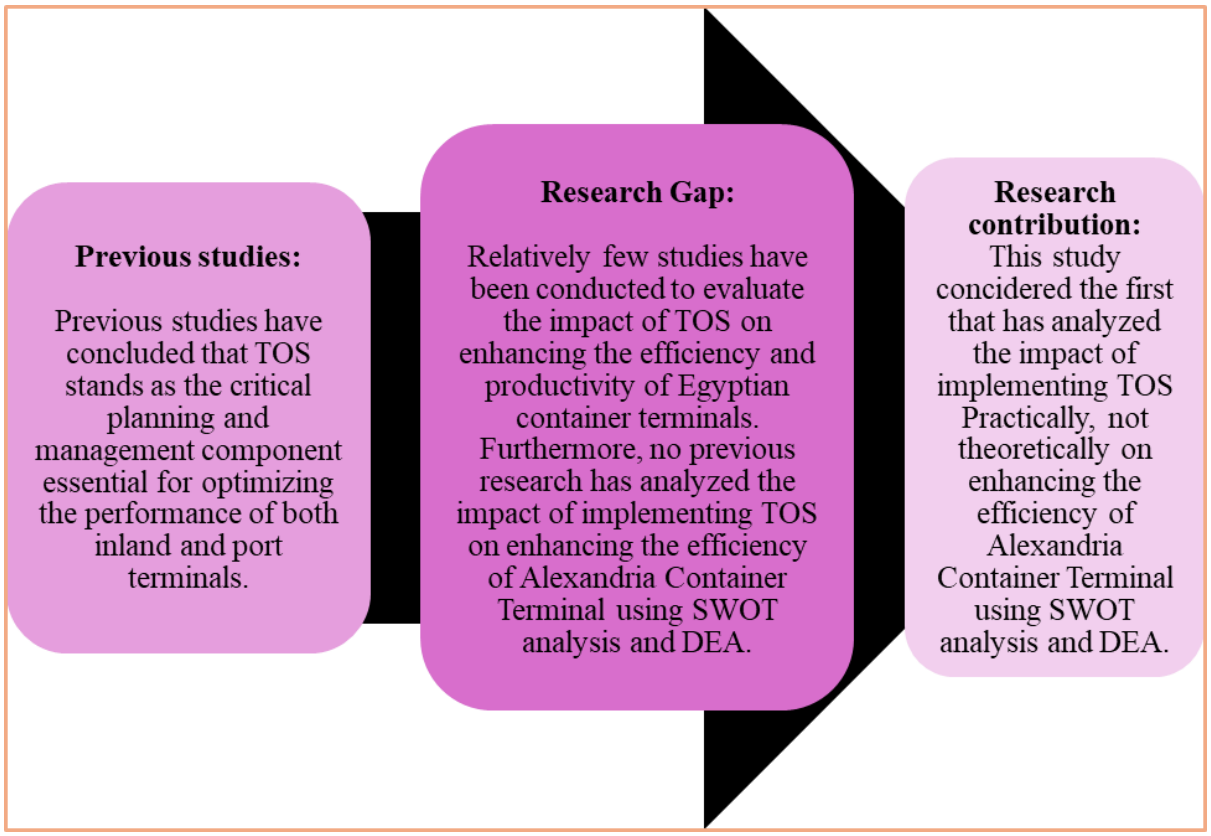

Figure 2. *Research gap and contribution. Source: Researcher's own elaboration.*

4. RESEARCH PROBLEM:

Despite the acknowledged advantages of adopting the Container Terminal Operating System (CTOS), Alexandria Port encounters substantial impediments that impede its effective integration and operation. These challenges encompass multifaceted issues including technological constraints, and organizational complexities. Understanding the specific nature and interplay of these challenges is essential for devising strategies to facilitate the successful implementation of CTOS at Alexandria Port, thereby enhancing operational efficiency and bolstering competitiveness in the global shipping industry. therefore, this research answers the following question: what are challenges that faces implementing container terminal operating system in Alexandria container terminal. The research problem can be summarized in the following question: ***Has the TOS system improved the efficiency of Alexandria Container Terminal?***

5. RESEARCH AIMS AND OBJECTIVES:

This research aims to investigate and analyze the challenges encountered during the implementation of the Container Terminal Operating System (CTOS) at Alexandria container terminal. Research objectives are:

- To identify the technological challenges associated with the implementation of CTOS at Alexandria container terminal.
- To propose recommendations for overcoming the challenges and improving the implementation process of CTOS at Alexandria container terminal.

