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Journal of ETA Maritime Science 2023;11(4):221-221

Selçuk Nas

Dokuz Eylül University Maritime Faculty, Department of Maritime Education and Training, İzmir, Türkiye

Dear Readers,

I am pleased to introduce JEMS 11 (4) to our valuable followers. Interest in JEMS is increasing day by day, and the editorial team and reviewers are being more selective. In this issue, there are valuable and intriguing studies. There is no doubt that these studies will contribute to the maritime field. Hereby, I would like to express our gratitude to the authors, who sent their valuable studies for publication in this issue; our reviewers; the editorial board; section editors; and the publisher, who provided quality publications by diligently following our publication policies.

"The 5th Global Maritime Congress (GMC'24)" was announced in our last issue. Congress activities continue intensively, and surprises await the participants in Istanbul. Valuable key note speakers, Prof. Atilla İncecik, Prof. Carlos Guedes Soares, Prof. Josep M. Guerrero, and Prof. Jin Wang, will make their valuable presentations in their own time.

Hope to see all stakeholders at the GMC'24,

Best Regards,

Prof. Dr. Selçuk NAS

Editor in Chief

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Quantitative Failure Analysis of the Ballast Pump System Onboard a Ship under HAZOP and the Extended CREAM Approach

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Abstract

Improper ballasting can lead to severe damage, potentially resulting in loss of life, vessel damage, and environmental disasters. This paper systematically assesses system failures in ballast pump operation related to human errors that contribute to operational risks. Considering this objective, we developed a hybrid approach that combines the Cognitive Reliability and Error Analysis Method (CREAM) with Hazard and Operability (HAZOP). Within this study's context, HAZOP analysis is harnessed to pinpoint the risks inherent in intricate ballast operations, a crucial component of maritime safety. By integrating CREAM analysis, a comprehensive understanding of the role of human factors in systematic failures and operational risks is achieved. The research emphasizes the critical role of cognitive activities, including monitoring, planning, diagnosing, and maintaining, in ensuring the safe and efficient operation of ballast pump systems. This study highlights the importance of cognitive functions such as observation, planning, interpretation, and execution in addressing these issues. The HAZOP analysis successfully identifies various potential deviations and failures within the system, providing insights into the complex nature of ballast operations and the significance of human factors. The analysis method effectively pinpoints vulnerabilities and weaknesses, underlining the necessity of meticulous planning and proper execution to mitigate identified failures. By not only delineating the fundamental causal factors behind ballast system failures and the potential consequences of these failures but also aiming to elevate safety control measures, this paper strives to mitigate prospective losses in critical shipboard operations.

Keywords: Maritime safety, HAZOP, CREAM, Ballast pump system, Safety operation

1. Introduction

Operational safety vulnerabilities often stem from stability issues, posing substantial risks tied to inadequate ballasting, excessive partial loading, heightened environmental forces, and suboptimal planning [1]. Recent years have witnessed significant maritime accidents that have resulted in substantial environmental damage, primarily due to instability during ballast water exchange. The ill-conceived ballast water exchange on the MV Cougar Ace caused its capsizing, narrowly escaping vessel loss in 2006 [2]. Within minutes, the vessel rolled more than 60 degrees due to the starboard ballast tank's failure to refill [3]. Likewise, MV Capri's blackout in 2017 resulted from incorrectly set ballast system valves and unexecuted de-ballasting procedures, triggered by a hammer effect caused by water pressure [4]. Ballast operations are integral to a ship's stability, ensuring that stress values (e.g., bending moments, shear forces, slamming) and other factors such as draft, trim, and propeller immersion remain within acceptable limits [5]. Ballast water is indispensable for safe and effective ship operations because it enhances manoeuvrability counterbalances weight loss due to fuel consumption and compensates for buoyancy changes. Given the precision and speed required, ballast operations demand utmost accuracy and compliance with relevant authorities such as the IMO, Class, and Port State. The complexity of these operations varies with vessel capabilities and ballast systems, transpiring within a dynamic working environment [1], necessitating immediate detection and response to forestall system-wide failures that could lead to hull damage,

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listing, or capsizing [6]. Responsibility falls significantly on the master and chief officer as decision makers and supervisors. They are tasked with planning, executing procedures, and maintaining records for ballast operations in compliance with set requirements. Crew members also require awareness of instructions and control procedures. Consequently, human performance assessment has emerged as a critical parameter for identifying potential hazards in vital shipboard activities [7].

Risk assessment and hazard identification hold paramount importance for shipowners, safety inspectors, engineers, and practitioners, given the inherently high-risk nature of most shipboard operations [8,9]. While some studies have presented applicable methods for maritime risk assessment [10-12], research specifically focusing on human error-based risks in ballast operations remains limited. Existing ballast water risk assessments mostly target harmful marine species that endanger human health, the economy, or the environment [13-15]. Considering the comprehensive literature review, various studies have explored the correlation between human error and ship ballast system failures [16-20]. However, despite this existing body of research, there remains a scarcity of in-depth investigations specifically addressing the intricate interplay of human factors in ballast pump failures. Recognizing this research gap, this study proposes a quantitative root cause analysis for ballast pump system failures. It does so by employing the Cognitive Reliability and Error Analysis Method (CREAM) integrated under the Hazard and Operability (HAZOP) framework to assess potential risks.

To achieve this, the paper is organized as follows: the importance of the study and the gravity of ballast failures are addressed in this section. Given the significance of each method, the subsequent section elucidates their theoretical foundations and their integration within the proposed approach. Section 3 showcases the meticulous application of this approach to shipboard ballast operations, while Section 4 encapsulates the research findings, conclusions, and contribution to maritime transportation.

2. Methodology

A hybrid approach is introduced to incorporate CREAM under HAZOP techniques to evaluate operational root causes and quantitative analysis of ballast operations onboard ships. In this study, HAZOP conducts systematic analysis of the ballast pump system and identifies deviations from the intended functioning and their causes and implications. At this point, the CREAM techniques that provide quantitative results are incorporated with HAZOP to prioritize the actions to mitigate identified failures. CREAM quantifies human error probability (HEP).

2.1. HAZOP Analysis

HAZOP is the most prominent hazard identification technique that provides a structured and comprehensive review of a defined system to identify the causes and consequences of deviations from the design intent [21,22]. It can identify potential hazards and operational problems not only for plant design but also for human error [23]. The HAZOP produces qualitative results that depend on the use of guide words that inquire how the intentions or operating conditions of system design might are not met at any point (Fuentes-Bargues et al. [24]), as illustrated in Table 1. HAZOP is usually performed during a series of meetings by a multidisciplinary team. In the meetings, the system, process, or procedure to be assessed and the specifications of the intention and performance are defined. The guidelines are then applied to check operating conditions and detect design errors or potentially abnormal operating conditions for each of the variables that influence the process [24].

Table 1. *Guide words for HAZOP*

Guide words	Interpretations	Examples
No	Failure to complete the task	The operator skips the next step
Less	Performing less than required	Completing a reduced amount due to partial valve openings
More	Performing more than required	Opening valves excessively, leading to a larger amount of processed
Reverse	Doing the opposite of the intended action	Closing valves instead of opening them
Part of	Incomplete execution of necessary actions	Omitting certain actions within a step
As well as	Additional actions in conjunction with the main task	Processing extra material by opening an additional valve
Other than	Actions deviating from the intended task	Processing of wrong material due to valve error
Sooner	Executing the action ahead of schedule	Rapid action by rearranging the step sequence
Later	Execute the action after the specified time	Delayed action by altering the step order
Other	Accounting for the various factors influencing the action	Considering shift changes as a contributing factor

The responsible teams must choose the parameters specific to each analysed system. Table 2 (Crawley et al. [25]) provides instances of potential parameters applicable to process operations.

2.2. CREAM

CREAM, a second-generation HRA method, was initially introduced by Hollnagel [26] to analyse cognitive human errors and reliability within nuclear power plant contexts [27]. Modified CREAM has been employed to quantify human error and assess human reliability in specific maritime applications [28,29]. It offers both retrospective and prospective analyses (Akyuz and Celik [9]) for diagnosing and predicting error-related events. In the prospective analysis, the basic and extended versions of CREAM evaluate human reliability. The basic version screens human errors (Rashed [30]), determining control modes and corresponding error rate intervals. The extended method quantifies cognitive function errors by building upon the outcomes of the basic version [26]. Both deterministic approaches must handle uncertainties in a common performance configuration (CPC). Prospective analysis identifies human errors, whereas retrospective analysis quantifies them [31], thus enhancing overall system safety through error identification and quantification. The CREAM model was chosen because it aligns with the objectives and context of our study for evaluating human errors. This model extensively delves into human cognitive processes and decision-making mechanisms, making it suitable for examining human errors within complex systems. Furthermore, the CREAM model provides a probability-based assessment of human errors, enabling quantitative analysis of potential risks.

2.3. Integration of Methods

The integration process encompasses two primary phases. The first phase involves the application of HAZOP, which consists of two key sub-stages: "Determining Process Parameters and Deviations" and "Identifying Possible Causes and Consequences." This method critically evaluates the process parameters and deviations, systematically exploring potential causes and consequences within the analysis. Moving forward, the second phase encompasses the CREAM approach, which unfolds across four distinct sub-stages: "Assessing Common Performance Conditions (CPCs)," "Identifying Context Influence Index (CII)," "Determining Performance Influence Index (PII)," and "Calculating Cognitive Failure Probability (CFP)." Within this method, a comprehensive evaluation takes place, appraising CPCs and gauging the influence of contextual factors. PII and CII indices contribute to delineating the potential impact of cognitive failures. The final step, CFP calculation, quantifies the probability of cognitive errors occurring. This integrated methodology combines the strengths of HAZOP and CREAM, fostering a holistic analysis that encompasses process parameters, deviations, possible causes, and consequences, along with cognitive factors.

Table 2. *Examples of parameters used in process operations*

Pressure	pH	Operate	Monitoring
Flow	Reaction	Phase	Signal
Mixing	Composition	Speed	Start/stop
Stirring	Temperature	Transfer	Aging
Particle size	Addition	Measure	Maintain
Level	Sequence	Control	Diagnostics
Time	Separation	Viscosity	Services

2.3.1. Determining the process parameter and deviation

In this phase, the paramount goal is to define process activities for shipboard operation, attuned to the prevailing context. Employing hierarchical task analysis (HTA), the main task is divided into subtasks Shepherd [32], forming a basis for HEP quantification. This systematic approach enables tailored error prediction calculations to assess associated risks. For HAZOP implementation, the initial steps involve identifying system parameters, evaluating them within the system's context, and selecting context-specific guide words. Subsequently, the focus shifts to potential parameter deviations as vital indicators of hazards. HAZOP guides researchers by suggesting precautionary measures linked to identified deviations, thereby enhancing risk management strategies.

2.3.2. Identifying possible causes

The following deviation identification, the team delves into uncovering potential causes and their subsequent outcomes. Each deviation's underlying causes are methodically examined, ensuring individualized evaluation. Thorough consideration of all potential causes is essential before finalizing the assessment process. Notably, deviations with substantial or critical consequences require immediate investigation. This phase ensures a comprehensive exploration of the origins of deviations, enhancing the understanding of their potential effects.

2.3.3. Assess common performance conditions (CPCs)

The CPC implies performance shaping factors that influence the value of HEP and determine the context of human perception and behaviour. Nine CPCs were introduced by CREAM to define several error modes and causes. Table 3 shows the degree of CPC and its corresponding performance implications and performance influence index (PII) values [33].

Table 3. *CPC level, performance effect, and PII values*

CPC	CPC level/description	Effects	PII
Adequacy of the organization	Very efficient	Improved	-0.6
	Efficient	Not significant	0
	Inefficient	Reduced	0.6
	Deficient	Reduced	1.0
Working conditions	Advantageous	Improved	-0.6
	Compatible	Not significant	0
	Incompatible	Reduced	1.0
Adequacy of MMI and operational support	Supportive	Improved	-1.2
	Adequate	Not significant	-0.4
	Tolerable	Not significant	0
	Inappropriate	Reduced	1.4
Availability of procedures/ plans	Appropriate	Improved	-1.2
	Acceptable	Not significant	0
	Inappropriate	Reduced	1.4
Number of simultaneous goals	Fewer than capacity	Not significant	0
	Matching the current capacity	Not significant	0
	More than capacity	Reduced	1.2
Available time	Adequate	Improved	-1.4
	Temporarily inadequate	Not significant	1.0
	Continuously inadequate	Reduced	2.4
Time of day	Daytime (adjusted)	Not significant	0
	Night-time (unadjusted)	Reduced	0.6
Adequacy of training and experience	Adequate and high experience	Improved	-1.4
	Adequate, limited experience	Not significant	0
	Inadequate	Reduced	1.8
Crew collaboration quality	Very efficient	Improved	-1.4
	Efficient	Not significant	0
	Inefficient	Not significant	0.4
	Deficient	Reduced	1.4

To determine the probability of human error by considering the effect conditions, the CPC scores are computed. After the final CPC scores were obtained, the control modes were established to assess the HEP interval. The combined $\sum$*reduced* and $\sum$*improved* scores have the required control mode that practically guarantees the probability of a human failure interval. Meanwhile, the important CPC does not affect the value of the HEP such that it is not considered. In the meantime, the HEP value is not influenced by CPC $\sum$*not significant*, so it is not considered.

2.3.4 Identify the Context Influence Index (CII)

To simplify calculation, CII is used for quantifying CREAM, in particular CPCs. This value can be measured by subtracting the number of CPCs decreased from the improved CPCs displayed in Equation (1), where *X* represents the number of decreased CPCs and *Y* corresponds to the number of improved CPCs [27].

$$CII = X - Y = \sum reduced - \sum improved \qquad (1)$$

2.3.5. Determine the Performance Influence Index (PII)

This stage generates PII values to determine correct weighting factors for entire cognitive functions, such as observation, planning, interpretation, and execution. As seen in Table 1, each CPC has a different PII value; therefore, different weigh factors play a role. It is a matter of obtaining precise quantitative results of the CSPs by using the PII values, instead of the linguistic expression (improved, decreased or not significant). This computation can only be used during the screening process, but never in detailed quantification [27]. In view of this, Equation (2) becomes feasible for the CII value.

$$CII = \sum_{i=1}^{9} PII \qquad (2)$$

The PII value in the equation depends fundamentally on the weighting factor provided in the extended CREAM method and evaluated by experts [27]. Therefore, the value of the cognitive failure probability (CFP) can be obtained by weighting and classifying the CPC in critical applications.

2.3.6. Calculation of Cognitive Failure Probability (CFP)

The CFP refers to the expectation of human failure for each form of cognitive failure to measure the HEP value. The CFP value (HEP) will be determined after the nominal cognitive failure probability (CFP_0) for each subtask has been assigned. CFP_0, which is obtained mostly from different sources, refers to the numerical value for cognitive function failure [26]. The CFP, which was mainly gathered from various sources, denotes the nominal value provided for failures of cognitive function [26]. The CFP table with respect to the four cognitive functions is given in Table 4 [26].

In this respect, it is possible to establish the association between CII and CFP using equation (3). The logarithmic function in the equation is used to explain changes in the relationships between humans and the variation in external conditions. The underlying assumption is technically acceptable [34].

$$\log\left[\frac{CFP}{CFP_0}\right] = k.CII \qquad (3)$$

where *k* is the coefficient of constant and is derived from Equations (4) and (5), respectively [21].

Table 4. *Nominal cognitive failure probability and the lower upper bond*

Cognitive function	Generic failure type	Lower bond (0.5)	Basic value	Upper bond (0.95)
Observation	O1. Wrong object observed	3.0E-4	1.0E-3	3.0E-3
	O2. Wrong identification	2.0E-2	7.0E-2	1.7E-2
	O3. Observation not made	2.0E-2	7.0E-2	1.7E-2
Interpretation	I1. Faulty diagnosis	9.0E-2	2.0E-1	6.0E-1
	I2. Decision error	1.0E-3	1.0E-2	1.0E-1
	I3. Delayed interpretation	1.0E-3	1.0E-2	1.0E-1
Planning	P1. Priority error	1.0E-3	1.0E-2	1.0E-1
	P2. Inadequate plan	1.0E-3	1.0E-2	1.0E-1
Execution	E1. Action of the wrong type	1.0E-3	3.0E-3	9.0E-3
	E2. Action at the wrong time	1.0E-3	3.0E-3	9.0E-3
	E3. Action on the wrong object	5.0E-5	5.0E-4	5.0E-3
	E4. Action out of sequence	1.0E-3	3.0E-3	9.0E-3
	E5. Missed action	2.5E-2	3.0E-2	4.0E-2

$$\log(CFP_{max}/CFP_0) = k.CII_{max},$$
$$\log(CFP_{min}/CFP_0) = k.CII_{min} \tag{4}$$

$$k = \log(CFP_{max}/CFP_{min})/(CII_{max} - CII_{min}) \tag{5}$$

$$\mathrm{CFP}_0 = CFP_{max}/10k.CII_{max} \tag{6}$$

According to the specific control modes and CII values, the maximum CII value can be 9 and the minimum CII value can be 7. In the equation the $\mathrm{CFP}_{max.}$ is accepted as 1.0000 (maximum HEP value), which indicates certainty for the probability of human error. The CFP_{min} is accepted as 0.00005 (minimum HEP value), which indicates almost impossibility. Then, *k* is found to be about 0.26. As a result, in the case of a definite CII value, the following equation (7) can be adopted to determine the adjusted CFP (HEP value) [35].

$$\mathrm{CFP} = \mathrm{CFP}_0 \times 10^{0.26.\mathrm{CII}} \tag{7}$$

4. Quantitative Failure Analysis for Ballast Pump System on Board Ships

In maritime operations, the ballast pump system significantly influences vessel stability and manoeuvrability. This analysis enhances operational safety by systematically evaluating failures and establishing mitigation measures for the ballast pump system on ships. These measures are essential for crew, vessel, and environmental safety. This section outlines the procedures for conducting quantitative risk analysis of the ballast pump system. The assessment includes hazard identification and evaluation of failure likelihood and potential control actions. Hazard identification involves scrutinizing potential issues that could affect the ballast pump system. The following identification, assessing the likelihood of human error failures quantitatively gages risks. Strategies to reduce these risks, such as design modifications and personnel training, are then evaluated for effectiveness. By quantitatively analysing risks within the ballast pump system, maritime operators can proactively enhance vessel safety and reduce environmental impact.

4.1. Problem Statement

While ballast pump systems are integral to maritime operations, ensuring vessel stability and safe maneuverability, the complex interplay of factors exposes these systems to potential risks. Despite their significance, a comprehensive quantitative analysis of these risks, encompassing hazard identification, likelihood assessment, and formulation of effective risk reduction strategies, remains limited. Consequently, the maritime industry lacks a structured approach to systematically quantify and address potential vulnerabilities within ballast pump systems. This study aims to bridge this gap by developing a rigorous quantitative failure analysis framework for ballast pump systems on board ships, contributing to enhanced operational safety, crew protection, and environmental conservation. Operational errors during ballast pump usage underscore the importance of this study. Improper valve configurations can lead to water distribution imbalances, resulting in vessel instability and listing. Neglecting water flow rate monitoring might lead to tanks being overfilled or underfilled, thereby affecting the vessel's trim, stability, and overall performance. Disregarding operational protocols may delay response time during emergencies due to incorrect sequencing of actions. Insufficient crew training can hinder effective ballast pump system operation, compromising decision making during critical situations. In addition, neglecting routine maintenance and inspection increases the likelihood of equipment malfunctions, potentially jeopardizing crew and vessel safety. These examples highlight the multifaceted nature of errors that can occur during ballast pump operations.

4.2. Numerical HAZOP Analysis

To assess system failures in ballast pump operation related to human errors that contribute to operational risks in ballast pumps, a detailed HAZOP framework is required. The HAZOP team was selected to determine the relevant process parameters and potential deviations (failures). The team consists of nine marine experts who have wide knowledge and experience of shipboard operations. HAZOP parameters and guide words have been presented to marine experts, and a brief introduction has been performed for detailed HAZOP risk analysis. Most of the experts are deck superintendents and master mariners. The experts have also been asked to advise potential causes of deviations in case of ballast pump system operational failures. Because of the parameters and deviations determined by the consensus of marine experts, the potential causes of deviations have been identified. Potential causes were considered separately for each deviation. To address potential causes, shipboard ballast operation is assessed in depth. Deviations might have more than one possible cause. Accordingly, a detailed HAZOP Table 5 is created. To quantify HAZOP deviations, which give potential failure of the system, a systematic extended CREAM is used. The PII values have been nominated in the view of marine expert consensus. Table 6 shows the PII values of CPC for each deviation in the system. To gather the cognitive failure probability (CFP) of deviation (failure) in the system, four cognitive functions are used: observation, interpretation, planning, and execution. Equation (7) is used to calculate the adjusted CFP for each deviation in the ballast pump system. Table 3 shows the cognitive function and basic failure rates. Accordingly, Table 7 shows the results of adjusted CFP values along with relevant cognitive activity, cognitive function, and generic failure type.

4.3 Findings and Extended Discussion

The HAZOP analysis, as demonstrated in Table 5, identified several potential deviations or failures within the system. These deviations (failures) encompass scenarios where water does not reach the pump, the pump suction level is near the waterline, ship trim affects pump suction, water cannot be delivered to the tank, the pump operates inadequately, the pump's capacity is low, there is a slow increase or decrease in tank levels because of unintentional ballast operations, and the liquid level in a tank increases unexpectedly. For each of these deviations, cognitive activities such as monitoring, planning, diagnosing, and maintaining were noted. The corresponding cognitive functions involved observation, planning, interpretation, and execution. The HAZOP analysis method successfully highlighted potential issues across various operational stages. The deviations identified provide insights into where failures might occur, and which cognitive activities and functions are involved in addressing these issues. It is evident that careful planning and proper execution are crucial for mitigating the identified failures. For instance, deviations related to pump performance underscore the importance of maintaining and diagnosing equipment to ensure reliable operation. Similarly, addressing deviations due to unintentional ballast operations requires effective planning and execution strategies.

The CREAM analysis method yields quantitative results through cognitive failure probability (CFP) values calculated for each potential deviation. These values enable a comparative assessment of their potential impact and range across deviations, with adjusted values reflecting the seriousness of the associated failure mode. This structured approach facilitates the assessment and prioritization of potential failures based on their estimated impact. By assigning CFP values, the CREAM analysis offers a quantitative perspective on potential system failures, enabling effective allocation of resources for mitigation strategies. This aid decision-making by highlighting failures with the greatest potential consequences and streamlining the focus on areas of concern.

Among the deviations highlighted in Table 7, deviations (failures) 4, 6, and 8 stand out due to their notably high adjusted CFP values, indicating significant potential risks within the system. In the Table 7, no 6, "Low-capacity working," boasts adjusted CFP of 1.82E-01. Requiring monitoring and observation, the high adjusted CFP value accentuates the substantial impact that low-capacity working can have on the overall system performance. Addressing this issue promptly through corrective actions, such as performing maintenance to enhance pump capacity or replacing malfunctioning components, is crucial to prevent potential repercussions.

Similarly, no 8, the "Liquid level increasing in tank" deviation, holds adjusted CFP of 1.27E-01. Centred on monitoring and observation, the elevated adjusted CFP value underscores the notable risk linked to unexpected liquid level increases within a tank. Swift interventions, such as installing additional level sensors or implementing automated alert systems, are imperative to effectively manage this situation and mitigate potential adverse effects.

Lastly, no 4, involving the deviation "Water not delivering tank," has an adjusted CF of 8.65E-02. This deviation, which necessitates diagnosis and interpretation, underscores the substantial risk associated with improper water delivery to the tank. To avert any adverse consequences, measures to ensure accurate water delivery, such as regular inspections of valves and pipelines or the implementation of redundant delivery systems, should be of utmost priority.

Table 5. *HAZOP table for the ballast pump system on board ship*

No	Process (target)	Keyword	Guide word	Potential deviations	Potential cause	Outcome	Existing control actions	Additional control actions
1	Line up and set up/ correct valve position	No	Water	Water not reaching the pump	1) Wrong line up/valve operation	No ballast water intake	1) Check line up again 2) Check the pump suction and pressure gages 3) Check overboard visibly (deballasting)/ check tank level change (ballasting)	1) Ensure that the ballast pipeline diagram is prepared correctly 2) Ensure manual operated valves are marked with the correct code
					2) Sea chest/filter blocked			
					a) Fouled by sea creatures		Clean up by back flushing/steaming	Proper cleaning during the dry dock period
					b) Fouled by garbage		Clean the sea chest filter	Avoid ballast operation in shallow waters/ low draft when sea chest is close to the surface at garbage fouled ports
				Pump suction level close to the water line			1) Use a pump priming unit 2) Use the existing ballast tank as line filling for initial suction	1) Install the pump on the lower platforms. 2) Proper draft calculation before ballast operations
				Ship trim and/or list not suitable for pump suction from ballast tank.	1) The wrong cargo/ballast sequence 2) An improper stowage plan 3) Improper dich/load port sequence	Node ballasting	Internal ballast transfer for sufficient trim/list Internal cargo transfer (if possible)	Proper stowage plan Proper planning of the cargo ballast disch. sequence Proper cargo dish/load port sequence
2		Yes	Pressure	Water not delivered to tank	1) Manual valve not operating 2) False indication of the remote valve indicator light (vise versa) 3) Remote valve actuator does not open/close (due to rust on valve spindle), but indicator shows that the valve is operating 4) Remote valve actuator hydraulic leakage	No ballasting	1) Overhaul the valve 2) Test with gravity ballasting/de-ballasting on a regular basis and prior port arrivals 3) Visual inspection and valve overhaul 4) Check the hydraulic storage tank level regularly 4.2) Ensure that the hydraulic tank low-level alarm is working	Start operation with gravity ballasting to prevent pressure surge on the pipeline

Table 5. *Continued*

2	Run the pump and generate the pressure	No	Pressure	Pump not properly running	1) Power source switch turned off 2) Loose wire/wire broken 3) Electric motor failed 4) Pump impeller fouled with nylon string	No ballast/ reballast	1) Check engine room for the main power source is on 2) perform the Megger test. Replace wire 3) perform the Megger test. Rewind the electric motor 4) Overhaul the pump	Use a second pump or any other general service pump if connection is available
		Low	Performance	Low capacity working	1) Unused valve left open pump circulate 2) Impeller worn out (clearance gap is big)/ impeller 3) The pump case has a crack/hole. 4) Pump gland leakage	Low ballasting performance	1) Check line up 2) Overhaul the pump and change the impeller 3) Temporary clogging of the hole with fast drying agents. 4) Change the pump gland packing	Performance test of the pump regularly Regular visual inspection of the pump Check the suction and pressure gage of the pump
3	Run the pump and fill in the intendent tanks	No/ low	Level	Level increase/ decrease slow Unintentional ballast operation	1) Line ruptured in transit of another tank 2) Valve seat worn out 3) Check valve disk is lost 4) Pipeline connection failure	Low ballasting performance	1) Clog the hole with temporary clamping	1) Replace line at dry dock time 2) Conduct regular line pressure test 3) Check for non-operational tank level change
4	No ballast operation	Yes	Level	Liquid level increasing in the tank	1) Hull damaged 2) Sounding pipe cover left open 3) Ballast manhole cover unsecured properly/gasket failure 4) Air vent head floating disk not operational 5) cargo tank/hold has cracks in ballast tanks	Unintended list due to water/cargo penetration	1) Temporary clog hull with wood chocks 2) Pre-departure check prior departure 3) Pre-departure check prior departure 4) Replace the floating disk 5) Plan to deviate from safe ports	1) regular thickness measurement 2) Keep the temporary hull clogging equipment agents' tools on board

Table 6. *PII values for deviation*

	PII value							
CPC	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Adequacy of the organization	0.6	1	0	1	0.6	0.6	0.6	0
Working conditions	0	1	0	1	0	1	0	1
Adequacy of the MMI and operational support	0	-0.4	-0.4	0	0	-0.4	-0.4	-0.4
Availability of procedures/plans	-1.2	0	0	-1.2	-1.2	1.4	1.4	1.4
Number of simultaneous goals	0	0	-0.4	0	0	-0.4	0	0
Available time	1	1	1	-1.4	1	-1.4	1	-1.4
Time of day	0	0	0.6	0,6	0	-0.6	0	0
Adequacy of training and preparation	-1.4	-1.4	0	0	-1.4	0	-1.4	1.8
Crew collaboration quality	0.4	-1.4	0.4	-1.4	0	1.4	0	-1.4
Total	**-0.6**	**-0.2**	**1.2**	**-1.4**	**-1**	**1.6**	**1.2**	**1**

Table 7. *Adjusted CFP values along with relevant cognitive activity, cognitive function, and generic failure type*

No	Potential deviation/failure	Cognitive activity	Cognitive function	Generic failure type	Nominal CFP (CFP0)	Adjusted CFP
1	Water not reaching the pump	Monitor	Observation	O3	7.0E-02	4.89E-02
2	Pump suction level close to the water line	Monitor	Observation	O1	1.0E-03	8.87E-04
3	Ship trim and/or list not suitable for pump suction from ballast tank	Plan	Planning	P2	1.0E-02	2.05E-02
4	Water not delivered to tank	Diagnose	Interpretation	I1	2.0E-01	8.65E-02
5	Pump not properly running	Maintain	Execution	E4	3.0E-03	1.65E-03
6	Low capacity is working	Monitor	Observation	O3	7.0E-02	1.82E-01
7	Level increase/decrease slow unintentional ballast operation	Maintain	Planning	P2	1.0E-02	2.05E-02
8	Liquid level increasing in the tank	Monitor	Observation	O3	7.0E-02	1.27E-01

Given the distinct potential risks associated with high adjusted CFP values, these deviations necessitate immediate attention and proactive mitigation strategies. By focusing on these areas of concern, the system's overall reliability and operational safety can be effectively preserved. The quantitative perspective provided by the CREAM analysis aids in informed decision-making by highlighting failures with the most substantial potential impacts and guiding the allocation of resources for focused mitigation efforts.

5. Conclusion

This study focused on addressing potential failures associated with ballast pump systems in maritime operations. By employing the CREAM integrated within the HAZOP framework, this study has offered valuable insights into the complex nature of ballast operations and the significance of human factors in these processes.

The HAZOP analysis effectively identified various potential deviations and failures within the system. The findings underscore the critical role of cognitive activities, such as monitoring, planning, diagnosing, and maintaining, in ensuring the safe and efficient functioning of ballast pump systems. The cognitive functions of observation, planning, interpretation, and execution correspondingly play a pivotal role in addressing these issues. The analysis method has successfully highlighted potential concerns throughout different operational stages, demonstrating the effectiveness of the method in pinpointing vulnerabilities and weaknesses.

CREAM analysis provides a quantitative perspective on the potential impact of failures within the system. By assigning CFP values, it is possible to prioritize areas of concern based on their adjusted values. This aids decision-making processes by highlighting which failures might have the most significant consequences, helping allocate resources for mitigation strategies more effectively. To guide potential researchers in this area, it is recommended that future studies include a section that outlines specific methodological improvements. This section discusses how the HAZOP and CREAM analyses can be further enhanced or refined to yield more accurate results. Suggestions for incorporating real-time data into the analysis and exploring a wider range of variables should be emphasized. Despite the insightful findings and contributions, this study has certain limitations. The analysis relies heavily on historical data and assumptions, which might not fully encompass all scenarios. The focus on cognitive aspects might overlook other technical, mechanical, or environmental factors that contribute to failures. Future studies could expand the analysis to encompass a wider range of variables, integrate real-time data for a more accurate assessment, and explore comprehensive training programs for crew members to enhance their cognitive performance during ballast operations.

In summary, this study sheds light on the significance of human performance and cognitive aspects in mitigating potential hazards in shipboard ballast operations. By integrating HAZOP and CREAM methodologies, this study provides a systematic approach for identifying, analysing and addressing potential failures, thus contributing to the enhancement of maritime operational safety and efficiency.

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Evaluating the Technical Efficiency of Dry-Bulk and General Cargo Terminals in Türkiye using Interval DEA

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Abstract

The efficiency of bulk solid and general cargo terminals, where ore, grain, and many raw materials are handled, plays a crucial role in socioeconomic development and lays the groundwork for reasonable trade costs. This study evaluates the relative performance of dry-bulk and general cargo terminals in Türkiye with interval data envelopment analysis (DEA). The dataset consists of 21 terminals operated by private companies for 2018-2021 and has been transformed into an interval form to apply interval DEA to imprecise data. The results imply that the efficiency levels of dry-bulk and general cargo terminals in the Marmara and Mediterranean tend to increase. It can be inferred that the average efficiency level of the Black Sea terminals has remained stable over the years, and the loss of efficiency in the Aegean is remarkable. The application of the Interval DEA in evaluating the efficiency of dry-bulk and general cargo terminals in the case of imprecise data can contribute significantly to the seaport efficiency literature.

Keywords: Dry-bulk, Terminal, Efficiency, Interval DEA, Fuzzy

1. Introduction

International trade is boosted by the efficient transport of raw materials and bulk solids from one end of the world to the other. Thus, general cargo ports become strategic nodes for sustainable and efficient maritime transportation. Among the common cargo types transported by sea, solid bulk and general cargo have the highest share, 45% [1]. In Türkiye, approximately 232 million tons of bulk solids and general cargo were handled at seaports in 2021 [2].

The essential functions of a dry bulk and general cargo terminal are to handle and transfer cargo that is physically separated from the others in terms of mode of transport [3]. Some of the difficulties encountered in preventing the current load potential of the terminals from shifting to rivals are the product handling speed at an appropriate level, adequate and efficient equipment, optimizing berthing times, reducing waiting and delays at anchor, providing sufficient storage capacity, and offering multimodal hinterland connections [4]. In addition, bulk solid and general cargo-oriented foreign trade firms experience fierce global competition [5]. Dry bulk and general cargo terminals tend to invest in infrastructure and equipment and keep up with new trends concerning technological developments to maintain their dynamic market share shaped by increasing ship sizes and shipowner cooperation.

The efficiency of bulk solid and general cargo terminals, where ore, grain, grain, and many raw materials are handled, plays a crucial role in socio-economic development and lays the groundwork for the competitive prices expected by port customers. The level of efficiency of the terminals varies according to the production technology, the economic behavior of the decision-making units, the environmental factors in which the process takes place and the management strategies adopted. In this context, assessing the relative performance of solid bulk and general cargo terminals is critical for the efficient use of existing resources and for planning future investment strategies of decision makers.

The existing literature constitutes several studies on the efficiency of seaports and terminals. Kutin et al. [6] evaluated the relative efficiency of ASEAN container ports. The authors

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categorized the seaports on the basis of their locations and handling systems to benchmark them with standard data envelopment analysis (DEA) and super-efficiency models under constant returns to scale (CRS) and variable returns to scale (VRS) options. Castellano et al. [7] evaluated the economic and environmental efficiency of Italian seaports using DEA considering an undesirable output approach. They concluded that efficiency converges toward the optimal target when ports feature a high pro-environmental attitude by implementing proactive green policies. da Costa et al. [8] evaluated the efficiency of container terminals in the northern region of Brazil using DEA under CRS and VRS production technologies. Their study is at a regional level and deals with the better management of seaports located in the region. Fancello et al. [9] also evaluated the efficiency of Mediterranean container ports using DEA under the CRS and VRS options. Similarly, Hsu et al. [10] assessed the operational efficiency of terminals located in the Kaohsiung Port using DEA. As inferred from the above recent studies, frontier-based efficiency evaluations are intensively based on standard DEA models.

On the other hand, stochastic approaches are also an alternative to DEA approaches such as stochastic frontier analysis. In particular, with small sample, it may be problematic to establish a parametric frontier model based on the maximum likelihood estimation procedure. Wiegmans and Witte [11] analyzed the efficiency of inland waterway container terminals using stochastic frontier and data envelopment to evaluate capacity design and throughput efficiency. Julien et al. [12] compared common frontier approaches to evaluate efficiency, productivity, and returns to scale in ports by applying them to Caribbean Small Island Developing States. These works also evaluate seaports from various perspectives. However, these studies are mainly related to container terminals, and the number of studies on bulk cargo terminals is limited. The OECD [13] has published a comprehensive study of the efficiency analysis of solid bulk terminals using standard DEA approaches. The most attractive aspect of this distinctive study is the benchmarking of dry bulk and general cargo terminals according to the cargo types handled. The authors concluded that technical efficiency, in other words, the efficient use of equipment and infrastructure, is the most critical factor affecting the overall efficiency of terminals. The most attractive aspect of this distinctive study may be benchmarking the dry-bulk terminals according to the cargo types handled, such as coal or wheat, with the aim of consistent findings.

Balci et al. [14] evaluated the competitiveness and selection criteria of solid-bulk cargo terminals using multi-criteria decision-making methods (MCDMM). The authors state that dry bulk shippers differ in their priorities regarding port selection criteria and highlight a heterogeneity of expectations. Although the dry cargo terminal selection criteria are similar to those of container shippers, the content may be different. Another striking result is that shippers in the dry bulk market deal with some of the same problems as container carriers when choosing a port. Suliman et al. [15] discussed the potential of using technical port indicators and DEA application specifically in dry bulk terminals and examined the technical and scale efficiency of Malaysian solid-bulk cargo terminals with standard DEA approaches. Following classical production theory, the authors propose a framework that consists of equipment, infrastructure/facility, and labor as inputs, and the total throughput in tons as output for dry bulk terminals. However, they highlighted that further studies are required to prove the effectiveness and accuracy of this method.

Based on the studies in the literature, there are some reservations due to data imprecision and the difficulties of the application of frontier models such as DEA to solid bulk and general cargo terminals. Considering the limited relevant literature, it is inferred that the most frequent inputs in determining the technical efficiency of solid-bulk and general cargo terminals are the terminal area, equipment, and pier length, and the most frequently used output is the annual total amount of cargo handled [13,15]. However, the different physical characteristics of the cargo handled at the solid-bulk and general cargo terminals obscure the standardization of the handling equipment. Bulk cargo-specific handling equipment varies as conveyors or cranes using grab, depending on the load type. However, comparing daily tonnage handled with both types of handling equipment, similar results can be achieved. Similarly, the handling cost per ton varies depending on the type of cargo. Moreover, load types with different densities and properties may be sensitive to various environmental conditions such as rain, humidity, swell affecting the dock, and strong wind. For these reasons, interval DEA instead of standard DEA was used. The interval efficiency approach is a convenient and practical method for evaluating the efficiency of bulk solid and general cargo terminals with imprecise data. If the lower and upper limit values of the data can be calculated, limited data may be obtained [16]. Therefore, the crisp data were fuzzified using their standard error (SE) in alignment with fuzzy theory. Thus, the upper and lower bounds of efficiency were obtained. Interval efficiency levels of each terminal were ranked using the minimax regret approach (MRA).

There are few studies on bulk solid and general cargo terminals in the literature, as mentioned above, and this can be related to data unavailability or partly imprecatory. This study aims to overcome the constraints caused by the unique features of private general cargo and dry bulk cargo terminals in Türkiye by using fuzzy logic theory to make a more precise comparison. In this context, it is argued that this study could contribute significantly to the literature. Regardless of the type of bulk cargo handled, interval DEA can act as an alternative efficiency analysis tool. Moreover, it can fill the critical gap in the literature by forming an interval efficiency level to draw inferences about how effectively solid bulk and general cargo terminals use their existing resources by practitioners, terminal managers, and other industry stakeholders.

The overall structure of the study is in the following form: Section 2 represents the analysis technique adopted, while Section 3 presents the results and the discussion with relevant literature. The last section summarizes the research conclusions.

2. Methodology

This study evaluates the technical efficiency levels of 21 large solid-bulk and general cargo terminals in Türkiye using the interval DEA approach based on pooled cross-sectional data consisting of 78 different observations from 2018 to 2021 collected from Turkish Port Operators Association (TURKLIM) annual reports [17-20]. This approach is an input-oriented DEA with interval data, assuming CRS production technology. The interval DEA determines a different efficiency range for each DMU, assuming either input minimization or output maximization. The efficiency frontier comprises a set of efficient decision units. The distance of the DMUs below the production frontier is measured as the radial distance, either input- or output-oriented. It aims to minimize the inputs, considering that solid-bulk and general cargo terminal managers cannot increase the output amount unless there is demand for the decisions they will make.

Multi-purpose seaports that intensively handle containerized cargo are not included in the study despite solid-bulk and general cargo handling because they use infrastructure and handling equipment for different cargo types. All assessed terminals are operated by private companies. Terminals P, G, and N are located in the Black Sea. Terminals L, U, V, I, J, F, and A are located in Marmara. Terminals T, M, and K are in the Aegean region, whereas Terminals E, C, and D, are in Iskenderun Bay in the East Mediterranean.

2.1. DEA

Data envelopment analysis is a mathematical programing technique developed by Charnes et al. [21] and based on Farrell's [22] frontier model to evaluate the relative efficiency of a set of homogeneous decision-making units (DMUs). This model is based on the assumption of CRS, is known as the CCR model, and consists of the first letter of the author's name. In 1984, Banker et al. [23] developed the BCC model based on the assumption of VRS. This model, used to derive the pure technical efficiency level, relaxes the constraint on scale efficiency by allowing output to change almost disproportionately with a marginal increase in inputs. The technical efficiency value of each DMU obtained using the VZA-CCR and VZA-BCC models is used to calculate the scale efficiency of each DMU using the equation $SE_k = U_{CCR,\ k}/U_{BCC,k}$. $SE_k = 1$ means the DMU is scale efficient, $SE_k < 1$ means the scale inefficient [24]. Scale inefficiency results from increasing or decreasing returns to scale, which can be determined by examining the sum of the weights under the specification of the CCR model. If this sum is equal to one, it means a constant return to scale (CRS). If the sum of the coefficients is less than or greater than one, it indicates an increasing return and a decreasing return to scale. Although these two standard forms (DEA-CCR and DEA-BCC) are frequently used in the current literature, advanced DEA models also exist.

During an efficiency measurement made with DEA, the data must be precise and reliable. Imprecise or missing data can cause relative efficiency levels to be overestimated or underestimated. The complex nature of the terminals makes it difficult to obtain an accurate dataset. Extreme conditions such as adverse weather conditions, strikes, and pandemics during the handling operation may adversely affect the accuracy of the data obtained. There may also be difficulties in obtaining precise data on private businesses or accurately measuring inputs and outputs for privacy and accessibility reasons [25]. If the sample size and the specification of the data are not appropriate for parametric efficiency analysis approaches that consider the error term, it would be suitable to use fuzzy modeling together with standard DEA to evaluate the relative efficiency of DMUs [26,27]. Thus, the standard DEA approach gains the ability to model real-life problems more appropriately [27].

Several fuzzy DEA techniques deal with efficiency measurement in the current literature. Sengupta [27], who used a combination of fuzzy set theory and the DEA approaches for the first time in the literature, developed an efficiency model based on tolerance levels of the objective function and constraint violations. Triantis and Girod [28] proposed an approach that transforms fuzzy input and output data into precise data compatible with the standard DEA model using membership function values. In this model, different efficiency scores estimated with various membership functions are averaged to compare the efficiency levels of decision-making units. Guo and Tanaka [26] proposed a fuzzy CCR model in which fuzzy constraints are transformed into precise constraints by defining a probability level. Lertworasirikul et al. [25] transformed the fuzzy DEA model into a probability DEA model, in which fuzzy constraints were treated as fuzzy events using probability measures on fuzzy events. Kim et al. [29] applied fuzzy DEA with partial data. On the other hand, Kao and Liu [30,31] and Saati et al. [32] adopted an approach that transforms fuzzy data into interval data by using α sets so that standard DEA models can be used with fuzzy data. However, because the efficiency level calculated at a certain α level with this approach will vary at each different α level, the comparison can only be made for a specific α level. Entani et al. [33] proposed a DEA model with interval efficiency estimated with pessimistic and optimistic perspectives for fuzzy data. However, this model selects only one input and one output data to obtain the lower bound efficiency of each DMU, regardless of the number of inputs and outputs. This leads to a lack of information about other inputs and outputs in the model. The interval efficiency model used in this study eliminates the downsides associated with other fuzzy DEA models. This model uses a fixed and unified production frontier as a benchmark to measure the efficiency levels of all DMUs; therefore, the generated models are more rational and reliable [34].

2.2. Interval DEA

Wang et al.'s [34] interval DEA approach can deal with imprecise data simply, rationally, and effectively using interval input and output data. Using this approach, the efficiency level obtained for each DMU is characterized by an interval efficiency bounded by the best lower bound efficiency and the best upper bound efficiency of each DMU.

Assuming n DMUs, each DMU consumes m inputs in different amounts for s outputs, DMU_j consumes number of inputs $X_j = \left\{x_{ij}\right\}$ $(i = 1,2,\ldots,m)$, and produces $Y_j = \left\{y_{rj}\right\}$ $(r = 1,2,\ldots,s)$ number of outputs. Without loss of generality, it is assumed that all inputs and outputs x_{ij} and $y_{rj}\,(i = 1,\ldots,m\ ;\ r = 1,\ldots,s\ ;\ j = 1,\ldots,n)$ it is not known precisely due to uncertainty. However, the values of the inputs and outputs are within the lower and upper bounds represented by x^L_{ij}, x^U_{ij} *and* y^L_{rj}, y^U_{rj} $(x^L_{ij}, y^L_{rj} > 0)$ respectively. In the case of uncertainty expressed in this manner, the following linear programing models are used to create the lower and upper bounds of the efficiency intervals of the DMUs.

$$\begin{aligned}
&\text{Max.}\\
&H^U_{j_0} = \sum_{r=1}^{s} u_r y^U_{rj_0}\\
&\text{Constraints;}\\
&\sum_{i=1}^{m} v_i x^L_{ij_0} = 1,\\
&\sum_{r=1}^{s} u_r y^U_{rj_0} - \sum_{i=1}^{m} v_i x^U_{ij_0} \le 0,\\
&\sum_{r=1}^{s} u_r y^L_{rj} - \sum_{i=1}^{m} v_i x^L_{ij} \le 0,\ j = 1,\ldots,n;\ j \ne j_0,\\
&u_r, v_i \ge \varepsilon\ \forall_{r,i.}
\end{aligned} \tag{1}$$

$$\begin{aligned}
&\text{Max.}\\
&H^L_{j_0} = \sum_{r=1}^{s} u_r y^L_{rj_0}\\
&\text{Constraints;}\\
&\sum_{i=1}^{m} v_i x^U_{ij_0} = 1,\\
&\sum_{r=1}^{s} u_r y^L_{rj_0} - \sum_{i=1}^{m} v_i x^U_{ij_0} \le 0,\\
&\sum_{r=1}^{s} u_r y^U_{rj} - \sum_{i=1}^{m} v_i x^L_{ij} \le 0,\ j = 1,\ldots,n;\ j \ne j_0,\\
&u_r, v_i \ge \varepsilon\ \forall_{r,i.}
\end{aligned} \tag{2}$$

where j_0 is the decision-making unit (DMU_0) under evaluation; u_r and v_i, weights assigned to outputs and inputs; H^U_{j0} and H^L_{j0} represent the best possible relative efficiency values for KVB_0 under the most favorable and unfavorable situations, respectively, and ε is infinitesimal non-Archimedes.

When the upper- and lower-efficiency DEA models specified in Equation 1 and Equation 2 are examined, the constraints used to measure the efficiency of DMUs differ among DMUs, and even the same constraints used to measure the lower- and upper-efficiency bounds of the same DMU are different. The most obvious downside of using different constraints to measure the efficiency of DMUs is the lack of comparison between DMUs due to the adoption of various production frontiers in efficiency measurement. Since each DMU can use minimum inputs to produce maximum outputs, the actual production frontier should be derived on the basis of each DMU's best production activity state. The interval efficiency model avoids obtaining different production frontiers to measure the efficiency of DMUs. This model is based on interval arithmetic. It also uses a single efficiency frontier that is created with the same constraints for all DMUs and lower and upper bound efficiencies. Upper- and lower-efficiency linear programing models created with the same constraints and projected to a single frontier are as follows for the upper- and lower-efficiency bounds, respectively [34].

$$\text{Max. } \theta^U_{j_0} = \sum_{r=1}^{s} u_r y^U_{rj_0}$$
Constraints;
$$\sum_{i=1}^{m} v_i x^L_{ij_0} = 1, \quad (3)$$
$$\sum_{r=1}^{s} u_r y^U_{rj} - \sum_{i=1}^{m} v_i x^L_{ij} \leq 0, \; j = 1, \ldots, n,$$
$$u_r, v_i \geq \varepsilon \, \forall_{r,i.}$$

$$\text{Max. } \theta^L_{j_0} = \sum_{r=1}^{s} u_r y^L_{rj_0}$$
Constraints;
$$\sum_{i=1}^{m} v_i x^U_{ij_0} = 1, \quad (4)$$
$$\sum_{r=1}^{s} u_r y^U_{rj} - \sum_{i=1}^{m} v_i x^L_{ij} \leq 0, \; j = 1, \ldots, n,$$
$$u_r, v_i \geq \varepsilon \, \forall_{r,i.}$$

θ^U_{j0} represents the best possible relative efficiency achieved by DMU_0 when all DMUs are in the state of best production activity, θ^L_{j0} represents the lower bound of the best possible relative efficiency of DMU_0. Thus, they establish the best possible interval of relative efficiency $\left[\theta^L_{j0}, \theta^U_{j0}\right]$.

Because the final efficiency scores for each DMU are characterized by their relative efficiency interval, a simple and practical approach is needed to rank and compare the efficiency of different DMUs. Several methods have been developed in the literature to compare the efficiency intervals of each of the DMUs and to rank the efficiency levels [35]. However, when interval numbers have the same center but different widths, they fail to distinguish one from the other [36,37].

Wang et al. [34] stated that the MRA can be used to rank and compare the efficiency intervals of DMUs, even if they are concentric but of different widths. The MRA for the interval DEA is summarized as follows.

Let the efficiency intervals of n DMUs be $A_i = [a^L_i, a^U_i] = \langle m(A_i), w(A_i)\rangle (i = 1, \ldots, n)$. $m(A_i) = \frac{1}{2}(a^R_i + a^L_i)$ and $w(A_i) = \frac{1}{2}(a^R_i + a^L_i)$ are the centers and widths, respectively. Without loss of generality, $A_i = [a^L_i, a^U_i]$ is assumed to be the best efficiency interval of DMU. When $b = \max_{j\neq i}\{a^U_j\}$, if $a^L_i < b$, DMU may experience inefficiency and regret. The maximum efficiency loss in this case is:

$$\max(r_i) = b - a^L_i = \max_{j\neq i}\{a^U_j\} - a^L_i . \quad (5)$$

If $a^L_i \geq b$, KVB as DMU has no regrets due to the loss of efficiency, $r_i = 0$. Maximum efficiency loss when both conditions are considered together can be written as follows:

$$\max(r_i) = \max[\max_{j\neq i}(a^U_j) - a^L_i, 0] \quad (6)$$

Thus, the minimax regret (MR) criterion determines the efficiency interval that satisfies the following condition as the best efficiency interval.

$$\min_i\left\{\max(r_i)\right\} = \min_i\left\{\max[\max_{j\neq i}(a^U_j) - a^L_i, 0]\right\}. \quad (7)$$

Based on the efficiency interval analysis above, Wang et al. [34] defined the following equation to compare the efficiency intervals and rank the DMUs.

Let $A_i = [a^L_i, a^U_i] = \langle m(A_i), w(A_i)\rangle (i = 1, \ldots, n)$ be the interval efficiency set. The maximum efficiency loss of each efficiency interval is

$$R(A_i) = \max\,[\text{maks}_{j\neq i}\, a^U_j) - a^L_i, 0] = \max$$
$$[\max_{i\neq i}\{m(A_i) + w(A_i)\} - (m(A_i) - w(A_i)), 0] \quad (8)$$
$$i = 1, \ldots, n.$$

Relative maximum efficiency losses are calculated on the basis of the maximum efficiency level. Therefore, they cannot be used directly for ranking. The following steps are suggested in order to rank the efficiency using the maximum efficiency losses obtained using the estimated efficiency intervals [34].

Step 1: Maximum efficiency loss is calculated for all DMUs. The lowest maximum efficiency loss is determined to be the most attractive option. Assuming A_{i_1} is selected, with $1 \leq i_1 \leq n$.

Step 2: A_{i_1} value is eliminated from the efficiency interval list. Among the remaining n−1 number of efficiency intervals, the efficiency loss with the lowest maximum efficiency loss is determined again. The value of A_{i_2} is determined so that $1 \leq i_1 \leq n$ ve $i_1 \neq i_2$ is.

Step 3: The value A_{i_2} is also eliminated from the efficiency interval list. Among the remaining n-2 number of efficiency intervals, the efficiency loss with the smallest maximum efficiency loss is determined again.

Step 4: A_{i_3} value is also eliminated from the efficiency interval list. This process continues until only one maximum loss of efficiency remains on the list. Ranking is conducted as ($A_{i_1} > A_{i_2} > A_{i_3} > , \ldots, A_{i_4}$) meaning ” >” sign is “superior” [34].

2.3. Input and Output Variables

It is critical to specify the inputs and outputs in the efficiency evaluations performed using data envelopment analysis. When the literature is examined, there are few studies on the efficiency of bulk cargo terminals [10,14,38]. Considering that inputs are transformed into outputs in a classical production function, the annual amount of cargo handled on a ton basis can be accepted as a service output at ports that handle solid bulk cargo. The inputs that likely affect the total throughput to reach the desired level are the existing infrastructure and handling equipment. Pier length (m), storage area (Ha), and handling equipment (units) are considered the inputs, whereas the output variable is the annual amount of cargo handled (Mt). Descriptive statistics of the input and output variables that comprise the dataset are shown in Table 1.

Due to possible data errors, the crisp data were transformed into intervals using Equations 3 and 4. For this, the SE of variables was subtracted from the crisp data, the lower

Table 1. *Descriptive statistics of the model variables*

Inputs and outputs	N	Mean	Standard deviation	Min.	Max.
Output					
Cargo throughput (mt)	78	5,449,548.11	3,179,457.7	2,072,089	15,510,380
Inputs					
Pier length (m)	78	1,266.372	610.55	417	2,974
Terminal area (Ha)	78	13.837	10.514	2.260	34.4
Handling equipment (unit)	78	9.205	4.655	2	25

Table 2. *Efficiency ranking of terminals based on the minimax regret approach*

Rank	Code	Year	Region	Lower Bound	Upper Bound	Max. loss.	Rank	Code	Year	Region	Lower Bound	Upper Bound	Max. loss.
1	Terminal A	2018	Marmara	1	1	0	40	Terminal H	2018	Aegean	0.564	0.774	0.436
2	Terminal B	2019	Black Sea	1	1	0	41	Terminal C	2019	Mediterranean	0.557	0.593	0.443
3	Terminal A	2020	Marmara	1	1	0	42	Terminal L	2020	Marmara	0.542	0.762	0.458
4	Terminal C	2021	Mediterranean	1	1	0	43	Terminal M	2021	Aegean	0.492	0.458	0.508
5	Terminal D	2021	Mediterranean	1	0.630	0	44	Terminal M	2020	Aegean	0.491	0.457	0.509
6	Terminal E	2018	Mediterranean	0.979	0.875	0.021	45	Terminal N	2021	Black Sea	0.471	0.488	0.529
7	Terminal F	2021	Marmara	0.977	1	0.023	46	Terminal K	2018	Aegean	0.474	0.456	0.526
8	Terminal F	2020	Marmara	0.966	0.991	0.034	47	Terminal O	2018	Mediterranean	0.461	0.483	0.539
9	Terminal A	2019	Marmara	0.956	0.962	0.044	48	Terminal K	2019	Aegean	0.458	0.443	0.542
10	Terminal D	2018	Mediterranean	0.925	0.587	0.075	49	Terminal N	2020	Black Sea	0.457	0.475	0.543
11	Terminal B	2020	Black Sea	0.928	0.933	0.072	50	Terminal N	2019	Black Sea	0.426	0.447	0.574
12	Terminal D	2019	Mediterranean	0.899	0.572	0.101	51	Terminal O	2019	Mediterranean	0.422	0.449	0.578
13	Terminal B	2018	Black Sea	0.889	0.897	0.111	52	Terminal N	2018	Black Sea	0.419	0.441	0.581
14	Terminal E	2019	Mediterranean	0.877	0.787	0.123	53	Terminal M	2019	Aegean	0.366	0.360	0.634
15	Terminal E	2021	Mediterranean	0.870	0.782	0.130	54	Terminal P	2018	Black Sea	0.356	0.262	0.644
16	Terminal D	2020	Mediterranean	0.863	0.552	0.137	55	Terminal M	2018	Aegean	0.350	0.346	0.650
17	Terminal G	2021	Black Sea	0.861	0.700	0.139	56	Terminal F	2018	Marmara	0.339	0.430	0.661
18	Terminal A	2021	Marmara	0.849	0.868	0.151	57	Terminal O	2020	Mediterranean	0.336	0.374	0.664
19	Terminal B	2021	Black Sea	0.830	0.841	0.170	58	Terminal P	2020	Black Sea	0.324	0.252	0.676
20	Terminal G	2018	Black Sea	0.801	0.677	0.199	59	Terminal R	2020	Marmara	0.317	0.319	0.683
21	Terminal E	2020	Mediterranean	0.794	0.717	0.206	60	Terminal S	2020	Mediterranean	0.311	0.300	0.689
22	Terminal H	2019	Aegean	0.789	1	0.211	61	Terminal P	2021	Black Sea	0.308	0.241	0.692
23	Terminal G	2020	Black Sea	0.786	0.643	0.214	62	Terminal S	2019	Mediterranean	0.308	0.298	0.692

Table 2. *Efficiency ranking of terminals based on the minimax regret approach (continued)*

Rank	Code	Year	Region	Lower Bound	Upper Bound	Max. loss.	Rank	Code	Year	Region	Lower Bound	Upper Bound	Max. loss.
24	Terminal H	2020	Aegean	0.767	0.978	0.233	63	Terminal R	2018	Marmara	0.307	0.311	0.693
25	Terminal I	2019	Marmara	0.733	0.766	0.267	64	Terminal S	2018	Mediterranean	0.300	0.291	0.700
26	Terminal F	2019	Marmara	0.707	0.759	0.293	65	Terminal P	2019	Black Sea	0.298	0.229	0.702
27	Terminal J	2018	Marmara	0.706	0.579	0.294	66	Terminal T	2021	Aegean	0.269	0.193	0.731
28	Terminal C	2020	Mediterranean	0.700	0.724	0.300	67	Terminal U	2021	Marmara	0.257	0.249	0.743
29	Terminal G	2019	Black Sea	0.689	0.588	0.311	68	Terminal U	2018	Marmara	0.255	0.247	0.745
30	Terminal I	2018	Marmara	0.668	0.709	0.332	69	Terminal C	2018	Mediterranean	0.248	0.309	0.752
31	Terminal K	2021	Aegean	0.654	0.597	0.346	70	Terminal U	2019	Marmara	0.242	0.237	0.758
32	Terminal J	2020	Marmara	0.648	0.534	0.352	71	Terminal U	2020	Marmara	0.245	0.240	0.755
33	Terminal J	2021	Marmara	0.634	0.524	0.366	72	Terminal R	2019	Marmara	0.241	0.259	0.759
34	Terminal I	2020	Marmara	0.631	0.622	0.369	73	Terminal T	2020	Aegean	0.235	0.172	0.765
35	Terminal I	2021	Marmara	0.608	0.602	0.392	74	Terminal V	2018	Marmara	0.230	0.221	0.770
36	Terminal L	2019	Marmara	0.599	0.828	0.401	75	Terminal T	2019	Aegean	0.224	0.189	0.776
37	Terminal J	2019	Marmara	0.594	0.493	0.406	76	Terminal V	2019	Marmara	0.198	0.196	0.802
38	Terminal L	2021	Marmara	0.592	0.814	0.408	77	Terminal S	2021	Mediterranean	0.195	0.208	0.805
39	Terminal K	2020	Aegean	0.578	0.538	0.422	78	Terminal T	2018	Aegean	0.168	0.149	0.832

limit was added, and the upper limit was obtained. While determining the upper efficiency limit, the lower limit of the input values and the upper limit of the output values were used. To determine the lower efficiency limit, the upper limit data of the input values and the lower limit of the output were used. The generated interval data for each DMU are tabulated in Table 2.

3. Results and Discussions

Descriptive statistics of the inputs and outputs in the efficiency model are given in Table 1. The berth length and terminal area draw attention with high standard deviation values. It can be argued that some observed terminals adopt the clustering strategy and use mutual resources with others serving the same or different load types. Table 3 shows that all correlation coefficients between inputs and outputs in the model are statistically significant at the 5% level. In other words, the DEA technique can be used to measure the efficiency of observed DMUs because the significant positive relationship between the input and output variables shows that the data meet the isotonicity criterion [36].