6. RESEACH METHODOLOGY:

This research follows a deductive approach. There are two phases to achieve research aims and objectives. Phase one: applying SWOT analysis. Phase two: analyze the impact of implementing CTOS on the efficiency of Alexandria container terminal; using DEA software. Because of unavailability of required data; analysis conducted from 2019 to 2023.

Many researchers consider Data Envelopment Analysis (DEA) to be the most effective method for quantifying a set of essential performance indicators. DEA is recognized as the optimal tool for efficiency assessment due to its non-parametric nature, which allows for the accommodation of multiple outputs without requiring prior assumptions about the relationships between inputs and outputs. This characteristic makes DEA particularly valuable for measuring port efficiency. In this context, the storage area has been frequently used as an input variable in several studies applying DEA analysis to measure efficiency in container terminals [21]; [22]; [23].

7. RESEACH VARIABLES:

The diagram illustrates the relationship between the independent variable, Terminal Operating System (TOS), and the dependent variable, efficiency. Efficiency is measured through various factors including Terminal Area, Storage Area, Berth Length, Draught, and Handling Equipment.

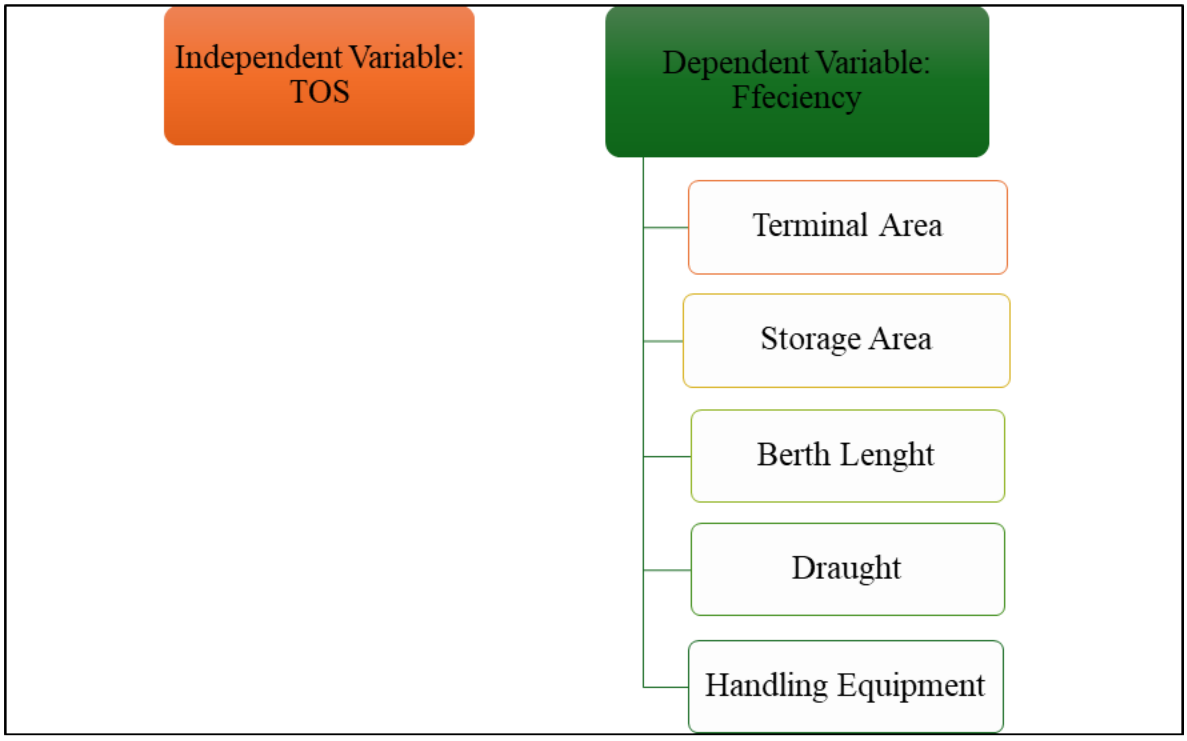

***Figure 3**. Research variables. Source: Researcher's own elaboration.*

8. EMPIRICAL STUDY:

8.1. SWOT ANALYSIS:

Alexandria Cargo Handling and Container Company's terminal used CTOS which is used in 80 container terminals around the world. CTOS is used in container terminals to manage and optimize the movement, handling, and storage of shipping containers. CTOS contains models such as: Berth Planning, Billing Operation, Delivery Reservation, DG operation, Gate, Operation Management, Reefer Operation, Rmrc, Security Management, Ship Planning, Terminal Monitoring, Yard Define, Yard Planning and Yard Equipment.