Table 3. *Spearman rank correlation coefficients*

Input and output variables	(1)	(2)	(3)	(4)
(1) Cargo throughput (m)	1.000			
(2) Pier length (m)	0.249*	1.000		
(3) Storage area (Ha)	0.507**	0.327**	1.000	
(4) Handling equipment (unit)	0.378**	0.564**	0.320**	1.000
Spearman rho= 0.320, p>0.05: “*”, p>0.01: “**”				

The technical efficiency levels of 21 dry-bulk and general cargo terminals operating in Türkiye for 2018-2021 were evaluated using the interval DEA technique. The interval efficiency values were calculated as suggested by Wang et al. [34]. The obtained values were used to rank the terminals via the MRA from the most efficient to the least efficient, as shown in Table 2.

These findings imply that Terminal C is highly efficient for 2021. Terminal C, which attracts attention in the Eastern Mediterranean with its modern infrastructure, is equipped to handle all types of project cargo, besides solid bulk and general cargo. Terminal A, located in the Northern Black Sea, is one of the 18 most efficient terminals. The findings state that it will be highly efficient in 2018 and 2020. Terminal B

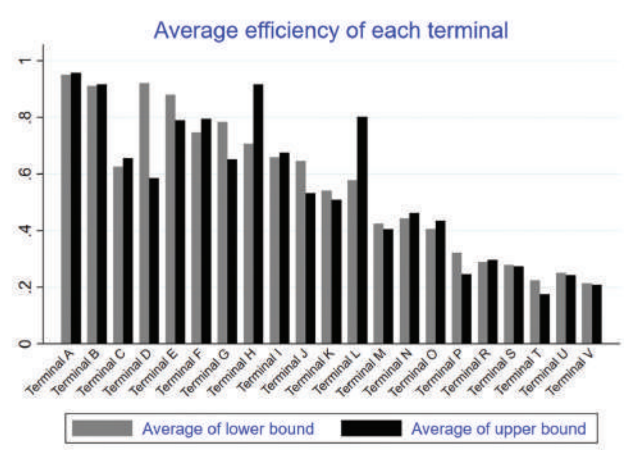

Figure 1. *The average efficiency levels determined by the average of the upper efficiency scores*

operating in the Black Sea draws attention to its efficiency level in terms of solid-bulk cargo and general cargo for 2019 and low-efficiency losses for other periods. Terminals T, S, and V were evaluated as the terminals with the lowest efficiency interval.

Figure 1 represents the average efficiency of each terminal. This figure illustrates that the average efficiency over the years is mainly related to the terminal rankings. Terminals D, H, and L have the highest range of their lower and upper efficiency bounds. This can be caused by high variation in the data of these terminals.

As seen in Figure 2, apart from the top four, the other terminals in the top ranking achieved a wider interval of efficiency than the other terminals in the lower ranks.

As shown in Figure 3, the efficiency levels of the terminals in the Marmara region have increased monotonically over the years. It has been observed that the increase in the efficiency level, which continued until 2020 in the Aegean region, started to decrease by 2021.

In a regional context, Balci et al. [14] evaluated the competitiveness and selection criteria of dry-bulk terminals in the Aegean region using MCDMM. The authors state that

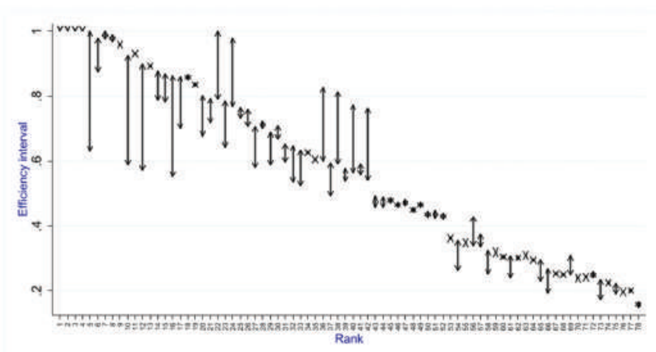

Figure 2. *Efficiency intervals of ranked terminals based on the minimax regret approach*

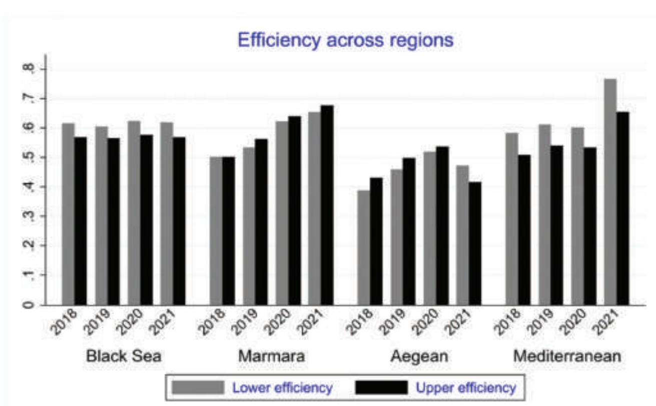

Figure 3. *Average efficiency levels across regions*

the terminals located in the Aegean region are located quite close to each other. Therefore, based on interval efficiency findings, the general cargo and dry bulk terminals in the Aegean region were adversely affected by the clustering strategies. On the other hand, a stable increment of efficiency levels in the Marmara region highlights the possible benefits of clustering triggered by high hinterland activities.

While the average efficiency level of the terminals in the Black Sea region remained stable over the years, it can be inferred that the Mediterranean terminals made a significant improvement in terms of technical efficiency in 2021. Cullinane and Song [38] and Jeh et al. [39] state that regional advantages such as proximity to transit routes positively affect the efficiency of terminals.

Yüksekyıldız and Tunçel [16] also applied the minimax-regret-based ranking approach [34] to rank the fuzzy efficiency intervals and found it beneficial while benchmarking the DMUs. The authors also calculated at five different α levels using Zimmermann's [37] set of α cut approach. Their study was based on container terminals. It can be argued that container terminals are more homogenous in terms of cargo specifications. However, general and dry-bulk cargoes differ substantially, especially in terms of handled cargo specifications.

Therefore, a possible explanation for the stable efficiency level of the general cargo and dry-bulk terminals located in the Black Sea might be the distance to the main routes. Moreover, the Black Sea terminals may suffer from being inland waters only accessible through the İstanbul and Çanakkale straits. Thus, it can be inferred that the findings are in alignment with the relevant literature.

For a dry-bulk terminal, to achieve optimum throughput, it is important that the infrastructure can support the storage capacity of the facility sufficiently [40]. The findings imply that there are significant infrastructure differences between clusters in the same region or geographical features. Moreover, as stated in Arslan et al. [41], an important issue is that the efficiency of supervision service varies depending on many factors, and these factors are connected with each other by a causal link. They stated that education and communication have an important place among the factors affecting the efficiency of cargo survey services.

4. Conclusion

Efficiency measurement using the standard DEA approach is too sensitive to data variations. The fact that the handling speed in dry-bulk and general cargo terminals also depends on many external factors, difficulties, and uncertainties to be experienced in obtaining the data reveals the necessity of blurring the crisp data. Therefore, the interval efficiency model, which is easily applicable, was preferred for efficiency measurement.

The efficiency model minimizes the inputs assuming that the terminal cannot increase the exogenous output. The ranking was made according to the maximum regret values obtained according to the interval efficiency analysis with the assumption of CRS production technology.

Although the interval efficiency model is practical and applicable, one of its limitations is that it can only be calculated according to the CRS assumption. In addition, with this approach, a good comparison cannot be made according to data categories because of specific terminal features and individual cargo types handled intensively in the terminals.

The efficiency levels of dry-bulk and general cargo terminals in the Marmara and Mediterranean tend to increase. It is concluded that the average efficiencies of the Black Sea terminals remain stable over the years, and the loss of efficiency in the Aegean region is noteworthy. While Aegean dry-bulk and general cargo terminals only serve their own hinterlands, fierce competition continues with rivals addressing the same hinterland. In other words, the demand is shared without any increase in potential cargo. Therefore, the transportation infrastructure and road/railway connection opportunities of private terminals, which are handicapped due to topographic reasons, need to be improved. In addition, solving the storage area problem, reducing the financial burdens on the terminals, and providing investment incentives to terminal operators can positively affect technical efficiency along with an increase in handling demand.

The differentiation of bulk solid and general cargo terminals among themselves draws attention as a critical downside of the study. Because of the nature of fuzzy DEA, similar decision units should be compared as much as possible. Although it is bulk, variability in the cargo type will result in more heterogeneity than handling standardized cargo. Therefore, the fuzzy cross-efficiency approach can be used for binary efficiency comparisons of general and bulk solid-liquid cargo terminals. Moreover, larger datasets pave the way for parametric stochastic approaches to evaluate efficiency.

In future studies, to fill the research gap of efficiency evaluations of liquid bulk, ro-ro terminals can be evaluated. The interval DEA model, which is stated to be more suitable for the complex structure of terminal operation processes than standard DEA, can yield new implications for efficiency and can be a guide for dry-bulk and general cargo terminal managers. Using the efficiency interval model, considering the production technology assumption of VRS in addition to CRS, we can draw inferences about scale efficiency. The interval efficiency approach can fill the gap in the relevant literature and contribute significantly to the literature for evaluating the efficiency of bulk solid and general cargo terminals when non-parametric methods are required in the case of imprecise data.

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Analysis of the Co-integration Between the Number of Cruise Tourists and the World Unemployment Rate

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Abstract

Cruise tourism has a great share in marine tourism and appears to be a fast-growing and income-generating sector in the travel industry. The cruise industry, which has a worldwide income of over 27 billion dollars, contributes to employment through the job opportunities it offers. The aim of this study is to analyze whether there is a short- and long-term co-integration relationship between the number of cruise tourists in the world and the world unemployment rate. In this context, data between 1991 and 2019 were analyzed using the Granger causality and vector error correction (VECM) methods. According to the results, there is an equilibrium relationship between the two series in the long term, a 1% change in the number of world cruise tourists reduces the world unemployment rate by 7.6%, and an imbalance between the two series in the short term will reach equilibrium after approximately three years.

Keywords: Cruise shipping, Marine tourism, Co-integration test, VECM analysis, World unemployment rate

1. Introduction

Because of technological developments in the world production of goods and services, labor-intensive production has been replaced by capital-intensive production. Although the growth and development of the market for a certain sector and its diversification with submarkets create opportunities for the labor market, unemployment, which occurs due to employment not increasing sufficiently compared with the population, negatively affects the economic and social situations of countries [1]. In this context, international marine tourism is one of the factors that affect countries' economic growth [2]. The marine tourism value chain consists of many varied factors and logistics processes, including accommodation, transportation, travel organizers, local tourism offices, ports, etc. [3,4].

Cruise tourism is one of the growing areas of marine tourism recently [5]. The economic effects of the cruise industry are shown in tourism, shipbuilding maritime enterprise, shipping agencies, tour agencies, ports, ship supply, and public revenues [6]. Cruise tourism is an economic activity that requires a range of services and facilities, including ports, hotels, restaurants, and tour operators, all of which can create jobs for local residents. In addition, the cruise industry employs many people, including crew members, entertainers, and administrative staff. These economic effects are directly related to the travel program. It is selected depending on the sea voyage and trip duration, port of departure, and tourist attractions included in the program, while optimal vacation periods in terms of geopolitical security and seasonality are also considered [7]. Cruise tourism in the world is concentrated in three main regions: the Caribbean, the Mediterranean, and Southeast Asia/Oceania and the sub-regions of Alaska, Scandinavia, South America, South Africa, Northwest Europe, Bermuda, Canary Islands, Hawaii, and the Indian Ocean Islands [8]. According to the Cruise Lines International Association (CLIA), the cruise industry supports over 1.2 million jobs worldwide and generates approximately $155 billion in economic activity annually. Therefore, the growth of cruise

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tourism can have a positive impact on the unemployment rate in countries where the industry operates, creating jobs and boosting local economies [9].

Studies by [10] and [11] state the direct and indirect economic effects of cruise tourism on destination ports. Direct economic effects are incomes from the activity and consumption of passengers and crew on land as well as the income received by local suppliers of cruise lines for provisioning port and ship services [10]. Indirect economic effects are the earnings produced by the purchases of consumables and services from local suppliers as well as by the increased consumption in the tourism area of influence caused by income growth generated by cruise tourist activities [12-14]. Consequently, this paper indicates that all of these economic activities impact world unemployment rates. Within this framework, the aim of the study is to observe the co-integration between the number of cruise tourists in the world (as an indicator of cruise tourism activity) and world unemployment using statistical analysis methods. In the period 1991-2019, the long- and short-term equilibrium relationship is evaluated between the number of tourists participating in cruise shipping in the world and the world unemployment rate. The reason why the research covers data since 1991 is that the popularity of cruise tourism has increased since the 1970s, it has become a mass market with a broader base, and there has been a noticeable increase in the number of passengers since the 1990s [15]. The reason why it is limited to 2019 is to prevent the temporary negative effects of the coronavirus disease-2019 (COVID-19) pandemic from causing deviations in the analyses. In this paper, the development of cruise tourism and the relationship between global economic activities and unemployment rates are given in the literature review. Datasets were evaluated using the Engle-Granger co-integration test and vector error correction (VECM) analysis to show the cointegration relationship between these variables. In this study, the co-integration relationship between cruise tourism, one of the important sub-branches of marine tourism, and the unemployment rate is revealed. It is thought that the results obtained will provide clues to researchers and guide future studies on the positive reflections of medium- and long-term investments on the workforce and economy for countries to obtain a larger share of cruise transportation.

Cruise tourism is a part of marine tourism activity called touristic sea travel by ship [16]. Albert Blain carried out the first passenger transportation in 1890, which is called cruise ship voyage Üçışık and Kadıoğlu [17], as cited in [18]. In the 1930s, cruise tourism started to develop in the world, especially with the enterprising of Germany. Rapid development in cruise tourism occurred after World War II within the economic development of Europe again. The increase in the number of passengers traveling in the cruise sector is an important indicator of the sector's growth [19]. The number of cruise passengers worldwide was 500,000 in 1970s, 22.04 million in 2014, 23.06 million in 2015 [20] and 27.8 million in 2019 [21]. In addition, the sector hit bottom in 2020 because of the COVID-19 pandemic [22].

Cruise tourism has direct, indirect, and induced effects on the economy. The direct effect is that goods and services are sold directly to cruise ships, passengers, and crew. Indirect effects result from direct suppliers purchasing goods from other companies. The induced effects arise from the expenditures of the parties whose income increases as a result of direct and indirect economic activities [13]. In the report published by CLIA (2018), the total employment created in direct proportion to the increase in cruise industry expenditures in Europe between 2012 and 2017 increased by 23% from 326.9 thousand to 403.6 thousand [23]. In this framework, the effect on total employment has increased since 2012 and is realized as an average of 4.3% per year. On the other hand, middle- and high-income tourists prefer cruise voyages, which are five-star floating hotels where comfort, luxury, and safety are prioritized [24]. These data show that cruise tourism stimulates economic activities and that there is a relationship between unemployment rates. To reveal the existence of this relation, a panel data analysis was conducted to determine whether there is a co-integration relationship between the number of cruise tourists travelled and the unemployment rate in the world.

A literature review shows that there are many studies on cruise tourism using panel data analysis. Bresson and Logossah [25] used panel data analysis to explain the relationship between accommodation tourism and cruise tourism in the Caribbean, revealing general trends. A 1% increase in the number of passengers arriving by cruise ships increased the per capita income of the cities by 3% [25,26]. The study by [27] focused on the determinants of cruise ships length of stay in port and the importance of the effects of length of stay in itinerary planning by collecting panel data on Japanese cruise ports. Accordingly, the cruise lines length of stay in ports is affected by the gross tonnage of the passenger ship, the number of passengers, the voyage distance from the previous port, the voyage distance to the next port, and the quality of the ship. Ahn [28] states that with panel data analysis, the cruise fleet built in the world increased by 0.3% when the world GDP increased by 1.0%, and the cruise fleet built in the world increased by 11.4% when the world maritime traffic increased by 1.0%. Bayat and Özdemir [29] measured the impact of transportation infrastructure and facilities on the turnover of businesses in the accommodation and food services sub-sector using panel data analysis. In this context, the number of cruise ships docking at the port impacts the turnover of businesses operating in the accommodation and food services sub-sector. Along with all these studies, no study on the subject of research has been encountered in the literature.

2. Methodology

The methodological framework of the study (see Figure 1) is based on three hypotheses (H1, H2, and H3) and data on the number of tourists participating in cruise voyages and the world unemployment rate between 1991 and 2019. H1 states that "there is a co-integration relationship between the number of tourists participating in cruise voyages around the world and the world unemployment rate". H2 states that "there is a long-term relationship between the number of tourists participating in cruise voyages around the world and the world unemployment rate". H3 states that "there is a short-term relationship between the number of cruise tourists participating in cruise voyages around the world and the world unemployment rate".

In accordance with the scope of the study, unit root tests of time series were performed with the Zivot-Andrews (ZA) unit root test and inverse unit root test of AR characteristic polynoma. The Engle-Granger cointegration test was applied for H_1 hypothesis and VECM analysis was applied for the H2 and H3 hypotheses in the EViews software [30]. Validity analysis with autocorrelation LM test and CUSUM test is performed for the outputs of the EG test and VECM analysis.

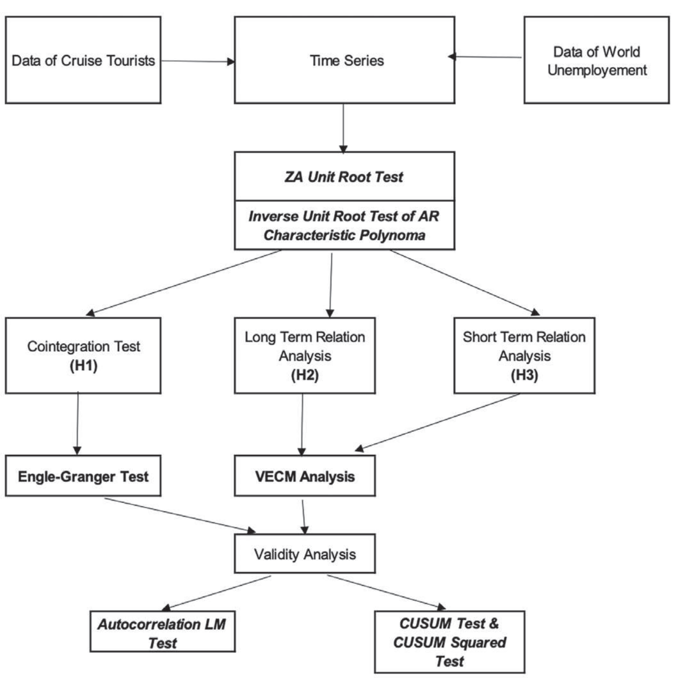

Figure 1. *Methodological framework of the study*

2.1. Unit Root Tests

The stationarity of the time series is evaluated with two types of root tests: unit root test and inverse unit root test. The unit root test is applied according to the methodology of Zivot Andrews, and the inverse unit root test is applied according to the methodology of AR Characteristic Polynoma.

2.1.1. ZA unit root test

The ZA Test is applied to evaluate whether the time series contains a unit root. The ZA test is based on the estimation of the regression equations. The t-statistics and the probability for the time series were calculated [31]. Probability values are calculated from a standard t-distribution and do not consider the breakpoint selection process.

2.1.2. Inverse root test of the AR characteristic polynoma

The inverse unit root test of AR characteristic polynoma is applied to the time series to observe the stability of the series.

2.2. Engle-Granger Co-integration Test

The Engle-Granger (EG) test is applied to evaluate the H1 hypothesis. The EG test is a widely used and easily implemented method in the field of econometry. "*Most importantly, the EG test shows a good size property. However, the power property of the EG test under the alternative can be an issue compared with other popular co-integration tests*" [32].

2.3. VECM Analysis

VECM analysis is applied for the long-term and short-term relation analysis between the time series of the world unemployment and number of cruise tourists, which is a widely used method in literature [33].

2.4. Data of the Study

Data for cruise tourists in the world between 1991 and 2019 are obtained from the World Bank [34], Organisation for Economic Co-operation and Development [35], and World Cruise Market [36]. Figure 2 shows the increase in the number of cruise tourists between 1991 and 2019.

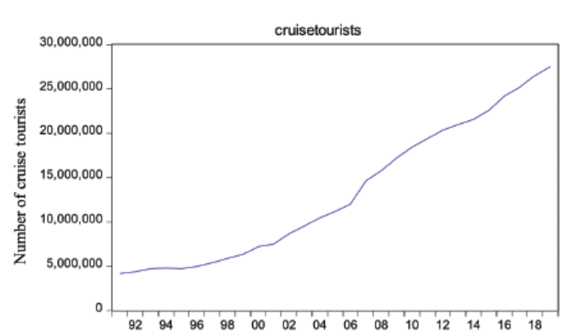

Figure 2. *Number of tourists who participated in cruise voyages around the world between 1991 and 2019*

A graph of the time series of world unemployment between 1991 and 2019 is shown in Figure 3.

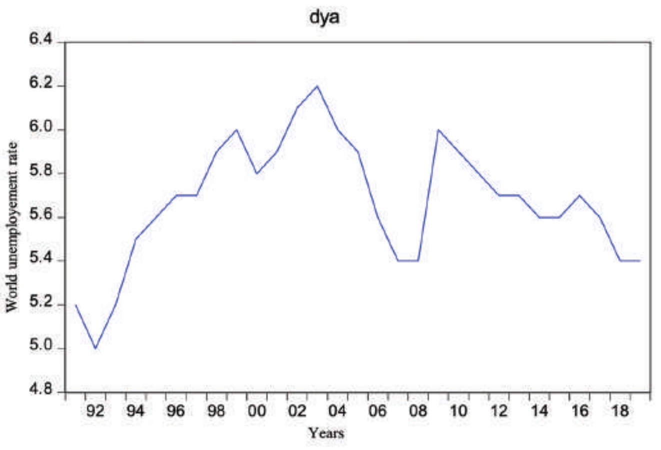

Figure 3. *World unemployment rate between 1991 and 2019*

3. Results and Discussion

Analysis of time series for the H1, H2, and H3 hypotheses according to the methodology given in Section 3 is performed. The optimal lag length of the time series is 1 according to Table 1.

3.1. Outputs of the ZA Structural Break Unit Root Tests for the Time Series

The Zivot-Andrews test, which is one of the structural break unit root tests, was applied to examine whether the series in the study contained a unit root. Probability and t-statistic outputs for the world unemployment time series are presented in Table 2.

The breakout time of the series regarding the world unemployment rate is seen in 2009 (see Figure 4). The t-statistic value is -6.719333 when considering the output measures in Table 2. This statistic value is less than the 1.5% and 10% critical values. The null hypothesis is rejected with error margins of 1.5% and 10% since the test statistic is t= -6.719333<1%; -5.34, 5%; -4.93% and 10%; -4.58%.

The ZA structural break test outputs of the series regarding the number of tourists participating in cruise travel between 1991 and 2019 are given in Table 3 and Figure 5.

The breakout time of the series regarding the number of cruise tourists is seen in 1997 (see Figure 5). When the table is examined, the ZA test statistical value was calculated as -5.370120. This stat value is less than the 1.5% and 10% critical values. The null hypothesis is rejected with error margins of 1.5% and 10% since the test statistic is t= -6.719333<1%; -5.34, 5%; -4.93% and 10%; 4.58%.

3.2. Outputs of the Inverse Unit Root Test of the AR Characteristic Polynomial for the Time Series

The outputs of the inverse unit root test of AR characteristic polynoma are given in Figure 6. The values in the circle indicate the stationarity of the series.

3.3. Outputs of the Engle-Granger Co-integration Test

The "Engle-Granger (Single-equation Co-integration)" test is conducted to determine whether there is co-integration between the number of cruise tourists and the world unemployment rate for the years of 1991-2019 (H1 Hypothesis). Table 4 shows the outputs of the EG co-integration test.

In the first stage of the EG co-integration test, the world unemployment rate is defined as the dependent variable and the number of cruise tourists is defined as the independent variable. Output measures of the test shows that tau= -4.625903 and probe <0.05. Consequently, H_0 hypothesis is rejected.

In the second stage of the EG co-integration test, the number of cruise tourists is defined as the dependent variable, and the world unemployment rate is defined as the independent variable. Output measures of the test shows that tau= -4.026428 and the probe <0.05. Consequently, the H_0 hypothesis is rejected [37].

In two conditions, the world unemployment rate and the number of cruise tourists are defined as dependent variables, the series have an equilibrium relationship in both cases. Consequently, both series are stated to be cointegrated [37]. The result of co-integration is in line with the direct and indirect economic impacts of cruise tourism on destination ports. As stated by Felde [38], revenue generated by cruise tourists and crew with the purchase of goods and services besides port income create a value chain as well as employment. Additionally, studies by [39,40] support the positive impacts of cruise tourism on employment rates.

3.4. Outputs of VECM Analysis

Dependent variable detection analysis is performed to assign the variables on long-term and short-term analysis (see Table 5). The probability value is meaningful at the

Table 1. *Optimal lag-length*

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-464.7474	NA	3.55e+12	34.57388	34.66987	34.60242
1	-377.6082	154.9142*	7.53e+09*	28.41542*	28.70338*	28.50105*
2	-374.7722	4.621640	8.26e+09	28.50164	28.98158	28.64435

1% level, as shown in Table 5. Consequently, the world unemployment rate is an accepted dependent variable for the analysis of Hypotheses H2 and H3).

3.4.1. Long-term relation analysis

The outputs of the long-term relation analysis for the H2 hypotheses are given in Table 6.

There is a significant long-term relationship between two series on four lag lengths (3.011086>1.96). In addition, the long-term relation equation is estimated with Equation 1 according to Table 6.

World Unemployment Rate (WUR)= -0.076130 x Number of World Cruise Tourists (NWCT) +2.992683(1)

Equation (1) shows that 1% increase in the number of world cruise tourists causes a decrease in WUR by 7,6130%. Although the coefficient is small, the number of cruise tourists in the world has an adverse effect on the world unemployment rate. These results show the notion that cruise tourism is a significant contributor to the global economy, providing jobs and generating revenue for many countries [41]. Additionally, the study by Arlı and Nemlioğlu [1] shows the impacts of world cruise tourist increase on the world female unemployment rate, in which a 1% increase in the number of world cruise tourists in the long term reduces the world female unemployment rate by 0.03531. In addition, in a study conducted on the sustainability of the cruise industry, considering the number of tourists, it is stated that in the long term, this industry can respond flexibly to external shocks and is in balance with the presence of an "invisible hand" [42].

3.4.2. Short-term relation analysis

The outputs of the long-term relation analysis for the H2 hypothesis are given in Table 6.

The evaluation should be done on the dependent variable first. The world unemployment rate is a dependent variable, the statistical value of CoinEq1 t is negative, and its absolute value is 2.37>1.96. Accordingly, the error correction model is meaningful and meets our expectations. In addition, an imbalance that may occur in the short term between the world unemployment rate and the number of cruise tourists will be balanced in the long term. The time of occurrence of the balance and the time period of the balance condition are estimated according to the coefficients in Table 7.

Based on the number of -0.369386, which is the coefficient of CoinEq1:

1/0.369386 = 2.707, which means that the two series will reach equilibrium after 2.707 periods. Because our data are annual, it is concluded that an imbalance between the two

Table 2. *ZA test outputs for the world unemployment time series*

Statistics	t-Statistic	Prob.*
Zivot-Andrews test statistic	-6.719333	0.003021
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

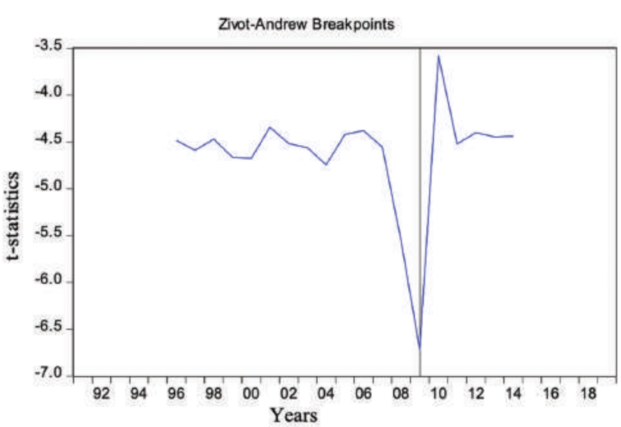

Figure 4. *ZA test statistics for the world unemployment series*

Table 3. *ZA test outputs for the time series of cruise tourists*

	t-Statistic	Prob.*
Zivot-Andrews test statistic	-5.370120	0.012369
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

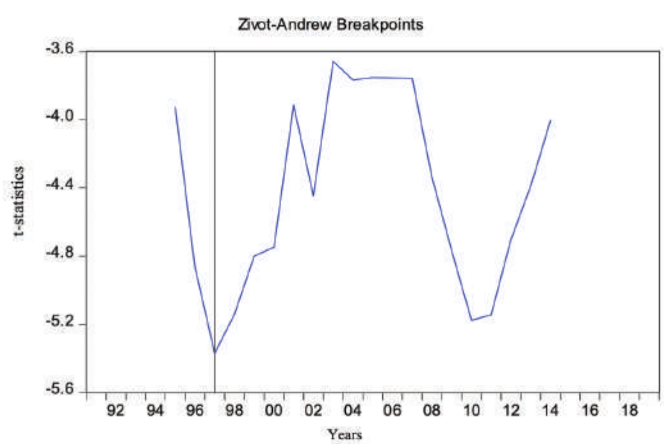

Figure 5. *ZA test statistics for the cruise tourists in the world*

Table 4. *Engle-Granger (Single-equation co-integration test)*

Dependent	tau-statistic	Prob.*	z-statistic	Prob.*
Unemployment	-4.625903	0.0052	-23.57834	0.0044
Cruise	-4.026428	0.0195	-20.87479	0.0124
*MacKinnon (1996) p-values				

series will stabilize after 3 years. Consequently, the short-term relationship between the variables can be considered after 3 years.

3.5. Outputs of the Autocorrelation Test

The Breusch-Godfrey Serial Correlation LM test was applied to determine whether there was autocorrelation between the series. The outputs of the test are presented in Table 8.

According to Table 8, there is no autocorrelation between the series because the Prob. values are greater than 0.05.