Next, we will review strength, weaknesses, threats and opportunities revealed from SWOT analysis depending on interview with Operators for CTOS in Alexandria Cargo Handling Company's terminal.

Figure 4. *SWOT analysis for CTOS at Alexandria container terminal. Source: Researcher's own elaboration.*

8.1.1. Strength

- CTOS increase the productivity and the efficiency of Alexandria Cargo Handling and Container Company.
- Thera are a connection between customs and CTOS which reduce procedures and operations time.
- CTOS plans loading and unloading operations, as well as the various operations of the ship before it arrives at the port and during its departure, which reduces the time the ship stays in the port.
- CTOS Makes fast and an effective reports ant time about any operation related to Alexandria Container and Cargo Handling Company.
- Any modification made to the CTOS will automatically propagate updates across all other cycles in the CTOS system.
- There are 18 yards in Alexandria Container and Cargo Handling Company, which reduce waiting time of ships at the terminal.
- Every yard in Alexandria Cargo Handling and Container Company has a supervisor, which helps to solve any problem in an effective way.

8.1.2. Weaknesses

- CTOS consists of successive steps, while the person responsible for the stage does not do his work, the work will stop at the next stage
- The current states of infrastructure in AlexandriaβContainer andβCargoβHandlingβCompany.
- Weaknesses of the current network because of near the Alexandria Container and Cargo Handling Company from the area of Naval Forces.
- There is no connection between Smart Port System (SPS) of Alexandria port authority and CTOS in all operations.

8.1.3. Threats

- A CTOS is generally designed to be a secure system, as it handles critical data and operations related to container management, logistics, and port operations. Therefore, there are no threats faces CTOS.
- There are no cyber-attack threats on CTOS system because it depends on an internal internet network.

8.1.4. Opportunities

- Updating the CTOS program to align with the future increasing demand and modern vessels, despite the system being sufficient in its current state, is essential.
- Making improvements to the internal internet network in Alexandria Container and Cargo Handling Company to enhance CTOS program's performance across the entire terminal.
- Enhancing the infrastructure is crucial to support the growing demands of modern vessels and the increasing volume of operations.

8.2. DATA ENVELOPMENT ANALYSIS:

8.2.1. Correlation between input variables:

Correlation is a statistical measure that describes the strength and direction of a relationship between variables. Therefore, the first step in statistical analysis is to calculate the correlation between variables. It has been revealed that there is a positive correlation between the variables under study as shown in Table 1. below.

Table 1. *Correlations between the variables used in research. Source: Researcher's own elaboration.*

Variables	Maximum design capacity	Terminal area	Berth length	Draft
Maximum design capacity	1			
Terminal area	0.891	1		
Berth length	0.899	1	1	
Draft	**0.812**	**0.783**	**0.686**	**1**

8.2.2. Calculating the Technical Efficiency:

To calculate the Technical Efficiency of the Egyptian container terminals, the CCR model is used by running MAX DEA Lite programs (V. 12.0.8) (http://maxdea.com/Index_En.htm) which reveals the efficiency score as illustrated in Table 2. below. It has been found that Alexandria, El-Dekheila, East Port Said and Port Said have efficiency scores equal to unity in 2021, 2020, 2021. and 2020, respectively. Under CCR model. Damietta port does not have an efficiency score equal to unity during the period of the study. The analysis reveals that most of the Egyptian container terminals under study suffer from inefficiency during the period of the study from 2019 to 2023 bearing in mind the geopolitical conflict, Covid-19, and Russian Ukrainian war, which have affected the economy, investments, security, shipping lines and internal policy.

Table 2. Efficiency score of the Egyptian container terminals during the period of the study.

Container terminal	2019	2020	2021	2022	2023
Alexandria	0.935	0.997	1.000	0.895	**0.984**
El-Dekheila	0.970	1.000	0.871	0.738	**0.738**
Damietta	0.839	0.761	0.746	0.775	**0.841**
East Port Said (SCCT)	0.718	0.856	1.000	0.955	**0.925**
Port Said west terminal	0.893	1.000	0.763	0.643	**0.420**
El-Sokhna terminal	**0.681**	**0.660**	**0.763**	**0.978**	0.004

The performance of Alexandria's container terminal shows notable fluctuations from 2019 to 2023. The terminal demonstrated strong performance in 2020 and 2021, reaching a peak of 1.000 in 2021, indicating optimal operations. However, there was a sharp decline in 2022 to 0.895, suggesting operational or external challenges. In 2023, the terminal's performance rebounded to 0.984, reflecting significant recovery and operational improvements. This trend highlights resilience despite temporary setbacks. During the last two years (2022-2024), Alexandria Port implemented the Container Terminal Operating System (CTOS), which enhanced operational efficiency by streamlining container management, improving logistics coordination, and optimizing resource allocation. This technological upgrade played a key role in the port's performance recovery and sustained efficiency.

8.2.3. Sensitivity Analysis

The Sensitivity Analysis (SA) in DEA-CCR measures how the input and output variables affect the efficiency scores. The next Table 3. shows that the removal of Maximum design capacity from the input variable combination decreases the efficiency score of all terminals under study such as Alexandria, El-Dekheila, Damietta, Port Said, and El-Sokhna to 0.983, 0.718 and 0.612, 0.288 and 0.002 respectively.; except for East Port Said port which retains the same efficiency score 0.925.

The removal of the terminal area has changed the efficiency score of all the Egyptian container terminals under study; except for that of East Port Said which remains the same. The efficiency scores of other terminals have changed such as Alexandria, El-Dekheila, Damietta, Port Said, and El-Sokhna, as they decreased to 0.715, 0.552, 0.835, 0.420 and 0.003, respectively.

The omission of berth length as an input variable in the efficiency benchmarking model decreases the same efficiency score of El-Dekheila, Damietta, Port Said, and El-Sokhna; however, it does not change the efficiency scores of El-Dekheila and East Port Said which remains the same.

Table 3. Sensitivity analysis of the Egyptian container terminals for the year 2023. Source: Researcher's own elaboration.

Egyptian container terminal	DEA CCR	Efficiency score after input deleted			
		Maximum design capacity	Terminal area	Berth length	Draft
Alexandria	0.984	0.983	0.715	0.877	**0.984**
El-Dekheila	0.738	0.718	0.552	0.738	**0.727**
Damietta	0.921	0.612	0.835	0.779	**0.795**
East Port Said (SCCT)	0.925	0.925	0.925	0.925	**0.924**

Port Said west terminal	0.420	0.288	0.420	0.408	**0.420**
El-Sokhna terminal	**0.856**	**0.002**	**0.003**	**0.003**	**0.003**

The removal of draft has changed the efficiency score of all the Egyptian container terminals under study; except for that of Alexandria, East Port Said and Port Said which have reserved their same scores. The efficiency scores of other terminals have decreased, such as El-Dekheila, Damietta, and El-Sokhna which have decreased to 0.727, 0.795, and 0.003, respectively.

In conclusion, the Egyptian container terminals face efficiency constraints stemming from several internal and external factors. Overcoming these hurdles will necessitate strategic investments in the infrastructure, the enhancement of operational processes, the fortification of security measures, and the simplification of administrative procedures. These endeavors are essential for improvement of the efficiency and competitiveness of the Egyptian container terminals in the global trade arena. To enhance the efficiency of container terminals, several key recommendations can be applied. First, investments in technology should be made to streamline operations and decrease waiting times. Second, optimizing the layout and design of container terminals can significantly boost efficiency. Third, implementing training and development programs for port workers can enhance their skills and knowledge, leading to increased productivity. Fourth, prioritizing sustainability by adopting environmentally friendly practices, including the use of renewable energy sources and waste reduction, is vital. Fifth, upgrading container handling equipment and enhancing safety and security measures are essential steps toward achieving greater efficiency in container terminals. Additionally, collaboration with stakeholders and leveraging investments support economic growth, while strengthening security and safety measures ensures sustainable operations, positioning the port as a competitive logistics hub regionally and internationally.