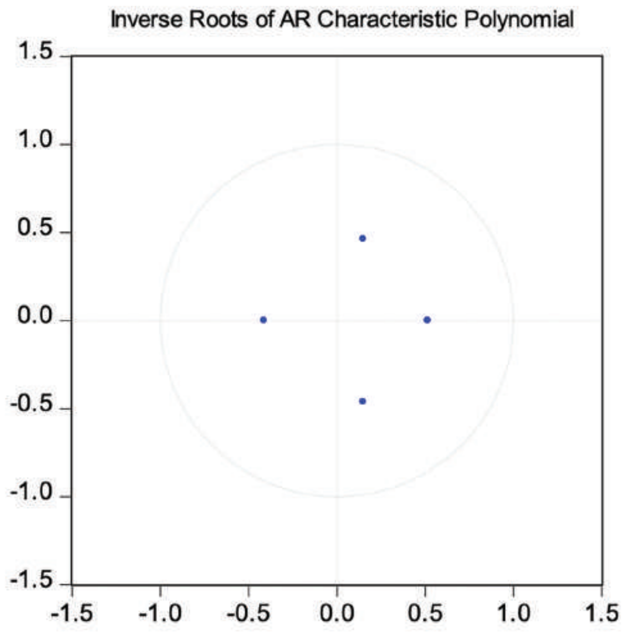

Figure 6. *Inverse unit root test of the AR characteristic polyoma*

Table 5. *Dependent variable detection analysis*

Cointegration Restrictions: A(1,1)=0	
Convergence was achieved after nine iterations.	
Not all co-integrating vectors are identified	
LR test for binding restrictions (rank=1):	
Chi-square (1)	10.91083
Probability	**0.000956**

Table 6. *Long-term relation analysis for the H2 hypothesis*

Co-integrating Eq:	CointEq1
LOGWUR(-1)	1.000000
LOGCT(-1)	0.076130
	(0.02528)
	[3.01086]
C	-2.992683

Table 7. *Short-term relationship analysis for H3 hypothesis*

Error Correction:	D(LOGWUR)	D(LOGCT)
CointEq1	-0.369386	-0.344921
	(0.15574)	(0.21865)
	[-2.37178]	[-1.57751]

3.6. CUSUM and CUSUM of the Squared Test

CUSUM and CUSUM of Squared tests were conducted to determine whether there was structural instability in all phases of the system between the two series. Figures 7 and 8 show the outputs of the tests.

There is no structural instability in all phases of the system between the world unemployment rate (dependent variable) and the number of cruise tourists in the world (independent variable), as shown in Figures 7 and 8. The CUSUM test outputs reveal that all of the findings are suitable for the analysis. These results guarantee the

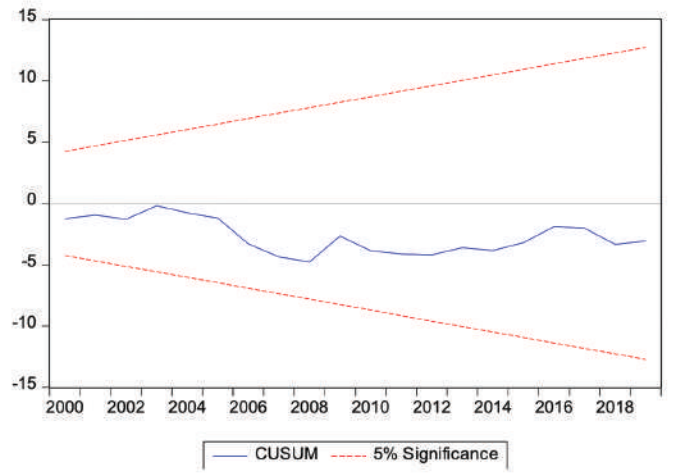

Figure 7. *Outputs of the CUSUM test*

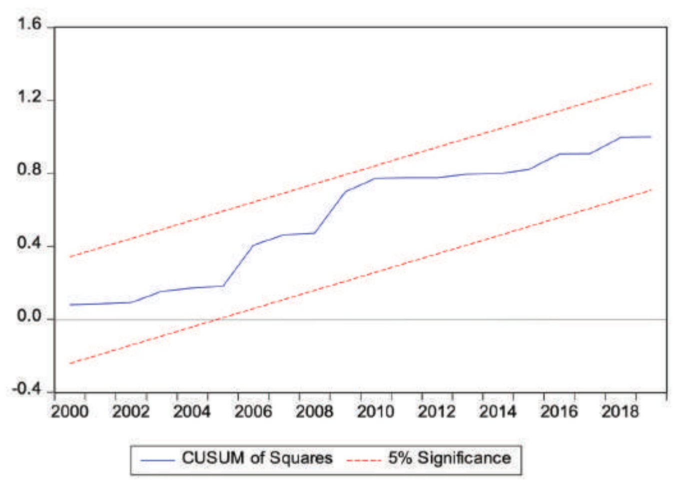

Figure 8. *Outputs of the CUSUM of squares test*

Table 8. *Breusch-Godfrey serial correlation LM test*

F-statistic	0.582468	Prob. F(4,22)	0.6785
Obs*R-squared	2.681328	Prob. chi-square(4)	0.6125

reliability of the long- and short-run estimates. The study by Shahbaz et al. [43] 2019 applied CUSUM and CUSUMsq tests to evaluate tourism-induced income distribution in Malaysia considering the number of tourist arrivals. Their results show that the test plots are between the upper and lower critical limits at 5%. Tourism (tourist arrivals, tourist receipts) improves income distribution by lowering income inequality [43]. Consequently, studies support that an increase in the number of tourists impacts economic issues positively in the world and local.

The aim of this study is to determine whether there is a co-integration relationship between the number of cruise tourists participating in cruise tourism (the factor that causes cruise travel service production) and the world unemployment rate. This study presents the EG co-integration test and VECM analysis for the number of cruise tourists in the world and the world unemployment rate in the period of 1991–2019. The H0 hypothesis is rejected for two different conditions of the variables: first, WUR is dependent and NWCT is independent, and second, NWCT is dependent and WUR is independent. It is observed that the variables have an equilibrium relation when both variables are dependent. Consequently, this study states that the time series of WUR and NWCT are co-integrated. According to Table 4, there is a bidirectional balance between the two series and they move together. In addition, the long-term co-integration equation obtained in Table 6 shows a negative co-integration relationship between the two series. According to the results obtained, 1% increase in the number of tourists participating in world cruise travel reduces the world unemployment rate by 7.6%. Additionally, the VECM analysis outputs for short-term relationships are statistically significant. Imbalance between the variables that may occur in the short-term reach equilibrium after approximately three years.

This study shows that the number of cruise tourist impacts on the world unemployment rate. Consequently, positive impacts and enterprises that increase cruise tourist numbers reduce the world unemployment rate. Considering the resulting relationship, it is recommended to diversify touristic areas and activities and support marketing activities by the public and private sector. According to the studies of Bresson and Logassah [25] and Ceyhan et al. [26], a 1% increase in the number of cruise passengers increases the per capita income of the current destination by 3%. In addition, compliance of port service quality with international standards is important for the satisfaction of visiting passengers. Dilek et al. [44] emphasized that ports should adhere to international standards to increase the share of countries in cruise tourism. Geopolitical conditions are also important for ensuring sustainability and achieving positive economic effects in cruise tourism as stated also by Ito et al. [7]. Therefore, policy makers are expected to make regulations according to geopolitical risks and operational risks.

4. Study Limitations

A limitation of this study is that the data were secondary instead of primary. This study used data on unemployment and the number of cruise tourists in the world for analysis as panel data. Additionally, world unemployment was only analyzed under the impact of the number of world cruise tourists. Furthermore, as stated in the studies by Görlich et al. [45], Güriş and Yaman [46], and Eser [47], macroeconomic indicators and socioeconomic variables are factors affecting unemployment, while Fakih et al. [48] focused on microeconomic causes of unemployment rate. Consequently, in future studies, macroeconomic indicators such as economic growth, inflation, exchange rate, interest rate, public expenditures, current account deficit, investment rates, budget deficit, savings rates, etc., as well as socioeconomic variables and microeconomic causes that affect unemployment can be included in the analyses to obtain outputs that depend on more variables.

5. Conclusion

This study forms the basis for researchers and guides future studies in terms of revealing the co-integration relationship between cruise tourism, one of the important sub-branches of marine tourism, and the unemployment rate. In this context, researchers who have reached the required amount of cruise ship panel data are recommended to conduct panel data analysis and compare the results. Also, all the above relation measures and literature show that the positive developments in cruise tourism cause positive outputs on the world economy. On the other hand, the outputs of the study show that cruise tourism is vulnerable to economic downturns and other external factors, such as natural disasters, pandemics, or geopolitical instability, which can lead to unemployment due to negative impacts on economic activity. Considering the direct and indirect economic impacts and overall outputs stated in this paper, a strategic approach for the development of cruise tourism is necessary in terms of the development of new cruise ship investments, new destination ports promoting the cultural, historical, and natural attractions of destinations, and the development of staff training levels, as global tourism and transport industry cruise tourism needs cooperation of countries with joint marketing campaigns. These strategies can be further developed in another scope of the study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept design: E. Arlı, and D. Ülker, Data Collection or Processing: E. Arlı, Analysis or Interpretation: E. Arlı, and M. S. Saygılı, Literature Review: M. S. Saygılı, and D. Ülker, Writing, Reviewing and Editing: E. Arlı, M. S. Saygılı, and D. Ülker.

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A Contemporary Analysis for COVID-19 Pandemic Related Port Congestion in Gemlik Region of Türkiye

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Abstract

Ports are vital global economic hubs that are essential for international trade. The coronavirus disease-2019 (COVID-19) pandemic has posed a significant challenge to ports worldwide, leading to congestion issues. Ships have faced extended waiting times because of heightened health protocols, resulting in increased costs and delayed deliveries. This study utilizes the ARENA simulation tool to analyze the pandemic's adverse impact on ship port times at a selected port. Weekly ship traffic data and port COVID-19 statistics from 2020 were collected. In 2020, prolonged ship operations and health protocol paperwork contributed to longer ship waiting times in queue. Notably, these delays occurred despite consistent labor and working hour management at the selected port. Average wait times surged from 0.157 to 17.33 min, while maximum waits skyrocketed from 0.285 to 74.977 h. This study underscores the importance of addressing pandemic-induced challenges in port operations.

Keywords: Port operation, COVID-19, Port congestion, System simulation, ARENA

1. Introduction

Ports are crucial components of global trade and commerce, serving as gateways for the movement of goods and people across international borders [1]. They play a vital role in facilitating international trade, supporting economic growth, and providing employment opportunities [2,3]. According to the United Nations Conference on Trade and Development-UNCTAD, approximately 80% of global trade by volume and over 70% of global trade by value are carried out through maritime transport, with ports serving as key hubs in the supply chain [4]. Effective port operations are therefore essential for ensuring the smooth flow of goods and reducing the overall cost of trade.

Port operations involve various activities, including cargo handling, vessel operations, customs and border control, security, and logistic coordination. These operations are typically complex and require careful planning, coordination, and execution to ensure timely and efficient delivery of goods [5]. However, the coronavirus disease-2019 (COVID-19) pandemic has had a significant impact on port operations worldwide, disrupting supply chains, reducing demand for certain goods, and increasing bureaucracy and trade costs. The pandemic has also highlighted the need for greater resilience and adaptability in port operations to cope with unexpected disruptions [6]. Therefore, the pandemic has presented several challenges for port operations [6-8].

- Reduction in the workforce: With the implementation of social distancing and quarantine measures, many port workers could not work, leading to a reduction in the workforce.

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• Disruptions to the supply chain: The pandemic disrupted the global supply cha in, affecting the flow of goods in and out of ports.

• Reduced and then dramatically increase cargo volumes: The pandemic has resulted in a decline in cargo volumes for a while due to decreased demand for goods and the closure of some businesses and then dramatically increase in cargo volumes overbuying.

• Increased health and safety measures: To prevent the spread of the virus, ports have had to implement strict health and safety measures, which have increased operational costs.

To mitigate the impact of COVID-19 on port operations, several measures have been implemented [9-12]:

• Adoption of technology: Ports have adopted technologies such as automation and remote monitoring to reduce the need for physical contact and minimize the risk of transmission.

• Collaboration: Port operators, shipping lines, and other stakeholders have collaborated to ensure the continuity of port operations and the smooth flow of goods.

• Implementation of health and safety measures: To prevent the spread of the virus, ports have implemented measures such as temperature checks, mandatory use of masks, and increased sanitation.

• Flexibility: Port operators have shown flexibility in their operations, allowing for changes in schedules and routes to accommodate disruptions to the supply chain.

In this context, system simulation has emerged as a useful tool for analyzing and optimizing port operations. The use of simulation tools such as ARENA can help port operators to model and test different scenarios, identify potential bottlenecks and inefficiencies, and optimize operations to enhance efficiency and resilience [13]. In this article, the authors explored the application of the ARENA simulation tool in the context of COVID-19 and its impact on port operations, as shown in Figure 1. We also highlighted the key issues and challenges faced by port operators and how simulation can help address them.

This study is structured in four sections. Section 2 covers materials and methods, including system simulation, modeling procedures of system simulation, data collection, and data analysis. Section 3 discuss and explains the results in the modelling environment for both pandemic and non-pandemic period and compare the results for pandemic period with non-pandemic period. Finally, section 4 deals with conclusions and discussion on the future research.

2. Materials and Methods

2.1. System Simulation

System simulation involves constructing computer models of real-world systems to analyze their responses in varying

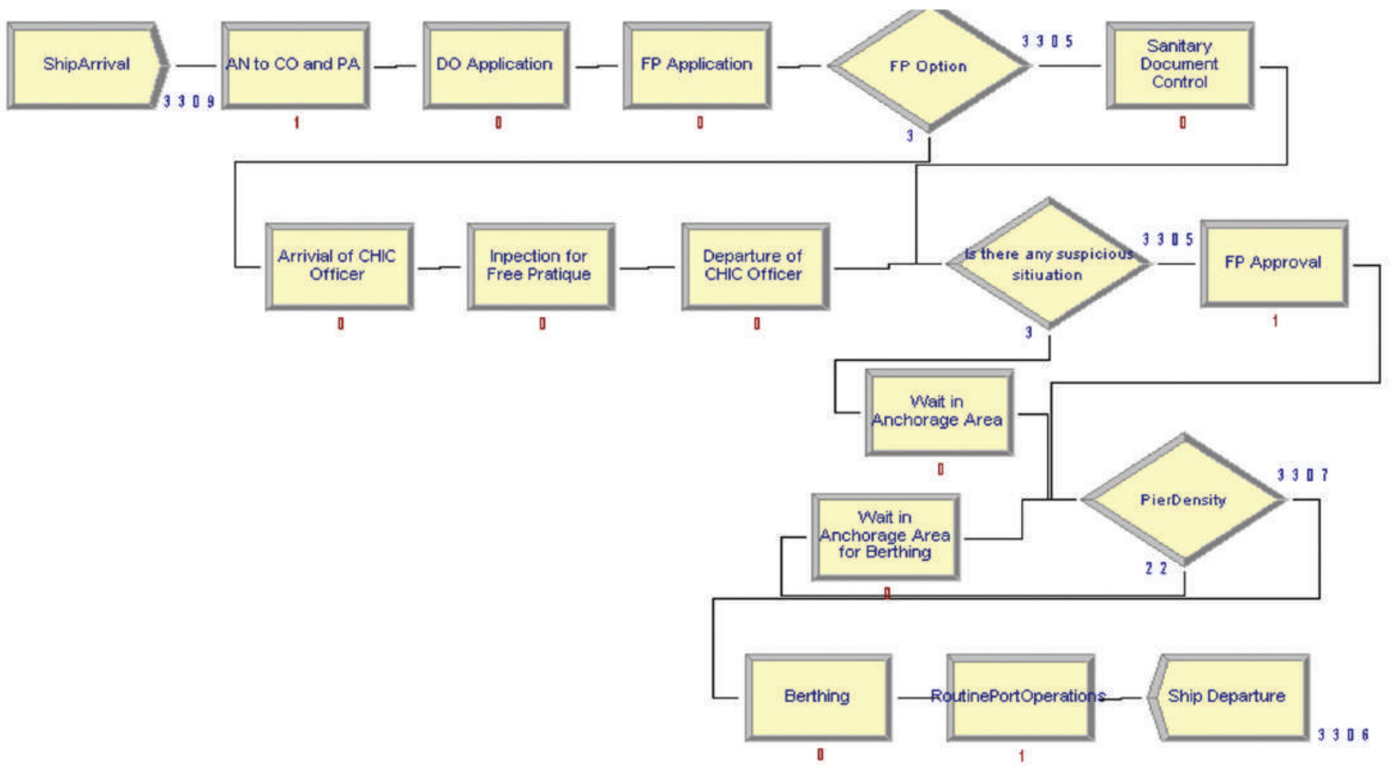

Figure 1. *System simulation model for port operations of ships under the effect of COVID-19 pandemic*

COVID-19: Coronavirus disease-2019

conditions [14]. These models are employed to study intricate systems in engineering, science, economics, and the social sciences. This procedure generally encompasses four core steps: formulation, simulation, analysis, and validation (Figure 2). In formulation, the system is depicted using mathematical equations, visuals, or other formal techniques. Simulation entails executing the model under diverse conditions and collecting behavioral data. Subsequently, data analysis provides insights into system behavior and identifies potential enhancements. The validation step entails comparing the model with real-world data to ensure accurate representation.

System simulation has extensive applications. For instance, engineering aids in comprehending intricate systems such as aircraft, vehicles, and structures, allowing engineers to refine designs and predict issues [15-18]. In the realm of science, it is used to explore phenomena such as weather, ecosystems, and disease spread [19-21]. In economics and social sciences, economics dissects market behavior, policy impacts, and group dynamics, aiding researchers in understanding and improving these systems [22,23]. System simulation also finds extensive applications within port operations and management. As per recent research findings, system simulation plays a pivotal role in the port industry, with a particular focus on container terminal operations, as evidenced by a substantial number of papers (166) [24]. Beyond container terminals, system simulation has been successfully applied to various facets of port operations, encompassing general port activities, port traffic management, bulk cargo terminals, and port congestion [24,25]. Notably, ARENA [26] emerges as one of the most commonly used software packages in these studies. For instance, numerous authors have employed the system simulation approach in Ro-Ro terminal operations to develop decision support systems [27], assess performance [28], and optimize container terminal equipment use [29]. This highlights the versatility and effectiveness of system simulation in addressing diverse challenges within the port industry.

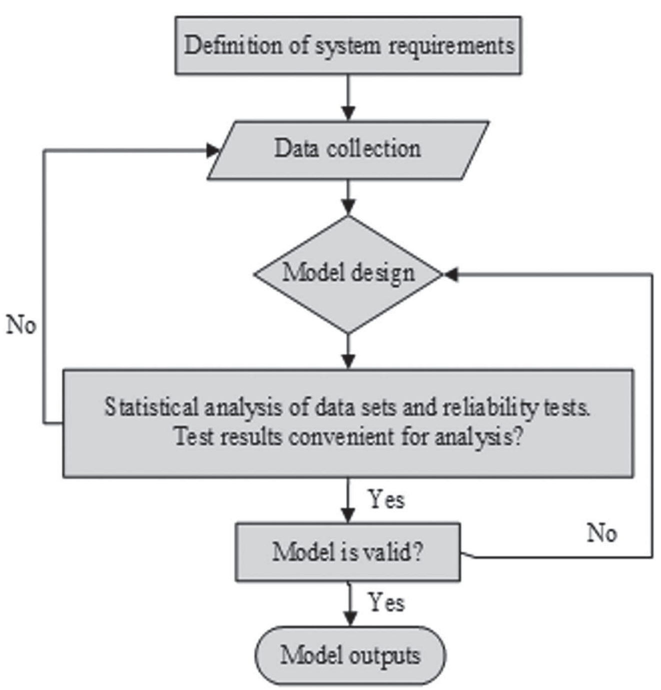

Figure 2. *The modelling procedures in system simulation approach [14]*

In essence, system simulation stands as a potent instrument to explore intricate systems and enhance their functioning [30]. Through the construction of computerized replicas of real-world systems, analysts can grasp their dynamics, devise enhancement approaches, and contribute to global betterment [31].

2.2. Data Collection

The effectiveness of system simulation models is constrained by the extent of information available in existing datasets regarding the problem's scope. It is imperative to elucidate the precise interactions among system components, considering their temporal sequences. This research addresses two key inquiries: firstly, the COVID-19 protocols implemented in ports, and secondly, their influence on port congestion resulting from prolonged ship waiting times or supplementary COVID-19 related procedures during ship operations. To determine the adopted COVID-19 protocols in ports, both domestic and international legal frameworks of ship and port operations were examined. To uncover the practical consequences of these protocols, a comprehensive data collection methodology was employed for the ports. The initial phase of this data collection process involves a thorough analysis by domain experts. During this phase, collaborative input from specialists at the port agency, coastal health inspection center, customs, and port authorities was used to define breakdowns in the ship berthing process. The port agency, coastal health inspection center, and customs experts contributed by delineating the workflow and processing timelines leading up to the ship's arrival at the port and its departure, while port specialists contributed insights into ship operational processes, including time spent during the berthing period (Table 1).

The second phase of the data collection process involves gathering data from the ship's Automatic Identification System to establish the count of ship arrivals at the chosen port. These data include the duration a ship remains anchored and berthed per week during both pandemic (2020) and non-pandemic (2019) periods. This information was sourced from Marine Traffic. The third phase of data collection revolves around the daily COVID-19 vaccination status of operators handling ship equipment such as ship to shore cranes and quay cranes at the selected port. These data were obtained from the occupational health and safety department of the port.

2.3. Data Analysis

Before initiating the investigation, experts indicated that the initial interaction between port agencies and ship officers involved the submission of pre-arrival information. Once the port agencies receive these pre-arrivals, a record is generated within 24 h before the ship's arrival. This record is established by aligning with the ship's estimated time of arrival in the port's single window system, overseen by the port authority (PA). After the notification from the PA, the port agent sends an arrival notice (AN) to the relevant customs office (CO), thus registering the ship's impending arrival in the port's single window system. Upon reaching the port area, an application for a delivery order (DO) is submitted, and subsequently, a request is forwarded to the General Directorate of Health for Borders and Coasts (CHIC) to obtain approval for "free pratique" (FP). A dedicated officer from the coastal health inspection center evaluates the ship's health-related documents. This evaluation leads to the granting of "free pratique" as long as the ship is determined to pose no health risks after the sanitary assessment. Although regulations in Türkiye dictate that all ships must undergo physical sanitary control (either at berth or anchorage) to attain FP in ports around Turkish waterways, practical limitations, such as a shortage of health officers, often result in the reliance on sanitary documents for this process. As reported by experts, this procedure typically takes around 3 h from the AN to the approval of FP. However, if the ship arriving at Turkish ports has encountered difficulties in terms of sanitary control during previous port experiences, a physical inspection of the ship is conducted regardless. This shifts the process from solely document-based scrutiny to a comprehensive physical examination, causing the time required to increase from 3 h to an average of 9 hours, even if no suspicious circumstances are detected. In cases where a suspicious situation arises, the ship is anchored and subjected to a 14-day waiting period. Once this entire process concludes, the ship becomes eligible to start its loading and unloading operations.

Based on thorough expert analysis, the average durations required for various stages within the process have been determined. These stages encompass the intervals from AN to CO and PA, the application for DO and FP, the control of sanitary documents, the arrival of a CHIC officer to the ship, the inspection for FP, the departure of the CHIC officer from the ship, and the approval of FP. The respective durations are 45, 30, 45, 60, 150, 30, 150, and 30 minutes, as detailed in Table 2. When examining the collected datasets for the

Table 1. *Expert profile*

Expert	Education	Experience
Port agency officer	Bachelor`s degree	4 years
Coast health inspection center officers	Bachelor's degree	10 years
Custom officer	Bachelor`s degree	12 years
Port officer	Bachelor`s degree	10 years

years 2019 and 2020, the weekly average ship arrivals were calculated to be 61.5 for 2019 and 57.3 for 2020. The total number of ships recorded was 3490 for 2019 and 3308 for 2020, all within the designated Gemlik region. Using the Arena Input Analyzer tool, an analysis of these weekly ship arrival datasets from 2019 and 2020 led to the identification of mathematical functions, which are outlined in Table 2. Given the necessity for precise timestamps within the context of system simulation, similar processes were applied to datasets related to other components, such as routine port operations and waiting times during anchoring and berthing. The derived mathematical functions for these components were synthesized through analogous procedures applied to ship arrival datasets and are also summarized within Table 2.

As an illustrative instance of this data analysis methodology, the authors selected the berthing time spans of 844 distinct vessels that arrived at the designated port between the years 2019 and 2020 (refer to Table 3). By employing the Arena Input Analyzer, the authors derived the mathematical function provided in Table 3 to encapsulate this data. The results of the statistical analysis conducted in the Arena Input Analyzer emphasized that the most suitable distribution model is the Erlang distribution. The mathematical representation derived for the dataset is 14.5 + ERLA(6.89, 3), with a corresponding p-value from the chi-square test being less than 0.005.

3. Results and Discussion

The COVID-19 pandemic has brought about adverse consequences across various facets of the supply chain, including ports. One of the most notable among these negative impacts has been a reduction in the frequency of port calls during the initial stages of the pandemic. During data analysis, it was observed that the summary statistics for ship arrival rates in the non-pandemic year (2019) and the pandemic year (2020) were 3490 and 3308, respectively. This indicates a decline of 5.2% in the number of port calls compared to the previous year. Another significant detrimental effect involves an escalation in operational timeframes and bureaucratic processes within shipping operations. This study delves into a comprehensive exploration of these negative impacts on ship-port

Table 2. *Arena input analyzer results for mathematical functions of datasets*

Variable	Distribution	Mathematical function	Time unit
Ship arrival for 2019 year	Exponential	2 + EXPO(0.842)	Day
Waiting in anchoring (berthing) for 2019 year	Normal	NORM(0.348, 0.178)	Day
Routine port operation for 2019 year	Lognormal	0.47 + LOGN(0.16, 0.104)	Day
Ship arrival for 2020 year	Lognormal	2.1 + LOGN(0.924, 0.6)	Day
Waiting in anchoring (berthing) for 2020 year	Lognormal	0.1 + LOGN(0.391, 0.213)	Day
Routine port operation for 2020	Normal	NORM(0.67, 0.0843)	Day
AN to CO and PA	Constant	45	Minute
DO Application	Constant	30	Minute
FP Application	Constant	45	Minute
Sanitary Document Control	Constant	60	Minute
Arrival of CHIC officer to ship	Constant	150	Minute
Inspection of the Free Pratique	Constant	30	Minute
Departure of the CHIC officer from the ship	Constant	150	Minute
FP approval	Constant	30	Minute
Waiting in the anchorage area due to health risk	Constant	14	Day
Berthing	Erlang	14.5 + ERLA(6.89, 3)	Minute

Table 3. *An example of the berthing time periods of 844 different ships in the selected Gemlik region and an appropriate mathematical function for these time periods*

Process	Berthing period of each ship	Mathematical function
Berthing	40, 30, 65, 65, 20, 40, 20, 55, 40, 35, 40, 35, 25, 25, 30, 30, 35, 25, 75, 22, 35, 32, 33, 35, 28, 38, 50, 30, 20, 30, 15, 35, 25, 45, 55, 40, 30, 33, 28, 30, 25, 35, 20, 49, 55, 27, 32, 27, 25, 30, 55, 30, 22, 35, 45, 25, 25, 35, 33, 47, 27, 75, 25, 35, 30, 40, 25, 35, 35, 36, 45, 35, 45, 30, 40, 25, 35, 47, 27, 37, 30, 33, 33, 45, 35, 45, 40, 35, 37, 30, 55, 35, 30, 35, 30, 25, 60, 30, 35, 45, 32, 30, 34, 30, 18, 105, 105, 40, 45, 20, 38, 30, 30, 29, 20, 19, 23, 30, 25, 40, 40, 40, 25, 30, 45, 40, 50, 33, 30, 27, 53, 30, 25, 30, 20, 37, 50, 39, 27, 33, 35, 15, 30, 30, 35, 55, 30, 33, 25, 28, 19, 15, 41, 35, 42, 25, 30, 31, 45, 25, 45, 40, 35, 25, 25, 25, 30, 35, 65, 45, 52, 25, 30, 20, 35, 50, 35, 45, 36, 26, 30, 30, 25, 45, 34, 20, 25, 25, 35, 30, 20, 25, 25, 25, 30, 40, 30, 30, 25, 31, 52, 45, 30, 65, 34, 30, 25, 30, 32, 25, 30, 65, 25, 45, 35, 51, 30, 28, 20, 35, 25, 39, 15, 30, 42, 40, 30, 35, 65, 40, 31, 30, 35, 45, 48, 58, 30, 45, 25, 45, 49, 25, 25, 25, 45, 40, 35, 55, 24, 29, 37, 25, 25, 30, 20, 43, 33, 18, 25, 15, 57, 30, 37, 20, 30, 48, 45, 50, 35, 30, 56, 38, 39, 36, 27, 52, 35, 35, 33, 25, 30, 28, 64, 40, 27, 25, 70, 20, 35, 20, 70, 39, 30, 40, 35, 25, 35, 30, 15, 20, 30, 40, 31, 35, 24, 30, 40, 32, 30, 30, 26, 40, 30, 45, 40, 30, 65, 50, 38, 25, 30, 25, 45, 30, 45, 45, 36, 40, 25, 25, 30, 40, 50, 60, 47, 35, 28, 20, 38, 35, 28, 65, 45, 33, 20, 42, 33, 20, 55, 30, 55, 30, 40, 25, 28, 42, 35, 45, 15, 38, 25, 35, 28, 20, 30, 30, 25, 30, 42, 25, 35, 49, 30, 27, 40, 30, 30, 33, 35, 35, 23, 28, 33, 30, 20, 45, 42, 30, 40, 32, 40, 20, 30, 40, 30, 95, 25, 90, 20, 45, 35, 33, 46, 28, 37, 25, 30, 45, 75, 29, 35, 20, 24, 60, 38, 50, 45, 35, 50, 35, 35, 35, 40, 35, 32, 25, 17, 22, 51, 47, 25, 18, 20, 37, 45, 30, 33, 25, 45, 22, 39, 25, 30, 25, 30, 30, 18, 25, 25, 35, 30, 25, 30, 40, 30, 78, 25, 30, 41, 30, 55, 50, 23, 30, 38, 40, 25, 60, 25, 35, 36, 45, 32, 30, 55, 30, 55, 40, 38, 35, 45, 25, 40, 39, 30, 60, 45, 30, 36, 40, 36, 20, 30, 38, 30, 30, 25, 30, 75, 40, 30, 45, 35, 45, 40, 60, 30, 35, 38, 20, 22, 45, 35, 48, 20, 30, 60, 15, 45, 42, 33, 25, 35, 38, 30, 20, 30, 30, 30, 40, 28, 25, 20, 25, 25, 42, 30, 35, 30, 25, 55, 35, 25, 40, 35, 50, 25.	14.5 + ERLA(6.89, 3)

interactions, seeking to elucidate their intricacies and investigating potential avenues for mitigation. To achieve this goal, the researchers employed the ARENA simulation tool, focusing on a specific port within the Gemlik region of Türkiye. Two distinct simulation models were devised for the non-pandemic year (2019) and the pandemic year (2020). To validate the accuracy of these simulation models, key performance indicators derived from system simulations within ARENA were juxtaposed against the existing data for ship arrivals and departures. According to the results obtained from the ARENA models, for the year 2019, the system yielded 3490 ship arrivals and 3488 departures, while for 2020, there were 3309 arrivals and 3306 departures. Notably, the number of arrivals closely matched the existing port statistics for both years, affirming the alignment between the developed ARENA models and the actual data. Similarly, the number of departures exhibited a high degree of concurrence. These outcomes underscore the robustness of the ARENA simulation models for the years 2019 and 2020, substantiating their effectiveness in accurately representing the dynamics of the port system under both non-pandemic and pandemic conditions.

In the context of system simulation, the selection of sufficient replications is vital to ensure the construction of confidence intervals around the desired output variable. While sometimes 3 to 5 replications can yield accurate confidence intervals, at other times, this range might prove insufficient. In the present study, we experimented with different replication numbers spanning from 1 to 10 and determined that all these replication numbers yielded identical ship departure figures within the developed simulation models. Once the optimal replication number was identified, the simulations were executed.

The simulation outcomes distinctly reveal the existence of a single queue, specifically within routine ship seaport operations for 2019. This value, translating to an average of 0.00483872 days or 6.97 minutes, and a maximum of 0.00541721 days or 7.8 min of waiting within a day. However, for the year 2020, this figure increased to an average of 0.00603184 days or 8.69 minutes, and a maximum of 0.00768511 days or 11.07 minutes, despite a reduction in total ship arrivals from 3490 to 3308 compared to the prior year. Additionally, the pandemic-related procedures, encompassing tasks like sanitary document control and ship sanitary inspections (including the departure of CHIC officers, FP approval, and anchorage wait due to suspicious situations), contribute to the waiting times. For sanitary document control, the average waiting time is 0.157 min (0.00010880 days) with a maximum of 0.285 min (0.00019795 days). Meanwhile, the average waiting time due to ship sanitary inspection is 17.33 minutes, with a maximum of 74.977 h. The daily count of waiting instances in the queue for routine seaport operations increased to an average of 0.05465012 for the year 2020, while it stood at 0.04626153 for the year 2019 (as presented in Table 4).

During the pandemic period, the daily count of instances of waiting within the queue has risen to an overall average of 0.00432285 and a maximum of 0.04985302. The use of three primary resources is crucial: port agent personnel, CHIC officers, and the seaport ship handling team, which encompasses QC operators. When accounting for port agent personnel numbering three individuals, operating in three shifts each lasting 8 h per day, the workload translates to an average of 0.7965 person-days for 3490 ships in the year 2019, and an average and maximum of 0.7550 person-days for 3308 ships in the year 2020. This indicates that the workload per ship for port agent personnel remains nearly consistent both in the years 2019 and 2020 (as outlined in Table 5).

Within the Gemlik region, there are three CHIC officers assigned to seaport operations. They operate in three shifts, each spanning 8 h per day. On average, each CHIC officer dedicates approximately 59.78% of their daily working hours (equivalent to 0.5978 daily resource usage) to seaport operations during the year 2019. This value averages 0.5685 and reaches a maximum of 0.5695 in 2020. The daily resource usage of 0.5978 is relevant for the handling of 3490 ships, while the value of 0.5685 pertains to 3308 ships. If the seaport had managed 3490 ships in the year 2020, the daily resource usage for CHIC officers, assuming consistent performance, would average 0.5998 and peak at 0.6008. The authors aimed to assess the influence of the COVID-19 pandemic on the seaport workforce, specifically targeting seaport crane operators. Insights were gathered with the collaboration of experts from multiple Turkish seaports. Some informants disclosed that certain seaports had reduced their daily shift count from 3 to 2 due to an increase in COVID-19 symptoms among operators, which resulted in a shortage of available operators on specific days. In contrast, in the Gemlik region, the shift size remained constant (3 shifts of 8 h each) throughout both pandemic and non-pandemic periods, although overtime

Table 4. *Average waiting time in queue for 2019 and 2020 years*

Process in the simulation model	2019 year	2020 year
Berthing	-	0.00004687
Departure of the CHIC officer	-	0.0417
FP approval	-	0.00024714
Routine port operations	0.00483872	0.00603184
Sanitary document control	-	0.00010880
Wait in the anchorage area for berthing	-	0.01104203
Wait in anchorage area due to suspicious situation	-	0.8389

Table 5. *Average number of waiting time in queue for 2019 and 2020 years*

Process in the simulation model	2019 year	2020 year
Berthing	-	0.00042465
Departure of CHIC Officer	-	0.00037701
FP approval	-	0.00223798
Routine port operations	0.04626153	0.05465012
Sanitary document control	-	0.00098493
Wait in the anchorage area for berthing	-	0.00072293
Wait in anchorage area due to suspicious situation	-	0.00942173

work was adopted when necessary. This study treated each crane operator assigned to a ship as part of the seaport ship handling team. The authors analyzed the daily usage of the ship handling team within the seaport. Results revealed that this usage value amounted to an average of 0.8590 for 3488 ships served (number out value) in the year 2019, and an average of 0.8671, reaching a maximum of 0.8691 for 3306 served ships (number out value) in the year 2020 (see, Table 6).

Table 6. *Resource usage (number of busy) for 2019 and 2020*

Process in the simulation model	2019 year	2020 year
Port agent personnel	0.7965	0.7550
CHIC officer	0.5978	0.5682
Port ship handling team	0.8590	0.8671
Tugboat	0.2336	0.2215

4. Conclusion

This study was conducted to examine the adverse impact of the COVID-19 pandemic on ship operation durations through the use of the ARENA simulation tool. The developed Arena model was employed to analyze a specific seaport situated within the Gemlik region. The outcome of the data analysis revealed that the number of ship arrivals amounted to 3490 in 2019 and 3308 in 2020. This considerable decrease, as compared to the prior year, underscores the evident decline in port calls. Moreover, the study findings indicated that out of the 3490 ships that arrived in the year 2019, 3489 successfully completed their seaport operations, leaving only 1 ship awaiting processing in the queue. System simulation results highlighted that, in the year 2019, ships experienced an average waiting time of 6.97 min and a maximum waiting time of 7.8 min per day. However, in the year 2020, these waiting times increased to an average of 8.69 min and a maximum of 11.07 minutes, despite the reduced number of ships compared to the previous year. This can be attributed to the prolonged ship operation durations and increased administrative tasks brought about by the pandemic. Particularly noteworthy is the observation that the preparation of sanitary documents and ship sanitary inspections, which took precedence under COVID-19 health guidelines, led to significant waiting times. When calculating the waiting times linked to sanitary document control and ship sanitary inspections, substantial differences were identified in both average and maximum durations. Specifically, the average waiting time increased from 0.157 min during the non-pandemic period to 17.33 min during the pandemic period, and the maximum waiting time surged from 0.285 min to an extensive 74.977 h. The study also focused on evaluating the performance of three core labor resources involved in seaport operations: port agent personnel, CHIC officers, and the seaport ship handling team, which includes QC operators. The analysis period assumed a workforce of three individuals working eight-hour shifts in three rotations. While numerous seaports necessitated a reduction in shift sizes and an extension of working hours per individual due to an abrupt surge in labor demands caused by COVID-19 cases among workers, the chosen port management asserted that shift sizes and daily working hours remained relatively unchanged from the non-pandemic period. The study's findings align with the seaport manager's report, revealing that the selected seaport did not require additional personnel, modified shifts, or extended overtime for workers. However, considering that the number of port calls had not diminished compared to the preceding year, the selected seaport might have had to consider increasing personnel numbers, adjusting shift sizes, or incorporating overtime if the decrease in port calls had been more pronounced. Even though this study has provided valuable insights into the impact of the COVID-19 pandemic on ship operation durations and seaport operations, the recommendations presented here may benefit from further elaboration. To address this concern, it is essential to delve deeper into both theoretical and practical aspects of the proposed strategies. Theoretical enhancements can involve conducting in-depth research into the development of crisis management protocols tailored specifically to seaport operations during pandemics. This may include exploring best practices from other industries facing similar challenges. Additionally, a comprehensive review of relevant literature and case studies should be conducted to provide a robust theoretical foundation for the suggested measures. On the practical front, future research efforts should focus on implementing and testing the proposed strategies in real-world seaport scenarios. Collaborative initiatives with seaport authorities and relevant stakeholders could offer valuable insights and data for practical assessments. Furthermore, the use of advanced digital technologies, such as IoT (Internet of Things) and AI (Artificial Intelligence), to streamline administrative tasks and optimize seaport operations should be explored in depth.

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Ship-Generated Waste Management in İstanbul Ports: An Analytical Methodology to Evaluate Waste Reception Performance (WRP)

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Abstract

Ship-generated pollutants constitute a significant portion of marine pollution, prompting the International Maritime Organization to regulate this issue. European countries have also adopted the 2000/59/EC directive on port reception facilities, and environmental performance indicators have gained prominence in European ports. This study examines two ports, Ambarlı and Haydarpaşa, located in İstanbul, Türkiye, a European Union candidate country. The research compares port size and computes their waste reception performance (WRP) indices: ship-based WRP, waste-type-based WRP, and waste-amount-based WRP. Additionally, statistical analysis with the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U tests are applied to observe the relation between the number of ships and waste reception amounts. This study enhances ship-generated waste management using port performance indicators to mitigate pollution. The performance indices reveal that although Ambarlı's port size is larger than that of Haydarpaşa, the WRP of Haydarpaşa is significantly larger than that of Ambarlı. This difference can be attributed to the greater waste volume generated by general cargo ships compared with container ships. Given the differences between terminal types, it is evident that there is no "one size fits all" policy approach, and mitigation strategies need to be tailored to the characteristics of each port.

Keywords: Marine pollution, Port reception facilities, Ship-generated pollution, Waste management, MARPOL

1. Introduction

Marine pollution, a consequence of human activities, has precipitated significant ecological damage, hindering marine ventures such as fishing, imperiling human health, and curtailing recreational prospects [1]. Various factors contribute to this dilemma, from land-based pollutants to maritime endeavors [2-6]. Of these, maritime activities stand out, being responsible for almost 20% of global marine waste discharge [7]. As these activities intensify, the imperative to devise sustainable environmental management strategies becomes evident, compelling ports to augment their performance [8].

Driven by the sheer magnitude of maritime transport, with over 100,000 ships crisscrossing global waters [9], the marine environment has been inundated with a myriad of pollutants, ranging from oily residues and sewage to plastics and cargo residues [10]. Historically, these wastes were either discarded into the vastness of the seas or incinerated onboard. However, the tide turned with rising environmental concerns, compelling the International Convention for the

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Prevention of Pollution from Ships (MARPOL) to implement stringent waste reception guidelines [11]. Specifically, Annex V of this convention categorizes and imposes stringent limitations on various forms of ship-generated waste, as detailed in Figure 1. Certain disposals, under specific conditions, remain feasible, particularly in the waters of the Sea of Marmara (SoM) [11]. This paradigm shift is not just international; the European perspective on ship waste has similarly evolved. By 2020, ship waste had risen to the 6th position in environmental priorities as green port parameters, marking an increase from its 10th position in 2004 [12-15]. Notably, two studies that examined Turkish ports [16,17] revealed a distinctive emphasis on waste management as a crucial criterion for attaining green port status, surpassing the level of importance assigned to this criterion in European ports. Reinforcing this sentiment, the European Community introduced Directive 2000/59/EC, which endorses dedicated waste reception facilities in ports [18]. Riding this wave of environmental reform, countries, including Türkiye, have adjusted their marine waste disposal strategies to align with MARPOL and EU directives, as exemplified by Türkiye's embrace of the online Ship Waste Tracking System (GATS) for methodical ship waste declarations [19-21].

The narrative turns pressing when focusing on the SoM, especially when considering adverse events such as marine litter and alarming mucilage occurrences [22-26]. This study concentrates on its lens to two of SoM's ports, Ambarlı and Haydarpaşa, proposing a novel methodology for indices that evaluate ports' WRP. This initiative is aimed at monitoring, assessing, and mitigating ship-generated waste impact in the SoM, thereby contributing to its sustainable management. As the marine traffic, predominantly international, heightens its imprint on the region's pollution, the findings of this research will prove instrumental in charting a course for an environmentally sound maritime sector in the SoM.

In the subsequent sections, we will unpack the prevailing studies in our literature review, delineate our investigative approach in the methodology, probe into the specifics of Ambarlı and Haydarpaşa Ports in our case study, and conclude with insights and recommendations.

2. Literature Review

Ship-generated waste is a significant environmental concern in the domain of port reception facilities. Discharging waste at sea is highly undesirable, and port reception facilities are critical for preventing marine pollution [27]. Prior to the work of Carpenter and Macgill [28] on North Sea ports, port reception facilities were defined as one or more fixed, mobile, and/or floating facilities and could be categorized based on ownership type, operational changes, and contract rules. All of these measures are aimed at ensuring a significant reduction in marine pollution by providing adequate waste reception facilities [27]. The increasing complexity of maritime activities, coupled with their inherent environmental repercussions, has led to

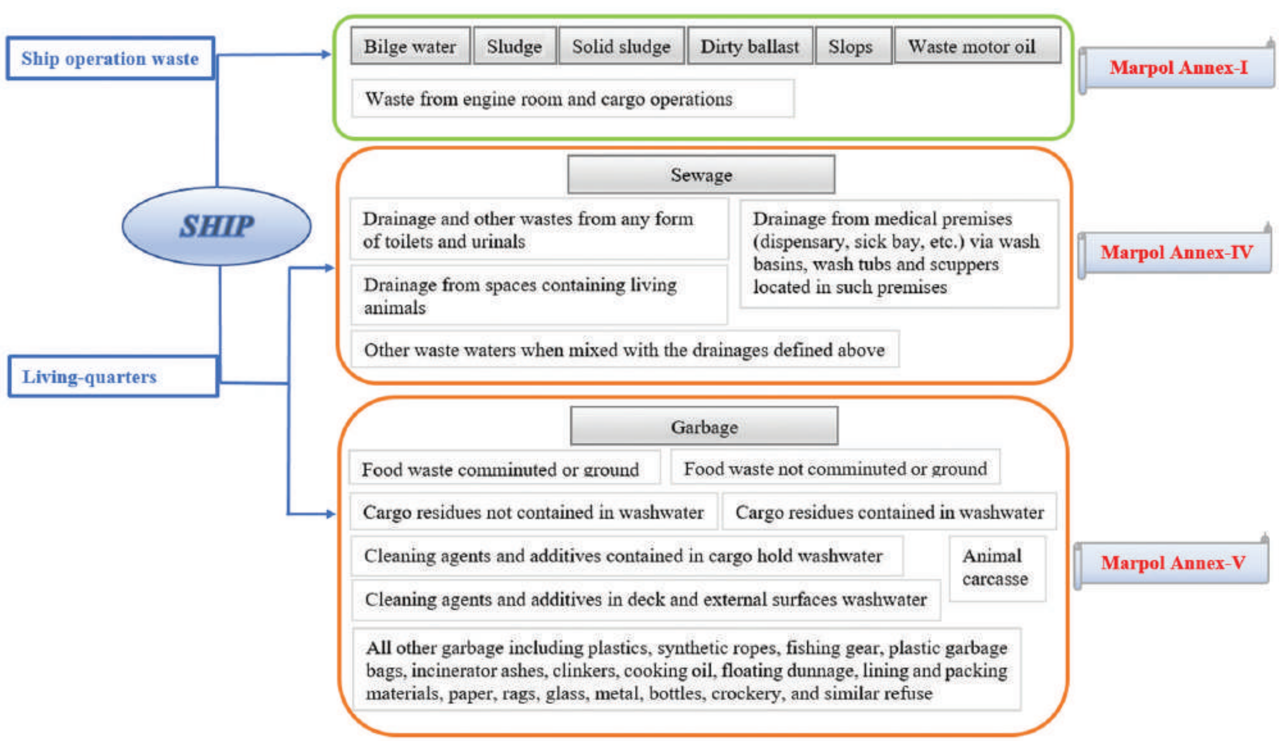

Figure 1. *Categorization of the ship-generated waste type within the framework of MARPOL 73/78 (based on [12,21])*

an enriched academic discourse around effective waste management systems between ship and port authorities. A noteworthy contribution comes from Di Vaio et al. [29], who proposed a novel approach based on environmental key performance indicators. This metric-oriented perspective is stated by Peris-Mora et al. [30], who designed an indicator framework to evaluate port environmental operations, notably referencing MARPOL 73/78/97 regulations. Mohee et al. [31] advanced this dialog by structuring a Port Waste Management System that, among other elements, encapsulates organizational paradigms, responsibilities, and goal-target-measurement parameters.

Ship waste, a nuanced subject, has often been categorized into two broad research categories: a) leaving-working-tourism and b) vessel operations-related studies. Delving deeper, tourism-centered investigations focus on passenger ships, including ferries and cruises. Notably, while constituting a mere 1% of total ships, cruise ships are responsible for an astonishing quarter of the total vessel waste, which is attributed to their multifaceted operations [32]. This proportion swells to 13% when ferry ships are included [33]. Consequently, the prominence of waste generated by passenger ships has been a recurrent theme in numerous academic explorations [32-38]. To quantify this, Ulnikovic et al. [37] conducted a comprehensive analysis, discovering that an individual typically produces 1 kg of solid waste daily. This sentiment is further stated by Beza et al. [39], who highlight a waste output of 3 kg/day per crew member in Greece. Onwuegbuchunam et al. [40] pivot the discourse toward vessel operations-related waste, splitting it into shipborne and cargo-related waste. They furnish empirical data illustrating that motorized cargo ships, tanker ships, and tugboats produce average volumes of 3.7 m^3, 4 m^3, and 3.5 m^3 of bilge water per service, respectively. Additionally, the multifaceted nature of ship waste has been quantitatively dissected by studies such as Zuin et al. [41], delineating the diverse types of waste produced annually. A pivotal study by Pérez et al. [42] adopted an analytical approach, correlating variables such as ship typology, age, and number of occupants to waste generation patterns. Their findings underscore the decisive role of ship size and onboard population in determining waste output, subsequently recommending a differentiated waste fee structure.

Waste disposal, especially sewage, has a profound environmental impact, with the potential to trigger marine eutrophication [36]. Despite regulatory measures such as MARPOL Annex IV [43], there remain stipulated conditions under which untreated sewage can be discarded, posing environmental hazards, especially in sensitive areas such as the SoM. Institutional responses to these challenges are noteworthy. The European Sea Ports Organization (ESPO) has pioneered environmental prioritization in European ports since 1998 [44]. Their Green Guide stands out as a robust blueprint that promotes waste management incentives and metrics. An evolution toward "Environmental Performance Indicators" in European ports is discernible, witnessing a 16% uptick between 2004 and 2013 [12]. ESPO's strategic port categorization [13] further accentuates environmental evaluation dynamics based on cargo handling volumes.

Despite the voluminous literature on European Union (EU) port reception facilities [29,37,42,45], there is a conspicuous paucity of research on Turkish ports [19,20]. This gap underscores the imperative for more comprehensive and localized studies in regions such as Türkiye to ensure holistic global advancements in marine waste management.

In the following sections, the methodological framework for this study is elaborated in Section 3, providing insight into data acquisition and analysis. Section 4 show cases an in-depth case study, illustrating the practical application of this methodology in a real-world context. Section 5 presents and analyzes our study findings within the broader academic landscape. Finally, the concluding section summarizes our key contributions and underscores the significance of our work.

3. Materials and Methods

3.1. Data Collection and Analysis

Waste reception and port size data for the Ambarlı and Haydarpaşa Ports serve as the foundation of this study. The waste reception data encompasses details about the number of ships and the amount of waste received, all

Figure 2. *Geographic location of Ambarlı and Haydarpaşa Ports*

sorted by the waste types delineated in MARPOL 73/78 (see Figure 2 and Tables 1 and 2). This information was sourced from ISTAC Inc., an entity under the Istanbul Metropolitan Municipality, and analyzed using the SPSS 29.00 statistical package. On the other hand, port size is gauged on the basis of cargo handling amounts as defined by [13], with categories ranging from less than 5 million tons to over 50 million tons Furthermore, the number of berthed ships is integrated as an additional determinant of port size. Both the volume of ship calls and the quantity of managed cargo at the mentioned ports are extracted from annual reports issued by the Ministry of Transportation and Infrastructure (MTI) of the Republic of Türkiye [46].

3.2. Proposed Methodology

The assessment of waste reception performance in ports can be effectively conducted using WRP indices, which provide valuable insights and indicators to evaluate the efficiency and compliance of waste management practices in accordance with the regulations outlined in MARPOL 73/78. The authors introduce a novel approach that involves the calculation of WRIs to evaluate and compare the efficiency and compliance of waste management practices across various ports while considering specific ship and cargo operations. To facilitate this assessment, a waste notification form is utilized, which encompasses eight distinct waste categories, as depicted in Figure 1, each designated by the corresponding notations provided in Table 1.

Table 1. *Ship-generated waste types*

Ship-generated waste (m^3/year)	Waste type code	Waste-type-based waste reception performance indices
Waste motor oil	w_1	Ps_1
Sludge	w_2	Ps_2
Slops	w_3	Ps_3
Bilge water	w_4	Ps_4
Dirty ballast	w_5	Ps_5
Sewage	w_6	Ps_6
Solid sludge	w_7	Ps_7
Garbage	w_8	Ps_8

Equation 1 outlines the methodology for determining the total waste reception amount in a port or terminal, achieved by aggregating the quantities of the eight waste categories.

$$W = \sum_{i=1}^{n=8} w_i \quad (1)$$

where the calculation of the WRP indices in this study involves using the amount of each waste type (w_i), as shown in Table 2, received by the waste reception facility. To perform the performance analysis, four parameters are required

i. The number of ships berthed,

ii. The number of ships serviced by the waste reception facility, and

iii. The types and amounts of waste received (in cubic meters per year),

iv. the total waste reception amount (in cubic meters per year), and

v. The size of the port (measured by the amount of handled cargo in tons).

The ship-based waste reception performance indices (P_w) are then calculated using Equation 2, which determines the ratio of the number of ships that received waste reception services to the total number of ship calls.

$$Pw = \frac{s_w}{s_b} \quad (2)$$

where the number of ships receiving the waste reception service (s_w) and the total number of ships berthed (s_b) are essential parameters for evaluating waste reception performance. Moreover, the amount of waste collected in each waste type serves as an important factor for classifying and assessing ports. Therefore, the waste-type-based waste reception performance indices (P_{si}) are expressed as shown in Equation 3.

$$Ps_i = \frac{w_i}{s_w} \textit{ For } i = \{1 \ldots, 8\} \quad (3)$$

Table 2. *Analysis of the difference between the number of ships served by the ports and the amount of waste collected*

Port	Statistical information	Number of vessels served	Amount of waste collected
Haydarpaşa Port	Mean ± std. deviation	654.17±105.01	6777.51±1312.42
	Median (min.-max.)	691.50 (490-763)	7253.24 (5121-8221)
Ambarlı Port	Mean ± std. deviation	693.00±77.62	4580.61±374.34
	Median (min.-max.)	679 (601-816)	4496.02 (4248-5205)
Sig.		0.818	0.004

where the variable "w_i" represents the quantity of each waste type received by the waste reception facility, while "s_w" corresponds to the number of ships that were provided with waste reception services. Within this framework, Equation 3 offers a calculation to categorize ports more specifically.

The computation of the waste amount-based waste reception performance indices is presented in Equation 4.

$$Ps = \sum_{i=1}^{n=8} Ps_i \quad i=\{1...,8\} \tag{4}$$

Additionally, Equation 4 is equal to Equation 5.

$$Ps = \frac{W}{s_w} \tag{5}$$

Port size is an additional parameter that is considered when evaluating waste reception performance, particularly with regard to the environmental indices of ports. This parameter encompasses both the amount of cargo handled and the number of ships berthed within a given year. It is important to observe the correlation between cargo handling and waste reception performance, as this can provide valuable insights into port performance.

$$P_p = \frac{x}{s_b} \tag{6}$$

where P_p is the port size parameter, x is the amount of cargo handled in a year, s_b is the number of ships berthed.

Calculations are performed in MATLAB for both Haydarpaşa and Ambarlı Ports. A comparative methodology was employed to evaluate the waste reception performance of these ports.

4. Case Study

The geographical location of the SoM makes the sea an attractive region for national and international ship transport [47]. The SoM is home to more than 30 international cargo terminals, 83 local piers for ferries, 8 marinas, and 50 fishing ports [48]. In this study, the authors selected the Ambarlı and Haydarpaşa Ports for analysis and evaluation purposes, which are known for their significant ship traffic. The Ambarlı and Haydarpaşa Ports were chosen because of their strategic importance within the SoM, serving as crucial hubs for national and international maritime trade. These ports not only handle a substantial volume of cargo but also play a pivotal role in the economic development of the İstanbul region and Türkiye as a whole. The Ambarlı and Haydarpaşa Ports are situated in the İstanbul region of the SoM. Specifically, the Ambarlı Port is in the western region of İstanbul, while the Haydarpaşa Port is situated at the entrance of the İstanbul Strait in the central region of İstanbul (see Figure 2).

Given their locations, the ship traffic around the Haydarpaşa Port is relatively more congested than that around the Ambarlı Port due to the high volume of ship traffic passing through the Istanbul Strait. Container ships constitute the primary vessels operating in the Ambarlı port. While the Turkish Republic State Railway (TCDD) manages the Haydarpaşa Port, private enterprises manage the Ambarlı Port [49].

In both Ambarlı and Haydarpaşa ports, ships generated waste reception service has been provided to ensure environmental sustainability and compliance with international regulations by ISTAC Inc., which is a corporation under the İstanbul Metropolitan Municipality responsible for waste receptions in the Ports of İstanbul [48]. In the management of waste reception services in İstanbul ports, including Ambarlı and Haydarpaşa, several procedures have been followed (see Figure 3). The waste

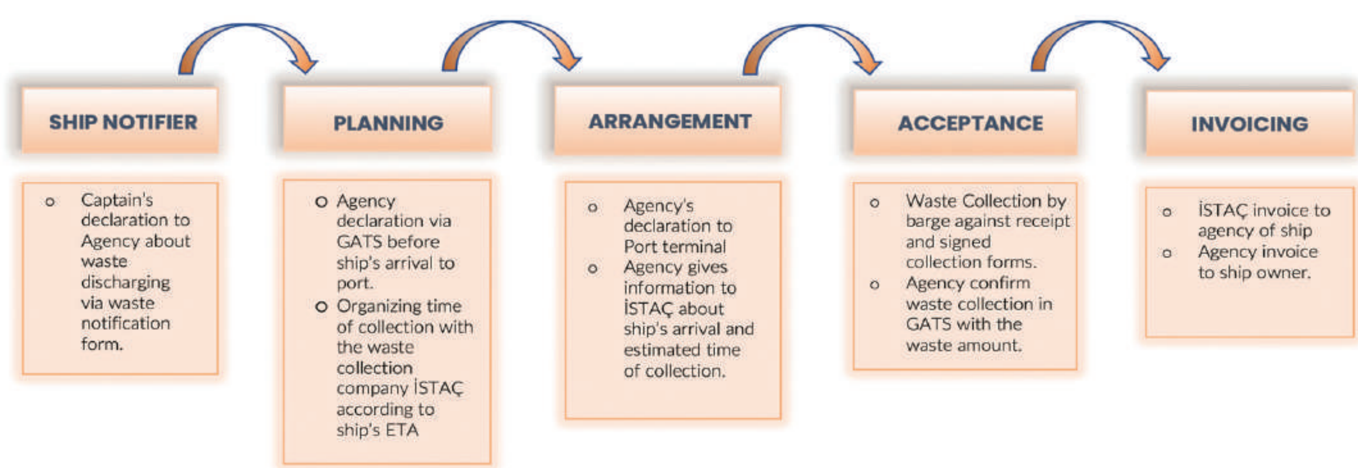

Figure 3. *Waste reception process in the ports of İstanbul*

reception process begins with notification by ships [29]. The remaining procedures are given in Figure 3 are followed by the ship's agency.

5. Results and Discussion

Waste reception amount and number of ship calls in Ambarlı and Haydarpaşa ports are given in Figures 4 and 5. According to these graphs, the mainly discharged waste type is sludge in Ambarlı Port and bilge water in Haydarpaşa Port. Additionally, the waste reception amount in Ambarlı Port is lower than that in Haydarpaşa Port even if the number of ship calls in Ambarlı Port is higher than that in Haydarpaşa Port.

The proposed computation of waste reception performance provides quantitative outputs to compare ports based on their performance indices. Within this framework, Haydarpaşa Port shows higher ship-based waste reception performance than Ambarlı Port (see Figures 4 and 5), indicating that the waste reception service provided in Haydarpaşa Port is nearly 1.5-2 times higher than that provided in Ambarlı Port with respect to the number of ships berthed in both ports. This result shows that Haydarpaşa Port has a much more active ship-based waste reception performance. However, it should be noted that the higher rate at Haydarpaşa port is also related to the time between ships' berthings and sailing. If the handling operation is fast, the ship may not discharge its waste to the waste reception facility, resulting in the waste reception organization going over to the next port of call or potentially causing illegal discharges [51].

Ambarlı Port generally serves container ships [52], while Haydarpaşa Port has a more diversified ship portfolio. According to data from 2015, container cargo services were 1585419, 1169019, and 335576 Twenty-Foot Equivalent Unit (TEU) for Marport, Kumport, and Mardas terminals in Ambarli Port, respectively, and only 121641 TEU in Haydarpaşa Port [53]. Considering the cargo service speed of container terminals, time is more restricted compared with that of general cargo terminals. Nonetheless, a waste reception organization that does not delay the ship supports the efficiency of ship-generated waste control and management.

Another factor that can influence the time required for waste reception is the location of the garbage barges. The central location of Haydarpaşa Port enables faster waste reception organization, whereas delays in waste reception declaration can lead to postponement or cancelation of the operation. ISTAC, the waste management company, can compensate for late declarations in Haydarpaşa because of its easily accessible location, in contrast to Ambarlı Port. Moreover, waste reception can be efficiently organized if a waste reception declaration is made by the ship and the agency two days before the vessel's arrival (as shown in Figure 2). As known from ISTAC, Haydarpaşa Port is busy also waste reception operation of city ferries.