9. CONCLUSION:

The SWOT analysis tool was used to evaluate the port's efficiency during the period of system implementation, helping to identify internal strengths and weaknesses, as well as external opportunities and threats facing the port. The analysis results showed that the port achieved good operational efficiency during the application period, with a noticeable improvement in both operational and administrative performance between 2022 and 2023. The indicators revealed that the port experienced positive progress in its operations in 2023 compared to the previous year, reflecting the success of the implemented procedures and developments, which contributed to enhancing the port's operational efficiency and increasing its competitive capacity.

The successful deployment of Container Terminal Operating Systems (CTOS) at Alexandria Cargo Handling and Container Company is contingent upon overcoming several organizational barriers that could impede its implementation. Firstly, resistance to change among employees and stakeholders poses a significant challenge. There may be apprehension about adopting new technologies, concerns over job security due to potential automation, or simply a preference for familiar, traditional methods of operation. Addressing this resistance requires comprehensive change management strategies, including clear communication about the benefits of CTOS, involvement of stakeholders in the decision-making process, and assurances regarding skill development and career pathways in the new operational framework. Secondly, the presence of legacy systems and infrastructure hinder the seamless integration of CTOS. Alexandria container terminal may have outdated technologies or infrastructure that are not compatible with modern CTOS requirements. Upgrading or replacing these systems can be costly and time-consuming, requiring careful planning and investment in technological upgrades. Moreover, ensuring interoperability and data compatibility between new and existing systems is crucial to avoid operational disruptions and maximize the benefits of CTOS.

Based on the SWOT analysis, it is recommended to enhance the internal internet network of the Alexandria Cargo Handling and Container Company, integrate the Smart Port System (SPS) with the Container Terminal Operating System (CTOS), and establish a connection with the nearest dry port to reduce congestion at Alexandria Port. In addition, to transform threats and opportunities to recommendations; researcher recommended to:

- Ensure Continuous System Security Measures. While the current CTOS is designed to be a secure system and operates on an internal internet network, it is essential to establish a proactive approach to maintain its security. Regular security audits, implementing updated encryption methods, and conducting periodic vulnerability assessments will ensure that the system remains protected against any potential future threats.
- Implement a Future-Proof Update Plan for CTOS. To meet the increasing future demand and handle modern vessels more efficiently, it is recommended to establish a structured update plan for the CTOS program. This plan should include upgrading system functionalities, integrating new technologies, and ensuring compatibility with the latest industry standards to maintain operational efficiency in the long term.
- Upgrade the Internal Internet Network. Improving the internal internet network infrastructure is essential to ensure the seamless performance of the CTOS program across the entire terminal. It is recommended to enhance the network's bandwidth, stability, and reliability to support the growing operational demands and reduce any potential system slowdowns.
- Enhance the Terminal's Infrastructure to Support Growing Demands. The terminal's physical and digital infrastructure must be upgraded to keep up with the increasing volume of operations and the requirements of modern vessels. Recommendations include expanding storage capacity, optimizing container handling equipment, and investing in smart port technologies to improve efficiency, reduce downtime, and enhance overall operational performance.
- Conduct Regular System Performance Assessments. To ensure that the CTOS system continues to meet operational needs effectively, it is advised to conduct regular improvement, ensure that the system remains up to date, and allow for proactive adjustments to handle future challenges.
- Establish a Long-Term Digital Transformation Strategy. To future-proof the terminal's operations, the company should consider developing a comprehensive digital transformation strategy. This strategy would focus on adopting advanced digital solutions, such as AI-driven predictive analytics, automation, and IoT technologies, to further optimize container management and streamline port operations.

To make further studies related to the current research, it is recommended to investigate the effectiveness of CTOS in enhancing port security measures and managing operational risks. Studies could focus on cybersecurity protocols, resilience against cyber threats, and compliance with international security standards (such as ISPS Code). In addition, Evaluate the environmental footprint of CTOS implementation at Alexandria port. Studies could assess energy consumption, emissions reduction strategies, and sustainable practices in port operations facilitated by CTOS. This includes exploring the use of green technologies and optimizing vessel berthing schedules to minimize environmental impact. This research is limited to Alexandria container terminal; to define challenges encountered during the implementation ofβthe Container TerminalβOperating Systemβ(CTOS) at Alexandriaβcontainer terminal.

This research is limited to measuring theβefficiency of the Egyptian container Terminals usingβData Envelopment Analysis (DEA); in addition, using SWOT to review strength, weaknesses, threats and opportunities.

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