Figure 6 shows the P_w indices for Ambarlı and Haydarpaşa Ports. P_w is one of the important indicators to show the waste reception activity of the port per ship. Haydarpaşa Port provides significantly higher waste reception service between berthed ships. It can also be stated that ships in Haydarpaşa prefer waste reception organizations over those in Ambarlı.

The waste reception types graphs, including the P_{si} values, are presented in Figure 7, which illustrates that Haydarpaşa Port has a higher performance in waste type-based waste reception. The highest waste type received in Haydarpaşa Port is bilge water (w_4). In contrast, the highest waste reception type in Ambarlı Port is sludge (w_2), with sludge being the second highest received waste type at Haydarpaşa Port. Furthermore, the sludge reception indices of Ambarlı Port are 1.5 times higher than those of Haydarpaşa Port. Garbage is the third highest waste type, with garbage reception indices being the same in both ports (see Figure 5). As demonstrated in Pérez et al. [42], the amount of garbage is related to the number of people on board ships. However, no data are available regarding the number of separated and recycled wastes. Considering the plastic

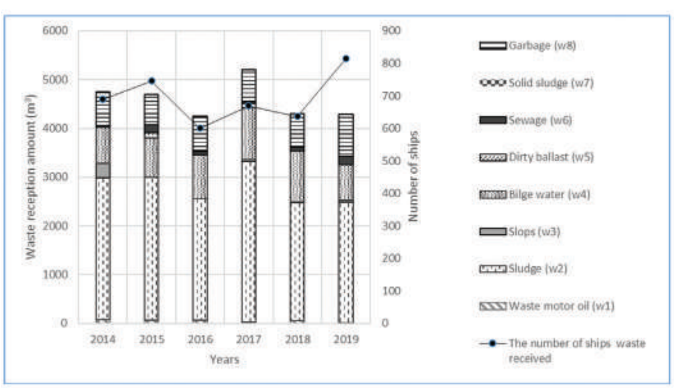

Figure 4. *Waste reception amount and the number of ship serviced in Ambarlı Port*

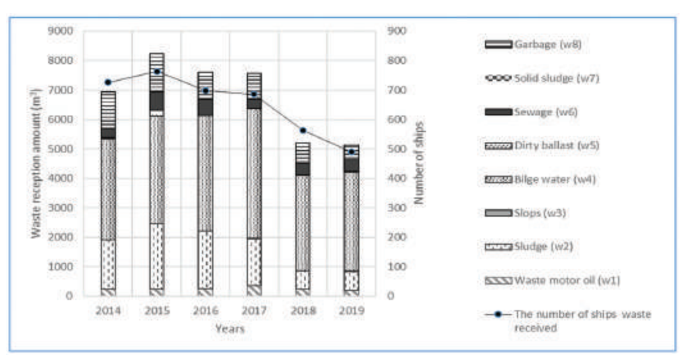

Figure 5. *Waste reception amount and number of ship serviced in Haydarpaşa Port*

threat in the region as estimated by Kaptan et al. [19], it is crucial to track the data on recyclable waste. Additionally, the separation and reception of recyclable waste onboard materials, such as plastic, metal, and glass, are significant in reducing marine litter pollution in the region.

The waste reception performances of both ports based on the amount of waste are presented in Figure 8. Despite the significant fluctuations in indices values from year to year, the indices values for Ambarlı Port range almost from 5 to 8, whereas those for Haydarpaşa Port range from 9 to 12. These findings show that the P values in Haydarpaşa Port surpass those in Ambarlı Port each year. Higher bilge water reception performance in Haydarpaşa than in Ambarlı is also related to the bilge water treatment technology and management of ships that call in Haydarpaşa and Ambarlı. The management of oily bilge water can change depending on each ship's amount of waste being treated, disposed at sea, or retained on board for delivery at port reception facilities, as stated by the report of CE DELFT and CHEW [54] for the European Maritime Safety Agency.

Puig et al. [12] used the parameters of port size defined by

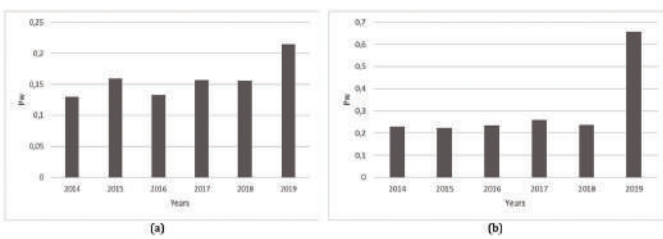

Figure 6. *Ship-based waste reception performance in Ambarlı Port (a) and Haydarpaşa Port (b)*

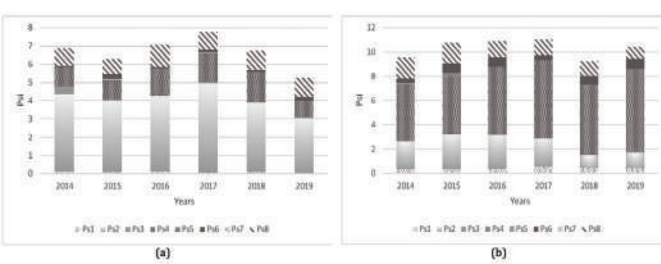

Figure 7. *Waste reception types for each ship-generated waste type in Ambarlı Port (a) and Haydarpaşa Port (b)*

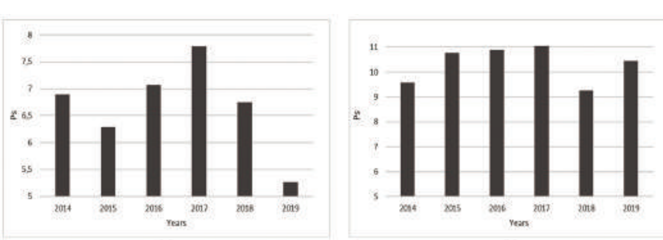

Figure 8. *Waste amount-based waste reception performance in Ambarlı Port (a) and Haydarpaşa Port (b)*

ESPO [14] to evaluate European ports. Based on the data (see Figure 9) from annual reports published by the MTI of the Republic of Türkiye [46], Ambarlı and Haydarpaşa ports

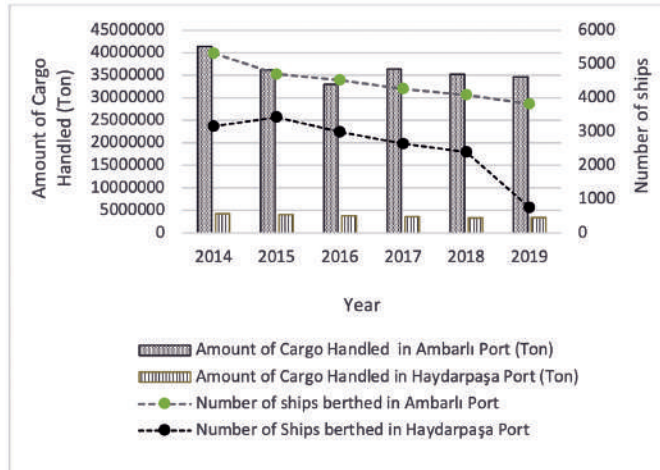

Figure 9. *Comparison of the amount of cargo handled and the number of ship calls between Ambarlı and Haydarpaşa Port (data received from [48]).*

were categorized into groups 3 and 1, respectively, according to ESPO [14] port size categorization. Figure 9 presents a comparison of these parameters between Ambarlı and Haydarpaşa Ports. The Ambarlı Port is significantly larger than the Haydarpaşa Port according to the port size values given in Figure 9. However, despite having lower operational activity in port size parameters, Haydarpaşa Port exhibits higher waste reception performance than Ambarlı Port. This inverse relationship is attributed to the difference in the type of serviced ships [42] in both ports. Moreover, as highlighted in the literature [55,56], a general cargo ship generates considerably more operational waste (garbage generated from the regular operation of a ship's main and auxiliary engines) during a voyage than a container ship of similar size, owing to its cargo, engines, and equipment. The findings of the study by Senarak [56] support this study as stated that general cargo ships have the highest impact on the amount of operational waste compared to container, Ro-Ro, and bulk carriers. Additionally, Carpenter [57] and Carpenter and Macgill [58] studied a survey based on 77 European ports to evaluate port reception facilities. Their results show that waste reception facilities are higher for general cargo ships than container ships.

6. Statistical Analysis

The data obtained at the end of the study were analyzed using the SPSS 29.00 statistical package program. During the analysis of the data, the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U test, which are non-parametric tests, were used as they would show a skewed distribution due to the number of data being less than 30. Relationships between variables with two categories were analyzed using the Mann-Whitney U test. The Mann-Whitney U test was used for unrelated measurements to analyze whether the scores obtained from pairwise unrelated samples of Haydarpaşa Port and Ambarlı Port differ significantly from each other. If the variables are more than two, the relationships between the variables are analyzed using the Kruskal-Wallis test. The change over the years regarding the total number of berthing ships and the total amount of waste received was examined using the Kruskal-Wallis test. The average standard deviation, median, minimum, and maximum values, categorical data, frequency, and percentage values of the variables of the number of ships docking at Haydarpaşa and Ambarlı Ports, and the amount of waste received from the ships were examined (Table 2). The Spearmen correlation test was used to determine the relationships between the total number of berthing ships and the total amount of waste received, which are two numerical variables. A significance level of 0.05 was set in the interpretation of the results.

A statistically significant difference was found between the amount of waste collected and the ports (p<0.004). While the mean and standard deviation of the amount of waste collected in Haydarpaşa port is 6777.51±1312.42, the median value is 7253.24, the mean and standard deviation of the amount of waste collected in Ambarlı port is 4580.61±374.34, and the median value is 4496.02. The difference is statistically significant. The number of wastes collected in Ambarlı Port was found to be less than that collected in Haydarpaşa Port.

In Table 3, it has been examined whether the number of ships serving and the amount of waste collected differs from year to year. No statistically significant difference was found (p-values >0.005). The average and standard deviation of the number of vessels serving in 2014 was 707.50±26.16, the median value was 707.5, the average and standard deviation of the number of collected waste was 5843.03±1555.56, and the median value was 5843.03. The mean and standard deviation of the sample were 146.50±207.18, and the median value was 146.5. In 2019, the mean and standard deviation of the number of ships serving was 653.00±230.52, the median value was 653.00, the average and standard deviation of the number of collected waste was 4708.29±584.92, and the median value was 4708.29. The mean and standard deviation of the amount were 27.65±13.22, and the median value was 27.65. As we approached from 2014 to 2019, the number of ships serving and the amount of waste collected decreased.

Analyses were performed using non-parametric tests, since the number of data was less than 30. The Mann-Whitney U test was used to measure the difference between variables with two categories, and the Kruskal-Wallis test statistic was used in cases where there were more than two categories. Numerical data are shown with mean standard deviation median minimum and maximum values, and categorical data are shown with frequency and percentage values. The Spearman correlation test was used to examine the relationship between two numerical variables. The significance level was set at 0.05 for all tests.

A correlation coefficient (r) of 0.0 indicates no relationship, a value between 0.01 and 0.29 indicates a low level of relationship, a value between 0.3 and 0.7 indicates a moderate relationship, a value between 0.71 and 0.99 indicates a high level of relationship, and 1 indicates a perfect relationship. When Table 4 is examined, it is seen

Table 3. *Analysis of the difference between the number of ships served per year and the amount of waste collected*

Year	Statistical information	Number of vessels served	Amount of waste collected
2014	Mean ± std. deviation	707.50±26.16	5843.03±1555.56
	Median (min.-max.)	707.50 (689-726)	5843.03 (4743-6942)
2015	Mean ± std. deviation	754.50±12.02	6457.68±2494.76
	Median (min.-max.)	754.50 (746-763)	6457.68 (4693-8221)
2016	Mean ± std. deviation	649.50±68.59	5926.73±2372.97
	Median (min.-max.)	649.50 (601-698)	5926.73 (4248-7604)
2017	Mean ± std. deviation	677.00±11.31	6384.31±1667.63
	Median (min.-max.)	677.00 (669-685)	6384.31 (5205-7563)
2018	Mean ± std. deviation	600.00±52.33	4754.38±644.82
	Median (min.-max.)	600.00 (563-637)	4754.38 (4298-5210)
2019	Mean ± std. deviation	653.00±230.52	4708.29±584.92
	Median (min.-max.)	653.00 (490-816)	4708.29 (4294-5121)
Sig.		0.416	0.827

Table 4. *Correlation results of the relationship among age, number of ships served, and number of wastes collected*

			Year	Number of vessels served	Amount of waste collected
Spearman's rho	Year	r	1	-0.424	-0.283
		p	.	0.169	0.373
	Number of vessels served	r	-0.42	1	0.175
		p	0.169	.	0.587
	Amount of waste collected	r	-0.28	0.175	1
		p	0.373	0.587	.

that the p-values are not significant. However, as the number of ships served increases, the amount of waste collected increases.

7. Conclusion

Operations for waste management emerge as a secondary activity, since the main activities of ports are ship and cargo operations. All of the operations must be in harmony with the holistic scope of port management. This study evaluates the secondary activities of ports depending on their main activities. Within this framework, this paper compares the WRP of two important ports in İstanbul by considering their ship call, cargo handling, and waste reception data.

WRP is evaluated in two categories: the amount of waste received per ship call and the amount of waste received per cargo handled. Additionally, these evaluations are performed for each waste type. To evaluate the relation of these variables' statistical analysis, the Spearman correlation test, Kruskal-Wallis test, and Mann-Whitney U test are applied. The study shows that the amount of waste received per ship served is much higher at the Haydarpaşa port. The study approached from 2014 to 2019, and the number of ships serving and the amount of waste collected decreased. Furthermore, the comparison of waste reception performances of the two ports in the SoM using computed indices reveals a significant difference between the Ambarlı and Haydarpaşa ports. The findings shows that the type of ship is a crucial factor in waste generation. The adequacy of port reception facilities should be improved by considering the port size, waste type, and amount of discharge. Effective organization of waste reception is crucial for preventing illegal waste discharges. Encouraging shipping companies to separate wastes such as plastic, metal, and glass can reduce the pollution of recyclable waste in the marine environment and support the circular economy. As a semi-enclosed sea, the location of the SoM is geographically at a critical point, making it a hub for local and international ship traffic. Regulations, including the MARPOL 73/78, 2000/59/EC directive, and Turkish laws, have been established to protect the marine environment from ship-generated pollution, which significantly contributes to the prevention of marine pollution. However, ship-generated waste reception organizations should be improved with local rules in the SoM considering that it is a SEPA. An efficient ship-generated waste management plays a vital role in the sustainability of the SoM. The performance indices reveal that while the port size of Ambarlı (group 3) is higher than that of Haydarpaşa Port (group 1), the waste reception performance of Haydarpaşa is significantly larger than that of Ambarlı. This issue arises from the fact that general cargo ships undertake additional operations, such as cargo hold cleaning, in preparation for the next load, resulting in the generation of additional waste compared with container ships. Given the differences between terminal types, it is evident that there is no "one size fits all" policy approach, and mitigation strategies need to be tailored to the characteristics of each port. Therefore, improving the definition of environmental indicators by ports is important for environmental management. It should be noted that this study was conducted only on two selected ports in the SoM. Future studies may be required to investigate different types of ports, regions, and terminals in the SoM. Future research endeavors may expand the scope to encompass a wider array of port types, regions and terminals within the SoM, facilitating a more comprehensive understanding of waste management dynamics in this critical maritime region.

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Simulation-Based Cost Evaluation of Maritime Transportation

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Abstract

In a globalized world, maritime transportation is a crucial component for both producers and consumers. In this sector, where 10 billion tons of freight are moved each year, both shippers and carriers grapple with financial obligations. The requirement for ship operators to perform precise cost calculations is growing daily to stay competitive and avoid financial difficulties because of high investment and operational costs. However, traditional costing methods, which are already in use, are believed to be unable to provide businesses with the precise information they require. Therefore, in this study, the cost structure of ship management is examined and the activity-based costing (ABC) method is used with the help of simulation. The data obtained from the ABC model created with simulation support were compared with the companies' current traditional costing methods. The results show that there is a difference in the calculations between the simulation-based ABC method and the traditional costing method. According to this study, the cost difference is approximately $7,000. Considering that the firm's annual total cost remains unchanged, it can be assumed that the costs for loadings other than the one under consideration are higher than expected.

Keywords: Simulation, ABC, Costing, Maritime transportation management

1. Introduction

In today's world, where global rivalry is increasing by the day, businesses must build a stringent and long-term financial management system to remain competitive. With the increase in competition, there is a greater requirement for precise cost structure evaluation [1]. A precise cost structure is an important factor that influences the entire company's management in all aspects [2]. Companies use a precise cost structure to establish prices and pinpoint areas where spending could be trimmed. Among all expenses, transportation expenditures play a significant role in the expenditure elements that comprise these cost structures.

Maritime transport is a key actor in supplying numerous needs, such as raw materials, products, and equipment, that enterprises in a global marketplace require. However, maritime transport takes its share from the strict financial management approach brought about by global competition. The expectations of cargo owners, who desire to transport their cargo in the most financially feasible manner, are forcing shipowners and/or ship operators (SOs) to implement a sustainable strategic financial management system. With the 80% volume of international freight transportation, the maritime transport service spectrum covers all sectors; thus, the effects of the financial management systems of shipowners and/or ship management companies could be felt by all sectors. Even with the global economy contracting owing to the pandemic, the volume of cargo transported by merchant vessels was estimated to be 11 billion tons in 2022 [3].

SOs confront various cost structures to perform their freight transportation. Two categories of maritime transportation expenses are examined. The first is the fixed costs that guarantee that the ship is ready for the next journey and the cargo, and the second is the variable costs, which change depending on the type of cargo being transported and the distance. On the other hand, fixed costs can be separated into two categories within themselves [4]. Capital costs include expenses such as building a ship, depreciation, and financial outlays. In addition to these costs, expenses for flagging, registries, insurance, staffing, and regulations

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could be categorized as fixed operational costs. The two fixed cost items mentioned above are the costs to keep the ship sailing. The owner of the ship must pay for these expenses even if it does not engage in transportation because otherwise, it will not be suitable for the next voyage and transportation. Variable costs, which vary on the basis of loading and distance, comprise the other cost category. Variable cost examples include fuel costs, canal tolls, and port fees. The age of the ship may impact all of these costs. As the ship continues to age, the cost of capital decreases. On a ship that is five years old, the capital cost is 47%; however, on a ship that is twenty years old, the cost just covers 11% of all expenses [5]. However, as a ship gets older, maintenance, repair, and operational costs, as well as costs associated with mandated changes to regulations, increase [6]. SOs focus on these adjustments as the most critical issues during the cost estimation stage. Investment and operational costs vary even at different ages of the same ship. It is becoming increasingly vital for SOs to perform accurate cost assessments for sustainable shipping due to changes in the global economy, cost variability [6], and a more competitive market.

As mentioned above, costing is a critical management tool [7]. For this reason, this study aims to improve shipping companies' financial capability to foresee [8] the financial challenges they will face in their freight transportation at an operational level. The improvement of financial capability and the development of several financial scenarios are expected to aid organizations in maintaining their competitiveness. It is also expected to be beneficial in the development of a sustainable economic model. In this study, the activity-based costing (ABC) model, which is commonly used in the service industry, particularly in manufacturing, is integrated with simulation to allow SOs to produce more accurate cost estimations. The research was conducted on a specific journey (from Tekirdağ Port to Bari Port) that transports bulk cargo to be a pioneer and an example of its utilization in ship management. Sparse, average, and intensive outcomes that can occur are achieved and evaluated through simulation. The generated findings were compared with traditional cost calculation results, which are the most frequently used cost calculation approach in ship management and other areas. The modeling findings employed in the study with the traditional costing method showed differences, as indicated by the comparison results. SOs are unable to compete effectively enough in the global marketplace because of these disparities.

2. Literature Review

Cost calculation is a critical issue for businesses in determining profitability. Increasing competitiveness because of the industrial revolution has compelled businesses to operate more prudently financially. According to the literature, various cost analyses have been conducted in all industrial and service industries. Despite this, there is less research in the maritime sector. However, these investigations discovered that they confined their cost estimations to certain cost elements. The majority of these studies fall under the category of maritime economies of scale. In other words, these are studies on the decline in cost items with an increase in service production. For instance, several corporations have explored the economic effectiveness of building bigger ships to lower the number of escalating expenditures per unit load [9]. It has also been stated that increasing the tonnage of ships, particularly bulk carriers and newly constructed ships, will cut unit prices [10]. Likewise, research has been conducted to reduce the unit price of container shipping with large-tonnage ships [11,12]. In contrast to economies of scale, another study observed that increasing passenger ship size increases unit price [13].

In addition, the daily operating expenses of the ships were investigated in another study [14]. However, because the cost calculations in this study were based on partially genuine statistics, the conclusions were insufficient to be extended to other firms. The claimed reason for this was that the SOs were unwilling to divulge the true cost data. In addition the expenses in each container slot of container transport ships were investigated using mathematical modeling and additional costing techniques [15]. Cost suggestions were provided to container transportation enterprises and ship charterers due to research conducted on a specific route. The study's shortcoming was stated to be that it was conducted in a certain route and that different results may be obtained in other regions.

In addition to prior studies, SOs have attempted to decrease expenses by lowering ship bunker consumption against rising oil prices and fuel consumption regulations [16]. This study examined the relationship between speed, route, and consumption using the stochastic linear integer programing model, and it was concluded that fuel cost may be lowered with the proper route and speed. Another author [17] utilized a mixed integer nonlinear programing model to optimize ship navigation in linear transport. It has been suggested that this could result in 6-10% improvement in both ship arrival times and prices. In addition to these studies, it was [18] attempted to find the ideal maintenance time policy in their study on ship engine maintenance expenses. In the MATLAB-simulated investigation, coding on probability analysis was done, and therefore optimal maintenance durations were identified. According to the study, ship engine maintenance expenses may be lowered by 11% each year.

Costing is crucial in transportation sectors other than sea transport, as it is in other industries. Cost studies at railway stations [19] and freight determination in train transportation were studied [20], and because of these studies, employment recommendations were made to firms. There are studies on the financial comparison of different airline companies [21], support, and guidance on the assessment of the freight/ticket price of the airline business operating a certain line in the aviation industry [22]. Furthermore, cost research attempts to raise airline company profitability ratios by integrating various mathematical and statistical methodologies [23]. There are studies undertaken with road transport firms, such as trip cost analysis of the bus company running on a certain route [24], empirical cost analysis, and suggestions for city bus and trolleybus services [25].

According to another study [26], precise estimation of expenditure items is critical not only for businesses but also for developing countries. While working on expenses, it is critical for the reliability of the research to establish and quantify overall costs rather than individual costs. In this regard, the ABC approach offers several applications. For example, it performed a cost analysis for truck transportation enterprises and developed a general financial framework for businesses [27]. Furthermore, by analyzing the supply management system in a non-profit hospital, a general health framework was developed [28]. However, as aforementioned, research in the literature on the shipping sector has been conducted on the optimization of individual cost categories. Contrary to the studies in the literature on the shipping sector, in this study, all cost factors that SOs encounter while transporting freight have been thoroughly investigated. More precise loading-specific costs are calculated using the general framework for SOs. The gaps in the literature were attempted to be filled in this way. Furthermore, unlike other studies in the maritime sector, ABC could assist enterprises in developing a sustainable cost structure by detailing the activities that impact costs using the ABC model [29].

3. ABC

ABC is a cost calculation method that takes into account the activities required for production or service while calculating the cost [30]. By assigning resources to activities and activities to cost objects depending on user usage, this modeling helps organizations understand the measurement costs and performance of activities, resources, and cost objects. It also helps identify causal links between cost drivers and activities [31]. This method, which emerged in the 1980s, has been used in various studies in many fields over the years. Such as; in health [32], manufacturing [33], banking [34], libraries [35], agriculture [36], and transportation [37]. Apart from the sectors, some studies have shown the ABC methods' impacts on management and decision-making progress. It was stated in the study [38] that different inventory quantities lead to different results in terms of management costs in the same period, which causes different results in the ABC model. In another study [39], authors explained that the rate of administrative adaptation to ABC remained at 24%, and 72% of them found themselves in traditional costing while eliminating the difference in facility costs, with statistical calculations.

The purpose of the ABC system is to determine the activities required for the production of services or products and to allocate these activities to the costs based on the amount of resource consumption [40]. In this model, cost objects consist of activities and activities consist of resources. Therefore, the model utilizes the two-step procedure defined below to place resource costs on cost objects, as demonstrated in Figure 1. Logic in Figure 1 is the underlying logic of the model, although ABC is not a single application method and may vary from company to company [41].

Step 1: This stage includes the distribution of resource drivers to activity centers in proportion to the activity performed.

Step 2: Cost items in the determined activity pools are collected on cost objects. The unit price is obtained by dividing the total cost by the total product produced.

On the other hand, the service and production sectors differ in the ABC implementation phase. The differentiation between sectors was mentioned in the study [42], and the reason for this difference is the fact that the service sector has more activity and activity producers than the production sector. Maritime transport includes more complicated operations. The first of these are operations that are not in other sectors, such as port operations, crew operations, and inspections.

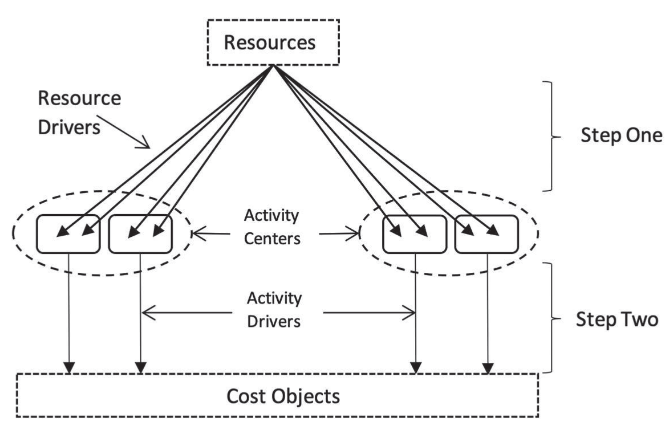

Figure 1. *Cost constitution steps in activity-based costing [22]*

In addition to its benefits, the ABC approach has drawbacks. The greatest difficulty is that a thorough analysis of the activities requires time. However, businesses are reluctant to adopt this strategy because of the significant financial resources that are moved. The main issues that businesses encounter while using the ABC technique are inadequate managerial support and a lack of coordination and integration of internal information systems [43].

3.1. Methodology of the Study

In this study, the ABC method was used to perform accurate cost calculations. Unlike other ABC studies, different possibilities were observed and interpreted with simulation support. The explanation of the models used in this study is as follows. To conduct a cost analysis for ship management companies, this study uses the advantages of the ABC method. A cost estimate study that takes into account all cost items has not been found in the literature, despite studies concentrating on various cost items in maritime transport. The research was conducted for the business operating a ship on a certain route to adapt this methodology to the maritime literature. Figure 2 illustrates the ABC flow diagram used in this research.

Step 1. Determination of Company Details: In the first step of ABC in this study, details of the company that is the subject of the study, such as company structure, number of employees, and departments, are specified.

Step 2. Determination of the Cost Object: In this step, information related to the voyage of the analyzed ship, such as route, duration, and amount of cargo, is determined.

Step 3. Determination of Direct Costs: This step specifies the direct costs that are added directly to the cost during the production of the service.

Step 4. Determination of Activity Centers and Cost Factors: This is the process of grouping the activities performed by the SOs company during service production according to certain characteristics.

Step 5. Determination of the Costs of Activity Centers: This is the process of allocating the expenses of ship management to the activity centers after the activity centers are determined.

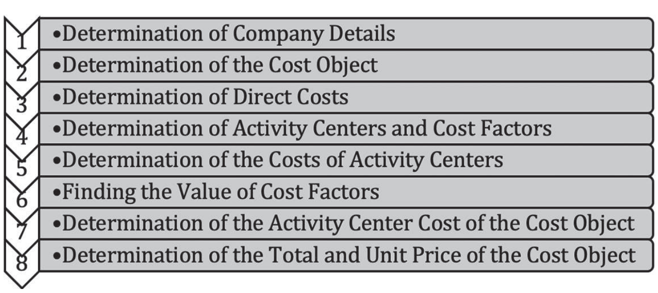

Figure 2. *Flow chart of ABC model in SOs companies*

Step 6. Finding the Value of Cost Factors; is the unit price calculation step obtained by dividing the costs of the activity centers found in Step 4 by each cost factor.

Step 7. Determination of the Activity Center Cost of the Cost Object: In this step, the total costs are calculated over the number of activities spent for the determined route.

Step 8. Determination of the Total and Unit Price of the Cost Object: By adding the total cost calculated in Step 7 and the direct expenses (Step 3) previously determined, the "Total Cost" of the voyage will be divided by the total amount of cargo carried, and the "Unit Price/Tonnage" will be found.

3.2. Application of the Model

This section presents ABC's proposed steps, which were mentioned in the previous section, with a case study.

Step 1. Determination of Company Details: X Ship Management company, where the study was conducted, is a company that performs transportation in all waters of the world with its 10 ships. Corporation X Ship Management owns all ships. Although it possesses ships of various tonnages, all of its vessels are bulk carriers. In this study, the transportation process in which the ship occurs on a certain route has been considered. The data obtained because of the study appear as the cost calculation for a specified monthly period.

It is possible to divide maritime companies into shoreside and shipboard companies according to their characteristic structure. The shoreside staff efficiently operates, manages, and maintains the fleet of ship management companies. The shipboard staff is responsible for the efficient operation of the ships.

The total number of people working in the company as land personnel is 35 and sea personnel is 228. The distribution of employees by department is shown in Figure 3.

Step 2. Determination of the Cost Object: The details of the voyage where the study was conducted are given in Table 1.

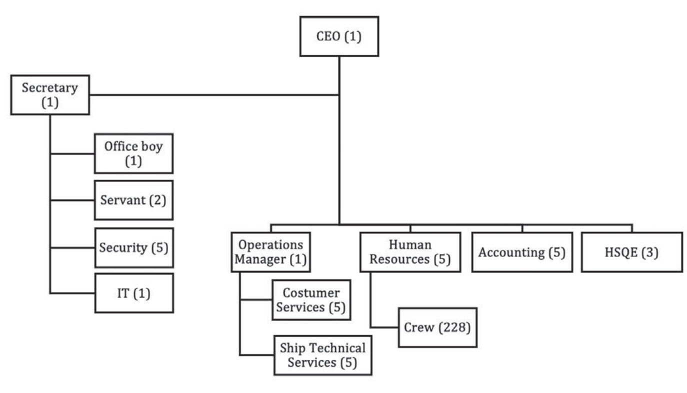

Figure 3. *Company Organizational Structure and Employee Distribution*

***Table 1.** Details of the voyage*

Details	
Port of loading	Tekirdağ/Türkiye
Port of discharge	Bari/Italy
Quantity of shipment	100,000 tons
Description of the goods	Bulk cargoes

Figure 4 demonstrates the route of the study. It starts from Tekirdağ/Türkiye to Bari/Italy. The route image was obtained from the NETPAS program, in which the bunker calculation was performed. The NETPAS program's route diagram also indicates that it takes roughly three days to travel the distance between Tekirdağ and Bari. Seven journeys were planned, each lasting three days: three days out and three days back. The simulation tool was used to examine several scenarios, accounting for factors such as weather, Bosphorus crossings, port disruptions, and maritime traffic density. It was discovered that the average length of the entire voyage was 28 days.

Step 3. Determination of Direct Costs: Direct costs are costs that can be directly attributed to the service or product and can be easily calculated [44]. In maritime transportation, there are some cost items to which the owner of the ship is exposed even if it does not perform the cargo transportation process. Therefore, in this study, the cost items that the ship will be exposed to whether it is transported or not are considered direct costs. The direct cost items used in this study are shown in Table 2. Data in Table 2 were obtained from a real shipping company that operates its own ships.

Step 4. Determination of Activity Centers and Cost Factors: This is the process of grouping the activities performed by the SOs company during service production according to certain characteristics. Table 3 shows the activity centers determined in this study.

The details of the activity centers are as follows:

C1 - Load Finding: This is the first element required for maritime transport. This section includes activities such as sales-marketing transactions, pro forma price offers, and

***Figure 4.** Demonstration of the route used in the study*

***Table 2.** Direct costs*

Direct Costs	
1. Cabin Store	17. Modifications
2. Chemical and Gas	18. Nautical Pub and Charts
3. Crew Clothing	19. Navigational Equipment Survey and Maintenance
4. Crew Flight	20. Oil (Lubricant)
5. Crew Handling	21. Other
6. Crew Payroll	22. Paint
7. Deck Maintenance	23. Provisions
8. Deck Store	24. Registration-Flag Expenses
9. Dry Dock	25. Ropes
10. Engine Maintenance	26. Safety
11. Engine Store	27. Spare
12. Initial Stores	28. Spare and Store Handling
13. Insurance	29. Stationary
14. Inventory	30. Survey
15. LSA and FFA Inspection	31. Telecom
16. Medical and Support	

***Table 3.** Activity centers*

Activity Code	Activity Center
C1	Load Finding
C2	Customer Operation
C3	Port Operation
C4	Ship Operation
C5	Inspection
C6	Crewing

carriage contracts. In general, it can be done with hundreds of mail or phone calls daily in ship enterprises.

C2 - Customer Operation: This section covers sharing all the situations concerning the customer with the customer for the agreed loading operation and organizing the organization. The loading operation for the agreed loading, the communication of the ship, voyage, and cargo details to the parties, keeping in touch with the customer during loading, transportation, and unloading, issuing the final invoice, calculating the demurrage/dispatch payments that may occur at the end of the loading, and performing the invoice processes are discussed in the customer operation section.

C3 - Port Operation: Ensuring the coordination at the ports where loading and unloading occur takes place in this part. It is ensured that the parts related to the ship, such as communication with the agency in the ports, communication with the ship, the realization of inspections, if any, and their organization, and the delivery of solid and liquid wastes, are carried out in a controlled manner. Here, the customer is informed about the parts that concern the customer by interacting with the customer operation department.

C4 - Ship Operation: Examines activities during the transportation of loaded goods. Ship-related events. It covers reports from the ship and unusual circumstances.

C5 - Inspection: These are the activities carried out in the case of regular or random inspections such as port inspection, classification inspection, and ISM inspection. This includes communication with inspection bodies, interactions, and activities during the inspection.

C6 - Crewing: This section covers the operation of the ship's boarding and disembarking crew. Crew planning, transportation and accommodation activities, crew certification, and training are reviewed in this section.

In this step of the ABC method, with the determination of the centers, the activities carried out for service production are also distributed to the centers. The activities carried out to produce the service are grouped under 3 main headings. These are the "Customer Operation", which communicates with the customer during cargo transportation, "Technical Operation", which connects the ship and the office for the ship to complete its course, and "Ship Operation", which establishes the connection between the seafarers and the ship. The distribution of activities to activity centers according to the main service production sites is given in Table 4, Table 5, and Table 6.

Table 4. *Customer operation activity analysis, activity centers, and cost factors*

	Activity	Activity Factor	Activity Center
Customer Operation	New shipment mails	Email	C1
	Port Cost requests	Email	C1
	Mail not available for a new shipment	Email	C1
	Bidding to the customer	Email	C1
	Contract approval	Email	C1
	Notification of ship details to the customer	Email	C2
	Notification of daily ETA information to the customer	Email	C2
	Laycan control with the customer	Email	C2
	Laycan agreement mail	Email	C2
	Notification of berthing details to the customer	Email	C2
	NOR information to the customer	Email	C2
	Report SOF information to the customer	Email	C2
	Sending samples of port documents to the customer	Email	C2
	Delivery of the bill of lading to the customer	Email	C2
	Send departure information to the customer	Email	C2

Step 5. Determination of the Costs of Activity Centers: The process of allocating expenses among the activity centers identified in step 4 was initiated. Financial data obtained from real ship management companies. While distributing the indirect costs, Table 7 was created by considering the conditions necessary for the voyage. Table 7 shows the distribution of indirect costs by activity centers and cost drivers. In this spot, expenditures are allocated to the participating units following their use. For illustration, office supply depreciation costs are distributed according to the amount of equipment in each activity center. There are 35 computers at the company. According to the number of computers in the departments, they were divided. It was found that it would cost $41.46 for the load-finding activities and $82.93 for the crew activity center. The proportioning item used to distribute the total amount of each cost item to the activity centers is shown in the Cost Driver column of Table 7.

Step 6. Finding the Value of Cost Factors: The calculation of unit prices of activities in the determined activity centers is accomplished in this step. As stated previously, the simulation of the study was repeated 60 times for a 1-month activity period using the ARENA simulation. This helped to determine the amount of activity with sparse, average, and intensive transactions that the firm may encounter in a month. Assuming that all activities are conducted via e-mail, unit price calculations are made. During the calculation, the average monthly activity amount was converted into an annual amount, and the unit price was determined as the percentage of the activity amount spent by each activity center. The average activity amounts and unit prices of each activity center are shown in Table 8. The ratio of the average activity amount to the total average activity and the percentage annual activity amount of each activity center are found. Because the total cost is calculated annually, the calculation was made over the annual average mail. By dividing the total figures of each activity center specified in Table 7 by the annual number of activities, the unit prices of each activity can be found separately according to the activity centers. As an example, according to the simulation results, an average of 6,556 emails were received per month. On average, 548 of these e-mails were related to the shipment in the study. The calculation example of C1 is as follows. C1's approximate unit price are calculated as follows:

- 142/548 = 0.26 (percent of C1)
- (6,556 x 12) 0.26 = 20,386 emails (yearly activity for C1)
- 6,410.05 / 20,386 = 0.31 USD/email (unit price of C1)

Step 7. Determination of the Activity Center Cost of the Cost Object: In this step, the total indirect costs are calculated over the activity amounts spent for the determined voyage. Indirect cost amounts determined over possible minimum, average, and maximum activities in Table 8 are given in Table 9.

Step 8. Determination of the Total and Unit Price of the Cost Object: In this step, the total cost of the voyage, which is determined by adding the direct, voyage, and indirect costs, is determined. The obtained results are shown in Table 10.

Table 5. *Technical operation activity analysis, activity centers, and cost factors*

Main Service Production	Activity	Activity Factor	Activity Center
Technical Operation	Inform the agency about port requirements	Email	C3
	Sending a bill of lading sample to the agency	Email	C3
	Sending agency details to the company for the needs	Email	C3
	Notifying the port of the seafarer information that will participate in the ship	Email	C3
	Learning the berthing details from the agency	Email	C3
	Monitoring agency emails	Email	C3
	Information to the agency about the company that will sell the material to be sent to the ship	Email	C3
	Supply of port arrival documents required for the destination port	Email	C3
	Submission of port arrival documents to the port authorities	Email	C3
	Arrangement of the port documents	Email	C3
	Reporting DPA information to the port	Email	C3
	Get a quote for the provision wishless	Email	C4
	Unforeseen PSC control information from the captain	Email	C4
	Notify Dpa for PSC	Email	C4
	Notifying the ship of the information about the seafarer to embark	Email	C4
	Notification of new shipment details to the ship	Email	C4
	Get quotes for store items	Email	C4
	Get spare parts to offer for ship urgent needs	Email	C4
	Get a fuel quote for the voyage	Email	C4
	Inform the ship about refueling	Email	C4
	Sending the information of those who want to disembark the ship to Human Resources	Email	C4
	Notifying the fuel company about the port/anchor area for refueling	Email	C4
	Checking fuel analysis details from the ship	Email	C4
	Notifying the port details for the seafarer who will disembark	Email	C4
	Reading the request mail of seafarers who want to disembark	Email	C4
	Notify the ship of the information about the seafarer to embark	Email	C4
	Sharing voyage details with HR for embarkation procedures	Email	C4
	Act for deficiencies in surveys	Email	C4
	Providing inspection information to the ship	Email	C4
	Inform the agent about refueling	Email	C4
	Reading health needs mail	Email	C4
	Inform the Agency about health needs	Email	C4
	Forward future loading information to the ship	Email	C4
	Review of the inspection report	Email	C4
	Reading the DPA report	Email	C4
	Sending an ambulance for a health problem	Email	C4

Table 6. *Ship operation activity analysis, activity centers, and cost factors*

	Activity	Activity Factor	Activity Center
Ship Operation	Request checklist from the ship for the survey	Email	C5
	Checklist control	Email	C5
	Forwarding the survey details to the agency authorities	Email	C5
	Flag state calls for an inspection	Email	C5
	Notifying agency for flag state inspection	Email	C5
	Notifying the port of office worker information to accompany the survey	Email	C5
	DPA's date adjustment for internal audit	Email	C5
	DPA report preparation and submission after the audit	Email	C5
	Notify the ship about the internal audit	Email	C5
	Post-audit report preparation	Email	C5
	Attending the port for the survey (DPA)	Voyage	C5
	Notifying the technical team of the seafarer information who will participate in the ship	Email	C6
	Obtaining voyage information for the seafarer who will disembark	Email	C6
	Checking eligibility for the disembarking seafarer	Email	C6
	evaluation after an interview with the intern	Candidate	C6
	Notifying interns of their admissions	Candidate	C6
	Evaluate intern applications	Candidate	C6
	Requesting the necessary documents for those who are suitable for an internship	Email	C6
	Evaluating job applications	Candidate	C6
	Checking and making appropriate the missing participation documents	Candidate	C6
	E-mailing new staff that has been hired	Email	C6
	Invite interns for interviews	Email	C6
	Number of interns interviewed	Email	C6
	Providing ship information to the seafarer who will embark	Email	C6

Table 7. *Activity centers and cost drivers (USD)*

Costs	Cost Drivers	C1	C2	C3	C4	C5	C6	Total
Telecommunication expenses	Number of personnel	144.40	144.40	108.30	90.25	54.15	36.10	577.62
Office overall expenses	Number of personnel	51.86	51.86	46.09	46.09	51.86	57.62	305.37
Cargo and postal services expenses	Number of shipments		190.01					190.01
Chamber and fee expenses	Number of ships				267.15			267.15
Bank expenses	Number of shipments	14.44	14.44	14.44	14.44	14.44	14.44	86.64
Meal allowance	Number of personnel	508.25	508.25	508.25	508.25	609.90	1,016.50	3,659.41
Workplace rental expenses	Meter square	311.91	311.91	277.26	277.26	311.91	346.57	1,836.82
Accounting expenses	Number of personnel		534.92		534.92			1,069.85
Transportation expenses	Number of cars	127.74	127.74	127.74	127.74		255.48	766.45
Consulting expenses	Number of ships				75.34			75.34
Vehicle maintenance expenses	Number of cars					53.59		53.59
Gross salary	Number of personnel	4,192.02	4,496.93	4,189.35	4,189.35	17,008.80	6,551.03	40,627.47
Vehicle insurance and policy expenses	Number of cars					104.21		104.21
Notary expenses	Number of agencies			40.19	40.19			80.39
Fuel expenses	Number of cars					1,965.09		1,965.09
Representation and entertainment expenses	Number of ships	385.08	385.08	385.08	385.08	385.08	385.08	2,310.47
Transportation charges of seafearers	Number of seafarers	491.36	491.36	491.36	491.36	491.36	491.36	2,948.16
Depreciation (Office tools)	Number of office tools	41.46	41.46	41.46	41.46	49.76	82.93	298.55
Finance expenses	Meter square	141.52	141.52	141.52	141.52	141.52	141.52	849.10
Total		**6,410.05**	**7,439.88**	**6,371.05**	**7,230.41**	**21,241.66**	**9,378.64**	**58,071.69**

Table 8. *Unit prices of the activity centers*

Activity Code	Activity Center	Sparse	Average	Intensive	% Activity	Email quantity	Unit price (USD)
C1	Load Finding	14	142	380	26	20,386	**0.314434**
C2	Customer Operation	110	115	123	21	16,510	**0.450629**
C3	Port Operation	98	134	221	24	19,237	**0.331187**
C4	Ship Operation	16	31	76	6	4,450	**1.624811**
C5	Inspection	8	15	19	3	2,153	**9.866077**
C6	Crewing	63	111	209	20	15,935	**0.588556**
TOTAL		309	548	1,028	100	78,672	
Simulation results		709	6,556	19,054			

Table 9. *Indirect costs according to ABC*

	Sparse	Average	Intensive
Indirect costs (USD)	228.43	404.54	682.05

Table 10. *Unit prices per tonnage for sparse, average, and intensive activities ($)*

		Yearly	Monthly	Daily	Voyage	Unit prices per tonnage
Costs of Sparse Activity	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				228.43	0.00
	Total	3,444,831.82	287,069.32	9,437.90	796,404.44	7.96
Costs of Average Activity		**Yearly**	**Monthly**	**Daily**	**Voyage**	**Unit prices per tonnage**
	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				404.54	0.00
	Total	3,444,831.82	287,069.32	9,437.90	796,580.55	7.97
Costs of Intensive Activity		**Yearly**	**Monthly**	**Daily**	**Voyage**	**Unit prices per tonnage**
	Direct Costs	3,444,831.82	287,069.32	9,437.90	264,261.07	2.64
	Voyage Costs				531,914.93	5.32
	Indirect Costs				682.05	0.01
	Total	3,444,831.82	287,069.32	9,437.90	796,858.06	7.97

4. Results

In this study, the cost of a ship operating company was calculated using the ABC method. Apart from the other sectors, in addition to the high costs faced by a ship even if it does not carry cargo, costs belong to only a determined voyage. These costs are called voyage costs. In addition to direct and voyage costs, cost items such as office workers and transactions, which are also used in this calculation, have also been included in the calculation as indirect cost items. In companies operating ships using the traditional costing method, indirect cost items are calculated by dividing the ships operated by the company equally. Table 11 shows the unit price and total cost amounts obtained from the traditional costing and ABC methods.

According to the data in Table 11, while the total cost of 100,000 tons of cargo is $803,491.66 according to the traditional costing method, the cost of the ship is $796,404.44 in an average activity period concerning the ABC method. This shows that the cost of this ship, which carries 100,000 tons of cargo by making 4 voyages in 1 month, is $6,911.11 less than ABC. It is concluded that even the same loading in a very busy period costs $6,633.60 less than the cost amount in traditional costing. Considering that the total cost incurred by the firm during the year has not changed, the $7,000 difference in this calculation indicates

***Table 11**. Traditional Costing and ABC Results*

	Traditional Costing ($)	Activity-Based Costing		
		Sparse ($)	Average ($)	Intensive ($)
Per tonnage	8.03	7.96	7.97	7.97
Total Shipment	803,491.66	796,404.44	796,580.55	796,858.06
Difference	0.00	-7,087.22	-6,911.11	-6,633.60
Percentage		-0.88	-0.86	-0.83

that the firm's cost in other shipments is higher than their calculations.

5. Discussion and Conclusion

It is a mode of transportation that possesses unique aspects of marine transportation. In this work, a marine transport company's operations are analyzed and simulated while considering its distinctive structure. The ABC method developed by Cooper and Kaplan [45] was utilized to interpret the simulation results, and the findings were evaluated.

In the fiercely competitive maritime sector, activities were decided upon by negotiating with corporations to establish the proper cost structure. Whenever there was a lack of data, assumptions were formed, as was the case with the previously mentioned [14] study. These assumptions were developed because of a lack of data as well as the reluctance of businesses, as seen in the study [46], to offer information on certain topics (such as financial information and operations).

This research examined the international marine transport process of a ship management company operating in Türkiye, which consists of 4 voyages between Tekirdağ and Bari. These 4 voyages lasted a cumulative 28 days. ARENA simulation was used to model the activities indicated using the ABC method. To improve the precision of the simulation results, a period of 5 years (60 months) was simulated. In this way, it has been determined how the expenses may vary depending on the sparse, average, and intensive period by examining the many variables that the company may encounter during this transportation voyage. The results of the 60-month simulation obtained using the ABC method were used to calculate the voyage cost. It is determined that the companies accomplish this transportation at a cost of approximately $7,000 less for this transportation voyage when the ABC results are compared to the traditional costing method. This outcome shows that the company might be more competitive during the bidding stage. Additionally, calculations are performed for yearly expenses. It might be claimed that the company transports $7,000 more on other shipments, given that the annual total cost remains the same. The reason for this is that the traditional costing method performs volumetric cost calculation. Since the ABC method considers the activities performed during service production, it does not include costs in volumetric service production. For this reason, the shipping company whose cost calculations were made in this study could not see that it incurred more costs than expected in other shipments because it did not consider the activity amounts in other shipments. The company's cost estimations diverge from one another and do not adhere to the idea of a sustainable financial structure. In addition to providing financial data, this modeling facilitates simulation updates and scenario analysis for SOs. International regulators have imposed obligations on SOs, one of which is decarbonization, which is a contemporary issue. By considering the potential outcomes while performing these duties, SOs will be better able to make strategic decisions that look forward.

The fact that the ABC approach is frequently used in other transportation techniques, despite the absence of studies using it in the field of maritime transport, speaks volumes about the significance of the topic and modeling. As instances of its significance, studies on the rail [19], road [47], and air [21] transportation sectors might be presented. These studies' recommendations to companies demonstrate the critical role that modeling can play in assisting companies to grow a sustainable cost structure.

As mentioned by earlier investigations, a closer examination of the ABC method stages is required to improve the quality of the studies. As a result researchers must collaborate with businesses for a longer duration and in a demanding setting. This might be described as one of the time- and money-related drawbacks of modeling. However, this undesirable circumstance, which is expressed next to the intended results, may be tolerated.

In this study, the outcomes gained through simulation indicate both the progress of modeling and its relevance to the marine industry. Modeling will be a pioneer in their implementation, especially in the marine sector where there are not only SOs but also various maritime phenomena, including brokerage, agency, and port management. In terms of modeling, it has been observed that simulation makes it simpler to find the idle capacity, which is challenging to determine using the ABC method. Even though the Time-Driven ABC technique makes it simpler to calculate idle capacity [48], simulation support also has additional benefits, including making it simple to determine idle capacity.

To obtain more comprehensive data for future studies, involving other stakeholders in the maritime sector will greatly enhance the findings. It goes without saying that obtaining precise activity data on the ship will enhance modeling and outcomes. As noted in other studies [49], company managers' comprehension of modeling and its necessity is the most important requirement for all of these to occur.

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Practical Design Framework for Lobster-Type Motor Yachts

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Abstract

Motor yacht design is a multidisciplinary process that includes qualitative, quantitative, and iterative analyses. There are many personalized design and engineering steps from construction material selection to interior design; therefore, a practical design guide is required. In this study, 27 active lobster-type motor yachts whose overall lengths range from 10.5 m to 22.6 m were investigated in terms of hull and superstructure design and propulsion. Hull forms are modeled with CAD and form characteristics are calculated. Moreover, the hull form, superstructure, and deckhouse design parameters are presented using CAD data, and length-based correlations are made using layouts. In addition, the Savitsky method is used for semi-planning and planning hulls to calculate resistance and power data. The existing conventional diesel-mechanical and diesel-pod drive propulsion systems onboard yachts are compared, and alternative propulsion systems are discussed. Finally, a novel and practical design framework is created for use in the preliminary design phase of lobster-type motor yachts.

Keywords: Yacht design, Motor yacht, Lobster yachts, Propulsion systems, Design framework

1. Introduction

Yacht design is a quantitative process that consists of iterations to satisfy specified requirements [1]. In general, a ship that is designed and planned to be built should include up-to-date technologies, be efficient in terms of construction and operation, and comply with applicable national and international safety and security rules [2]. Although it is a multidisciplinary study, the yacht design process is conducted under the leadership of the engineering discipline [3]. In previous studies [1,4,5], the design process of ships was illustrated with a spiral to express its iterative nature. Although the number, sequence, or name of each step in these design spirals may differ, they all consist of processes that follow sequential progress to reach the optimum solution. Therefore, a holistic approach has been used in the design of ships, and this approach aims to solve the generic design optimization problem, which is established on parametric models, and multi-objective optimization criterion under constraints [6].

Compared with sailboat forms, motor yacht forms are more open to diversity and innovation [7]. The absence of sailing and rigging equipment allows for increased freedom in the arrangement of interior spaces of motor yachts [8]. The fact that they offer more functional and larger interior volume compared with sailing yachts is among the reasons why motor yachts are preferred [9]. Although the categorization of the hull form as displacement, semi-displacement, or planning is used for motor yachts, this categorization is not sufficient to define the above-water parts of the motor yachts. At this point, the type names of lobster, trawler, open, sport, weekend, flybridge, or hard-top etc. are used based on all or some of the parts of these yachts above the water [10]. Among the many motor yacht boat types used, some stand out with their historical backgrounds. One of the classical motor yacht forms, lobster-type boats, is also a prominent motor yacht type. Approximately 25% of the classical boat market in the world comprises lobster-type boats [11].

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A semi-displacement hull, a shear line rising from aft to the flared bow, and a stern form with a remarkable tumblehome are listed as the characteristics of a classic lobster boat, which has been used for fishery purposes [12]. With the effect of the depression experienced in the market in the 1930s, the companies producing luxury boats turned to the production of smaller and affordable boats, which was effective in the emergence of lobster-type yachts [11]. The lobster-type boats, which were originally a fishing boat type and manufactured from wood in the past, are now manufactured with composite materials and have become comfortable boats that can reach higher speeds thanks to their innovative forms [13]. Figure 1 illustrates a classic lobster-type boat [11].

With technological development not only in the construction material but also in the equipment used, it is possible to see an increase in variety and efficiency in lobster-type yachts. Figure 2 shows a lobster-type yacht built in Bodrum, Türkiye.

In their research, Özgel Felek and Arabacıoğlu [14] have investigated trawler-type yachts in terms of partition and layout parameters and obtained a parametric design guideline for this specific motor yacht type. In another study [11], classic lobster-type boats have been compared with other yacht types, and a lobster boat with a L_{OA} of 14,32 m has been designed. Arslan [8] has focused on the interior design process and criteria of motor yachts. Similarly, in the research of Aydın and Yılmaz Aydın [9], yacht interior design was analyzed with both qualitative and quantitative data.

This study examined 27 active lobster-type motor yachts with overall lengths ranging from 10.5 m to 22.6 m. The focus of this investigation includes the design of both the hull and superstructure, as well as the propulsion systems. Computer-aided design (CAD) is employed to model the hull forms to compute their specific characteristics. The study also presents the design parameters of the hull, superstructure, and deckhouse using CAD data. Additionally, the Savitsky method is used to calculate the resistance and power data for the modeled semi-planning and planning hulls. This study compares traditional diesel-mechanical and diesel-pod drive propulsion systems installed on these yachts and explores alternative propulsion options. Finally, a practical design framework is developed for use in the initial design stages of lobster-type motor yachts. In an area where research has traditionally focused on more common yacht types, this study delves into the features of lobster-type motor yachts that will be used in the design process, which has seen limited academic research. Moreover, by providing innovative alternative propulsion system suggestions and establishing a correlation for power estimation at the initial design stage, this research not only advances knowledge in lobster-type yacht design but also makes a valuable contribution to the yacht design and engineering sector.

2. Methodology

In this research, 27 lobster-type motor yachts were investigated to obtain hull form and superstructure design parameters. L_{OA} of the investigated yachts ranged from 10.50 to 22.58 m. The investigated yachts were built between 1996 and 2022, and all are currently in service. After the data collection phase, the 3D hull model of each0 yacht was created using Rhino3D [15] and exported to Maxsurf [16] in IGES format for hydrostatic calculations. In addition, some non-dimensional hull form and superstructure parameters are calculated manually. After obtaining the hull form characteristics and deckhouse parameters, the resistance of the hulls is estimated using the Savitsky semi-planning/planning method. Using the resistance values, power predictions were made and compared with the installed propulsion power capacities of existing yachts. Alternative propulsion systems are discussed, and a practical design framework is obtained. The workflow of the study is presented in Figure 3.

Figure 1. *A classic lobster-type boat [11]*

Figure 2. *A lobster-type yacht built in Bodrum, Türkiye*

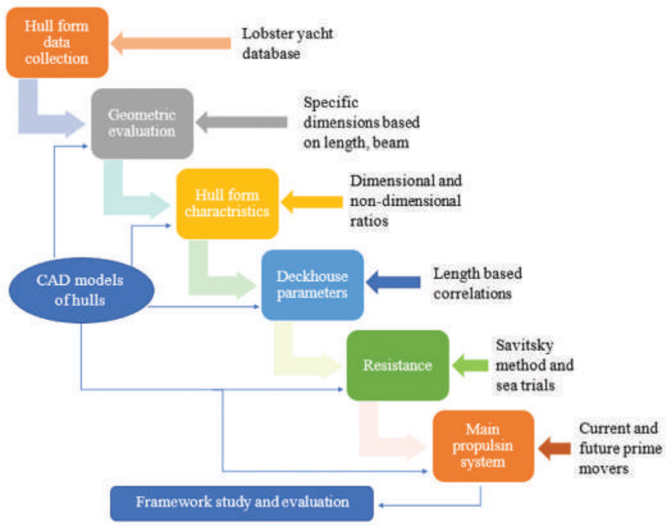

Figure 3. *Workflow of the design framework study*

3. Results

The results of the study were discussed from two main perspectives: design-based evaluation and engineering-based evaluation. Design-based evaluation includes the explanation of parameters related to the hull form and the superstructure design. In the engineering-based evaluation, the hydrostatic parameters and propulsion system selections of the investigated yachts are evaluated.

3.1. Design-Based Evaluation

In the design-based evaluation of lobster-type yachts, hull form characteristics and design parameters related to deck layout were examined. Hull form parameters are used for predicting the resistance, seakeeping, maneuvering, and hydrostatic characteristics of yachts [17,18]. Moreover, dimensionless coefficients obtained from some main dimensions are seen as distinguishing parameters in defining the hull form, as they vary depending on the type of boat. In this context, the evaluated parameters are as follows:

• Hull form design parameters;

o Hull form coefficients: C_B, C_P, C_M

o Displacement with respect to L_{OA}

o Longitudinal center of buoyancy (LCB), as a percentage of L_{WL}

o Length to beam ratios: L_{OA}/B and L_{WL}/B_{WL}

o Length ratios: L_{WL}/L_{OA} and L_{HULL}/L_{OA}

o Beam ratios: B_{WL}/B and $B_{TRANSOM}/B$

o Angle of the bow

• Superstructure and deckhouse design parameters;

o Starting and end locations of the superstructure

o $L_{SUPERSTRUCTURE}/L_{HULL}$

o B_{DECK}/B

51.9% of the motor yachts examined in the research were made of composite material and 48.1% of them were made of wood. In addition, it was observed that 78.6% of the boats made of wood were manufactured with the lamination method and the others with the traditional method.

3.1.1. Hull form design parameters

Hull form coefficients are listed among the key parameters for estimating hull form characteristics in the design process [18]. The block coefficient (C_B), prismatic coefficient (C_P), and midship coefficient (C_M) are commonly used not only for comparing different hull forms but also for making estimations by calculations. Lower values of the block coefficient (C_B) indicate low power requirements and high seakeeping characteristics [19], whereas a higher value of this coefficient is seen as an indicator of high wave resistance at some specific speeds [20]. The Prismatic coefficient (C_P) is a parameter that gives an idea about the fullness of the underwater part of the hull and the slenderness of the bow and stern [21] and is also among the factors affecting the resistance calculations of the boat [22]. Used in combination with parameters such as block coefficient (C_B) and B/T, the midship coefficient (C_M) is used to determine the wetted area of the hull and various resistance characteristics [5].

The LCB is one of the key parameters used to distribute the loads correctly and eliminate trim [23]. In addition, if the LCB is shifted too much to the bow, intense wave formation occurs around the bow shoulders, and too much shifting of this point to the aft side causes a loss in propulsion efficiency due to separation and eddy formation in the flow [5]. Table 1 represents the minimum, maximum, and mean values of LCB (% of L_{WL}), C_B, C_P, and C_M for the yachts investigated.

As the total weight of the yacht has to be equal to the displacement, determining the displacement properly is the most critical step in yacht design [23]. Figure 4 shows the distribution of displacement (ton) with respect to L_{OA} (m) for lobster-type yachts.

The ratio between L_{OA} and L_{WL} is a parameter used to estimate overhangs in the fore and aft directions of a yacht hull [18,24]. Another ratio used in the design process,

Table 1. *Minimum, mean and maximum values of LCB (% of L_{WL}), C_B, C_M and C_P*

	Minimum	Mean	Maximum
LCB (%)	43.270	46.228	49.017
C_B	0.239	0.307	0.370
C_M	0.459	0.510	0.629
C_P	0.508	0.604	0.739

LCB %: Longitudinal distance from the aft perpendicular to the center of buoyancy (as a percentage of L_{WL}), C_B: Block coefficient, C_M: Midship section coefficient, C_P: Prismatic coefficient

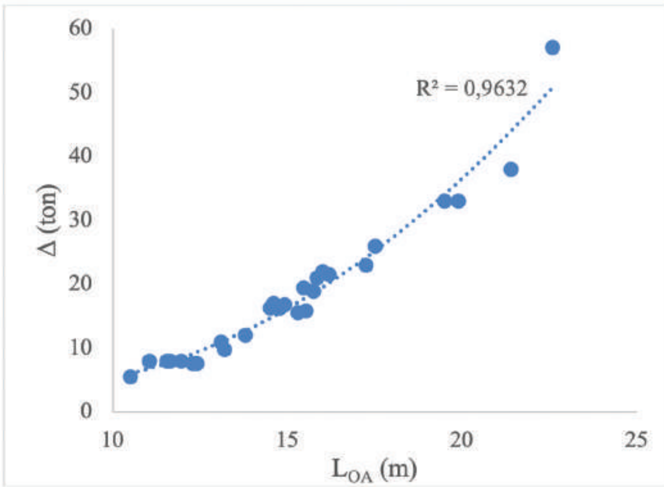

Figure 4. *LOA (m) -Displacement volume (m³) distribution*

L_{OA}/B, provides information about the mid-section width characteristic of the boat [1] and is used in speed-resistance calculations [19]. L_{OA}/B and L_{WL}/B_{WL} are used to quantify the beaminess of a boat [25]. L_{HULL}/L_{OA} ratio is used to have an opinion about the attachments in the fore and aft direction, such as the platform or the bow spirits in the yachts. In this research, the only attachment included within the L_{OA} was the platforms. The ratio of B_{WL}/B gives an idea of the geometry of the midship section above the waterline for a hull. Because the geometry of the transom is among the distinctive characteristics of lobster-type yachts, the $B_{TRANSOM}/B$ ratio was calculated within the research. Table 2 includes the minimum, maximum, and mean values for the design parameters of the lobster yachts' hull forms.

When the type of the stern form in the transversal section was investigated for lobster-type yachts, 21 of the 27 yachts had a tumblehome form, while the others had other forms in the stern. Another design parameter related to the hull form was the angle of the bow for the lobster-type yachts, which varied between 47° to 83° and its mean value was calculated as 60.89°.

3.1.2. Deck layout parameters

The superstructures are at such a level that they can form the heart of life on the boat, as it is an area that yacht owners and guests will prefer in bad weather, but that they can always enter and exit [26]. When the design parameters related to the superstructure design were examined, it was observed that the superstructure design parameters had high variability in contrast to the hull form parameters. Figure 5 illustrates the starting point, endpoint, and partition of the superstructure + deckhouses as a portion of L_{HULL} for lobster-type yachts.

3.2. Resistance and Propulsion

The propulsion systems of lobster-type yachts are based on conventional diesel engines. The evaluated group of yachts

Table 2. *Minimum, maximum, and mean values of the hull design parameters*

	Minimum	Mean	Maximum
L_{OA}/B	3.027	3.370	4.038
L_{WL}/B_{WL}	2.801	3.291	3.750
L_{WL}/L_{OA}	0.846	0.894	0.941
L_{HULL}/L_{OA}	0.911	0.951	0.969
B_{WL}/B	0.821	0.917	0.980
$B_{TRANSOM}/B$	0.730	0.858	0.943
L_{OA}: Length overall (m), L_{WL}: Length of the waterline (m), L_{HULL}: Length of the hull (m), $B_{TRANSOM}$: Beam of waterline (m), B_{WL}: Beam of waterline (m),			

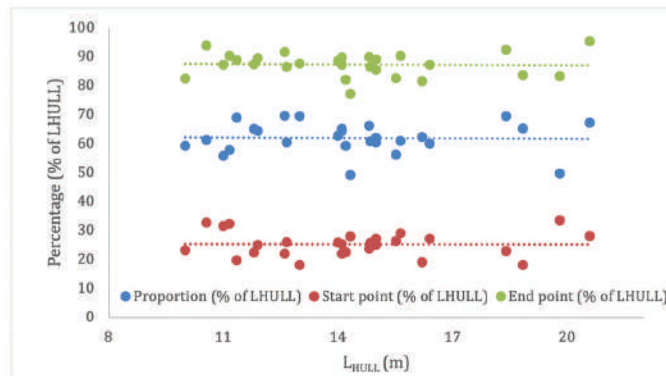

Figure 5. *Deck layout parameters*

had twin diesel engines coupled with shaft-propeller or pod drives. In this section, the resistance of the hulls is estimated for the calculation of effective and brake power. Then, the existing prime movers and available options are evaluated.

3.2.1. Resistance of hulls and power

The yacht hulls in the analyzed group are mainly planning types. The design speeds of yachts range between 13 and 35 knots. There are only two hulls designed for semi-planning in this group. Planning hulls, on the other hand, are high-speed crafts, and their design is challenging because of the complex hydrodynamic interactions that form at high speeds. These interactions can lead to problems such as porpoising, slamming, and cavitation [27]. To overcome these challenges, hull designers consider several factors, including hull geometry and configuration, hull weight and center of gravity, speed and operating conditions, and wetted surface conditions. In addition, the Savitsky method [28] is an early and effective tool based on empirical correlations developed from experiments to estimate hull resistance and performance. Empirical formulas were created after investigating the effects of length-to-beam ratio, displacement, deadrise angle, and center of gravity of hulls in regular waves or calm water [29]. Using the Savitsky method, resistance values of hulls are obtained at different speeds, as shown in Figure 6, which indicates the resistance change of a 15.5 m hull. According to the results, the calculated maximum resistances of the hulls are 10.33 kN (@35 knot), 17.82 kN (@34 knot), 28.74 kN (@30 knot), 40.25 kN (@29 knot) and 66,28 kN (@28 knot) for 10.5 m, 13.2 m, 16,20 m, 19.50 m and 22,58 m, respectively.

The effective and brake powers can be estimated using the calculated resistance, corresponding speed, and efficiencies [17,18]. The brake power of the yacht for which resistance change is presented in Figure 7 is calculated as 715 kW. The existing yacht has two pod-drive engine systems that generate 960 HP. Therefore, with an overall efficiency of 0.6, the existing brake power agrees with that of the calculated one. It is noteworthy that according to the resistance calculations based on the Savitsky planning and semi-planning models, the hull efficiency ranges between 0.50 and 0.60. Moreover, Figure 7 shows the brake power of the installed engines and the corresponding maximum speeds. According to the results, even if the overall lengths are similar, form characteristics and especially design speed determine the propulsion power.

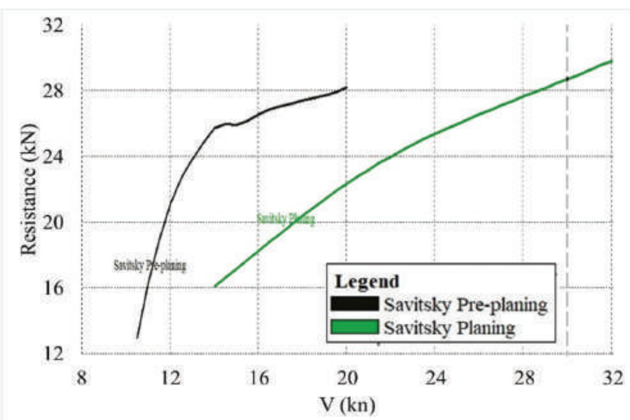

Figure 6. Resistance of a 16.2-m planning hull based on the Savitsky method

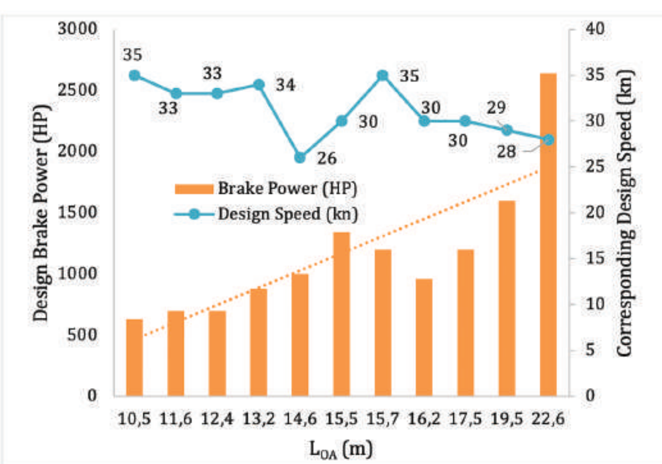

Figure 7. Brake powers of engines and corresponding design speeds of hulls

3.2.2. Main prime movers

Engine brake powers range from 450 HP to 2640 HP in accordance with the design speed and hull dimensions, as indicated in Figure 6. The propulsion system of the analyzed yachts consists of twin diesel engines coupled with shaft-propeller or twin diesel engines coupled with pod drives. Nineteen of the yachts have conventional diesel propulsion and 8 of them have an IPS (Inboard Performance System) configuration, which is claimed to be up to 30% more fuel efficient, has a lower noise level, and provides higher manoeuvrability compared to conventional diesel-shaft-propeller system [30]. The propulsion system selection for yachts is mainly based on customer choice, cost, dimensions, power requirements, and emission regulations, where marine diesel engines of above 130 kW power output have to comply with Annex VI NO_X limits [31].

Strict emission regulations have led the maritime industry to find alternative propulsion systems or fuels. Commercial ships have started to use cleaner fuels like Liquified Natural Gas (LNG) or methanol instead of Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO), which is the primary fuel for boats. Even if regulations regarding energy efficiency are not applied to yachts below 400 GT, there are many cleaner propulsion system options for small-scale boats. LNG-powered dual-fuel engines are mainly used in two-stroke divisions, and compared with methanol- and MDO-powered engines, they occupy much space onboard and are costlier [32]. On the other hand, a hybrid propulsion system that consists of diesel or gas engine-driven gensets integrated with battery units has been installed for yachts and is a viable option considering fuel saving, emission reduction, and comfort [33]. Apart from internal combustion engine-powered propulsion systems, all-electric yachts are on the agenda based on significant developments in battery technology [34]. Compared with other systems, the overall efficiency of all-electric propulsion systems is reported to be 67.8%, since the values for conventional diesel-mechanical and hybrid systems are 31.4% and 28.2%, respectively [34]. Using literature studies and engine manufacturers' reports, propulsion systems are compared in terms of basic properties, as shown in Table 3. Note that the assessments were made using the qualitative data obtained from the given references.

3.3. Design Framework

A design framework was developed based on the results obtained from design-based and resistance-propulsion analyses, as shown in Figure 8. Hull form characteristics and deck layout parameters are presented as correlations or mean values. In addition, a correlation is developed using the equation x which depends on displacement and velocity, to estimate the brake power of engines, as shown in Figure 8.

Table 3. *Comparison of Diesel-mechanical (D-M), Diesel-pod drive (D-P), Diesel-electric (D-E), and fully-electric (F-E) propulsion systems [30,33,35,36]*

Property	D-M	D-P	D-E	F-E
Engine type	Diesel	Diesel	Diesel	Electric
Drive system	Straight shaft	Pod drives	Shaft drives	Pod drives
Noise level	Louder	Quieter	Quieter	Quietest
Vibration level	Higher	Lower	Lower	Lowest
Fuel efficiency	Lower	Higher	Highest	Highest
Emissions (Hull to wake)	Higher (NOx, SOx, PM)	Lower (NOx, SOx, PM)	Lowest (NOx, SOx, PM)	Zero
Maneuverability	Less	More	Similar to D-M	Similar to D-M
Cost	Lower	Higher	Higher	Highest

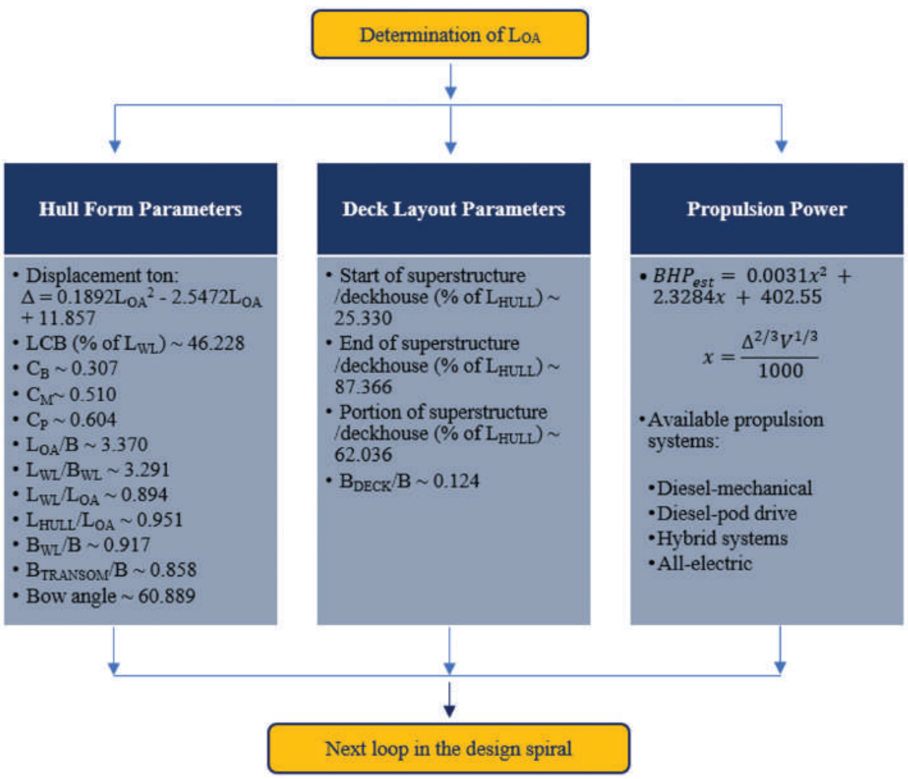

Figure 8. *Design framework for lobster-type motor yachts*

In this equation BHP_{est} shows the brake power requirement of the yacht in terms of HP. It should be noted that these correlations are practicable for lobster-type yachts whose overall lengths are between 10 and 24 m and design speeds are between 15 and 30 kt.

4. Conclusion

In this research, 27 lobster-type motor yachts are examined to collect relevant data on hull form, superstructure design parameters, and propulsion power. Collected data are used to obtain a novel design framework that enables estimating important parameters in the design phase of these motor yachts using only L_{OA} as an input. The following conclusions are drawn according to the analyzed data:

• Although the overall length range of lobster-type motor yachts varies between 10.5 and 22.6 m, it has been observed that the common usage range is between 14 and 17 m.

• When the deck layout parameters are examined, the values obtained vary in a wide range compared to the hull length of the boat. This variety is related to the design preferences and the design identity of each lobster-type yacht.

• The typical design speed of lobster-type yachts is observed at 30 kts (±2 kts). Twin diesel engines are used as prime movers coupled with shaft-propeller or pod drives.

• Lobster-type yachts are suitable for innovative solutions in areas such as propulsion systems and construction materials consistent with the general characteristics of motor yacht-type boats. Accordingly, it is possible to design and manufacture these yachts using innovative construction materials and higher energy-efficient propulsion systems.

The obtained results can be used as inputs for design optimization problems. Life-cycle assessments of alternative propulsion systems can be conducted for motor yachts in further studies.

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Authorship Contributions

Concept design: B. İ. Turan, and M. Akman, Data Collection or Processing: B. İ. Turan, and M. Akman, Analysis or Interpretation: B. İ. Turan, and M. Akman, Literature Review: B. İ. Turan, and M. Akman, Writing, Reviewing and Editing: B. İ. Turan, and M. Akman.

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An Empirical Study on the Influence of Internal and External Factors on Port Enterprise Employee Performance: A Case Study in Indonesia

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Abstract

Indonesia is an archipelago country with thousands of islands ranging from Sabang to Merauke. Because of these circumstances, port services are essential as a mode of transportation for transporting people or products from one island to another. To improve the performance of port services, the performance of its employees must be consistently upgraded. The purpose of this study was to investigate the components that influence the performance of Port Enterprise (PEs) employees. The total sample for the research is 262 PE employees spread across Jakarta. A survey was used to collect data, which was then processed using principal component factor analysis and ordinary least squares regression techniques. We categorize the factors that influence employee performance into two groups: those connected to the environment/company (external) and those related to employee personal characteristics (internal). According to the regression results, organizational climate, work environment, and job autonomy are work/environment components that have been empirically demonstrated to affect employee performance. Employee adaptability and skill development, on the other hand, represent components related to employee qualities.

Keywords: Employee performance, Port enterprise, Work environment, Job autonomy, Adaptation

1. Introduction

Port services encompass all aspects of port logistics, from cargo loading and unloading to marine engineering work. These activities are controlled by port companies, the majority of which are open to the public. As a result, proper management and supervision are critical for effectively carrying out all of the processes required for port activities [1]. In the context of Indonesia, there are 17,840 islands with a coastline of 95,181 km. This makes Indonesia the world's largest marine country [2]. Because Indonesia is an archipelagic country with two-thirds of its area covered by water, ports play a critical role in promoting economic growth, social mobility, and regional trade. This is achievable only if port activities are conducted efficiently [3]. Employee performance is inextricably linked to efficient company activities. Employees are a company's most valuable asset because their actions can have a substantial impact on its reputation and profitability [4]. Therefore, ensuring optimal employee performance is a crucial responsibility of the company.

The Tanjung Priok Port in Jakarta is a large port that serves as the main gateway for exports and imports and contributes significantly to national growth. According to the most recent data, the Non-Tax State Revenue (PNBP) generated by Tanjung Priok's Main Port in 2022 is IDR 413,162,043,000 [5]. This port has also contributed significantly to more than half of the transportation of products into and out of other nations through this port. Thus, Tanjung Priok Port is the busiest port in Indonesia [6]. Considering the significance of Tanjung Priok port, employee performance must be maintained and should not decline, as it did in 2018 at a port enterprise [7].

Employee performance can be influenced by a variety of factors, including characteristics at the individual level or those related to employees, such as a lack of intrinsic

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motivation, relevant knowledge, skills, and employee attitudes. Furthermore, several environmental factors (related to the company/work) such as corporate culture, organizational structure, job design, performance appraisal systems, power and politics in the company, and work and group dynamics are very likely to influence this decrease in performance. Several studies have found that both external and internal factors significantly impact employee performance [8,9]. Diamantidis and Chatzoglou [8] examined the influence of company-related factors, job-related factors, and employee-related factors on employee performance. The results of the study concluded that employee performance is a complex variable that can be influenced by many factors. The research indicates that both factors from management or the work environment (external) and internal employee factors are closely related to each other in influencing optimal performance. Nevertheless, research on the factors influencing the performance of port service companies is still very limited.

To assess performance, several studies have sought to link the operational effectiveness of port service companies with customer perceptions [1]. While studies from the perspective of employees are relatively uncommon, Pang and Lu [10] examined the influence of motivation on job satisfaction and organizational performance within the context of container shipping companies in Taiwan. This study exclusively used intrinsic factors to assess their correlation with employee performance. This research seeks to address this research gap by investigating both internal and external factors that could impact employee performance in the port industry. The purpose of this survey is to analyze the perceptions of Port Enterprise employees about the company for which they work. We attempt to provide a more exact and reliable research strategy for grouping indicators into appropriate variable dimensions by employing principal component factor analysis (PCFA).

Finally, this research contributes to stakeholders in several ways. First, it contributes to the development of knowledge and research by addressing the literature gaps on employee perceptions within the Port Authority. Research on factors influencing employee performance in the port industry is limited. Second, for management, this research assists them in understanding the internal and external factors that affect employee performance in port companies. This can provide crucial insights for management to enhance efficiency and productivity. Moreover, the research findings can serve as a knowledge foundation for developing more effective human resource management strategies in the shipping industry, especially within port environments. Furthermore, by understanding the factors influencing employee performance, port companies can enhance their competitiveness in the shipping industry. High-performing employees contribute to operational efficiency and customer satisfaction. Lastly, the context of Tanjung Priuk is crucial for continuing research due to its significant contribution to national development. The findings of this research can also have implications for government policies related to the development of the shipping industry. The government can use these insights to design policies that support sustainable growth and development. This research can serve as a crucial foundation for improving human resource management and employee performance in port companies, with a positive impact on the shipping industry as a whole.

The next section discusses the theory relevant to this research topic, namely, the self-determination theory (SDT). SDT is widely used in research on motivation, human behavior, and psychological well-being. In addition, the second section discusses the hypotheses we have developed. The third section addresses the methods used. To establish the main variables, we used the PCFA technique. To obtain estimates of the relationship between employee motivation and performance, we employed ordinary least square (OLS) regression. The fourth section is dedicated to discussing the results of PCFA and regression. This section also presents arguments and justifications for the findings. The final section contains the conclusions drawn from the research results.

2. Theoretical Framework and Hypothesis Development

2.1. SDT

According to SDT, different types of motivation have different functional catalysts, accompaniments, and consequences [11]. When applied to the organizational work environment, this theory posits that the type of motivation employees have for their work activities influences their performance and well-being [11]. This motivation can come from within the individual (without the interference of other forces), known as intrinsic motivation, or it can be created by conditions or controls outside the employee's self, known as extrinsic motivation. Based on this explanation, SDT illustrates that when a person (employee) is motivated (especially intrinsically motivated) toward the activities or tasks they are performing, they tend to work or complete their tasks well, independently, and possibly with more creativity. Thus, the expectations of satisfactory achievement or performance can be achieved.

Furthermore, the new SDT framework model specifically mentions two main indicators or elements that can affect employee performance: social context variables related to the workplace (workplace context) and variables related to individual differences [11]. Both of these aspects can influence employee performance, either directly or indirectly through motivation. The core concept of SDT's theory in describing employee performance is how employees can generate autonomous motivation, which is a circumstance in which employees engage in an activity (job) with a complete feeling of will, desire, and choice [12]. Employees are more likely to be independently motivated, produce better work, learn more effectively, and adapt to changing circumstances when they are aware of the value and purpose of their job, experience a sense of ownership and autonomy in carrying it out, and receive clear feedback and support [11]. Although this study does not specifically address motivation and employee performance, the logic of SDT can be used to explain how external (internal) factors related to extrinsic and intrinsic motivation can influence employee performance, as demonstrated in previous studies [9,13]. Figure 1 illustrates the framework of SDT.

SDT can be applied to the maritime port industry to understand and enhance employee motivation, performance, and well-being within this specific context. SDT can help explain the motivation of employees working in the maritime port industry. Port workers, including dockworkers, crane operators, and logistic personnel, often perform physically demanding and safety-sensitive tasks. SDT stated that understanding their intrinsic motivation (e.g., a genuine interest in their work, a sense of competence) and extrinsic motivation (e.g., recognition, fair compensation) is crucial for managers. This understanding can assist managers in designing motivation strategies tailored to their needs [13]. In addition, safety is a top priority in the maritime port industry due to the potential risks and hazards associated with port operation. SDT can be used to study the factors influencing employees' compliance with safety regulations and guidelines. For instance, autonomy-supportive management styles can enhance employees' intrinsic motivation to adhere to safety protocols [14]. High turnover rates can also be a challenge in the maritime port industry. SDT emphasizes the importance of addressing employees' basic psychological needs to enhance their motivation and commitment to the organization. By creating a work environment that nurtures autonomy, competence, and relatedness, port authorities can improve employee retention rates.

In summary, the SDT can be a valuable framework for studying and improving various aspects of the maritime port industry, including employee motivation, safety compliance, job satisfaction, skill development, and employee retention. By recognizing and addressing the basic psychological needs of port workers, organizations can create a more engaged and motivated workforce, leading to improved performance and overall well-being in the industry.

2.2. Employee Performance Influencing Factors

There are internal and external factors related to the employees themselves that affect employee performance within the company [15]. Regarding employee motivation, social context variables, such as organizational support and individual differences, are the two most significant factors determining the quality or quantity of employee work (performance). Diamantidis and Chatzoglou [8] further classified the factors influencing employee performance into three categories: corporate environmental factors such as management support, training culture, and organizational climate; work-related factors such as on-the-job communication, job autonomy, and work environment;

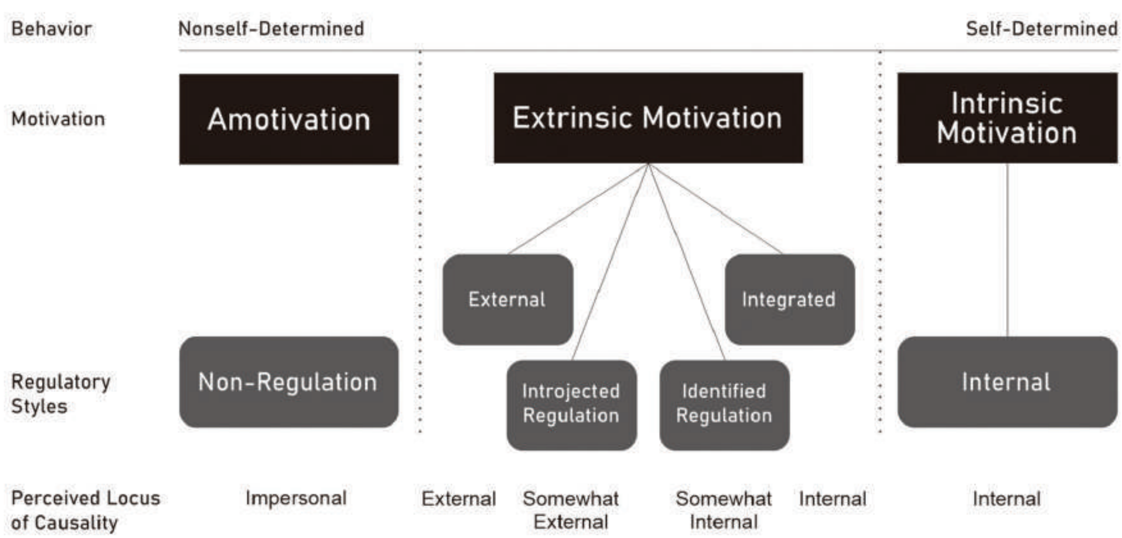

Figure 1. *Self-Determination Theory (SDT) Framework*

Sources: Ryan and Deci [12], redrawn by the researcher (2023) and employee characteristics such as intrinsic motivation, adaptability, skills, and commitment. Using the Diamantidis and Chatzoglou [8] employee evaluation model, this study divides the main hypotheses into two categories, with external factors related to the work environment and job factors and internal factors related to employee personal characteristics. Thus, the hypothesis developed can be explained as follows.

2.2.1. Environmental/company-related factors (external)

Employee performance is thought to be influenced by a variety of organizational factors, including corporate culture, organizational structure, job design, performance appraisal systems, and the political dynamics that emerge within them [4,11]. Several more studies discuss environmental/company characteristics such as leadership style [16,17], company values and beliefs, and how the organization recognizes/supports employees. In essence, things that are unrelated to the personal characteristics of employees are included in the external factors of employees [15].

According to the SDT, the existence of organizational support can facilitate employee motivation to fulfill some or all of their overall basic psychological needs, so that the support felt by employees directly or indirectly can significantly improve performance [11]. In other words, when employees receive positive organizational support (such as raises in salary, incentives, a comfortable work environment, competent leadership, and so on), their need for competence, connectivity, and independence (autonomy) is achieved. As a result, employees will be motivated to work more thoroughly and diligently, and their performance will improve. Thus, a positive relationship exists between extrinsic motivation from organizational support and employee performance, according to the SDT framework. This relationship can be explained by examining employees' level of effort, which is higher when people are extrinsically motivated (by organizational settings), and this level of effort results in higher performance [9].

Many studies have proven the relationship between organizational support, social aspects of the work environment, and employee performance. Parker et al. [18], for example, discovered that management support is positively linked to employee commitment and proactivity. Similarly, previous studies' findings yield the same results [19]. Furthermore, Ouakouak and Zaitouni [16] found that ethical and emotional leadership improves employee motivation, which has a favorable impact on employee job performance. Similar results were found in Pawirosumarto and Sarjana [17], a study of an Indonesian manufacturing company.

Other forms of organizational support that improve employee performance include intense training or educational programs [4,20]. Employees who undergo workplace training will be more motivated to achieve higher levels of performance. According to SDT, providing this training can be a method of meeting competency and autonomy needs. By teaching employees how to master or 'become proficient' in their tasks, training may generate a "feeling of competence" [9]. In addition, this sense of autonomy can also be increased when the organization emphasizes training that is really needed by employees (compatibility with tasks feelings of competence and autonomy over employee work may improve intrinsic motivation and result in better performance [11]. Other factors, such as company culture, have a significant impact on work performance, attitudes, and even the behavior of workers [21].

In addition to being influenced by factors related to the environment/organization, employee performance can also be influenced by factors related to employee work (job-related factors) [8]. For example, how work is delegated (job autonomy), communicated (job communication), and work environment circumstances that may limit or help employees work. Previous research has provided empirical evidence of the impact of these components. For example, Imam et al. [22] discovered that in addition to support from leaders (supervisors), internal communication (the exchange of work-related information between superiors and subordinates) plays an important role in increasing employee engagement. Clear, high-quality information from leaders can promote employee involvement, and they are more likely to reciprocate with positive behavior, leading to improved work performance.

Furthermore, Diamantidis and Chatzoglou [8] found that working environment conditions influence employee performance, either directly or indirectly. Employees face many challenges because of the constantly changing working environment conditions, such as changing tasks/jobs, endless career advancement, continual learning, and many types of additional mental and emotional pressures. These conditions necessitate that employees remain involved and satisfied with their work to achieve the intended outcomes [22]. The involvement of a leader or supervisor who can give positive affirmation in both the tasks and responsibilities of employees in the organization can improve employee performance [8]. In the context of the port industry, Hussein and Simba [23] examined the motivation influencing the behavior of employees at Mogadishu Al Port. Their research findings indicated that external factors such as wages, remuneration, and recognition from superiors significantly influence employee performance. Subsequently, more recent studies have confirmed this significant relationship [24].

The complex relationship between various organizational supports to improve employee performance can be explained by SDT, which shows that encouraging workplace conditions in which employees feel supported in their autonomy leads to better employee satisfaction and growth, as well as assurance of organizational effectiveness [11]. In brief, various organizational supports or company policies that promote employee autonomy and competence in the workplace can lead to increased employee intrinsic motivation, which in turn influences the quality and quantity of expected employee work.

Using SDT rationality, this study hypothesizes that the presence of organizational support, both related to the various aspects of the organization and the work of these various employees, will later facilitate greater employee motivation, particularly when this support fulfills or is consistent with the basic psychological needs of autonomy, competency and employee engagement [11,12]. As a result, these circumstances should enable them to increase their job performance. Formally, this study constructs the first hypothesis on the basis of the theory and evidence from the numerous studies mentioned above.

H1: Environmental/company factors influence the performance of Port Enterprise employees.

2.2.2. Employee characteristic factors (Internal)

Hiring employees with multiple skills is a beneficial asset for companies [8]. Apart from supporting them in performing their own specific tasks, these abilities are also used to assess the overall success of the company. This shows that the personal characteristics inherent in employees are critical in supporting the achievement of company targets. These characteristics are frequently related to intrinsic aspects that encourage employees to work, owing to the inherent nature of individual personalities. Nonetheless, Diamantidis and Chatzoglou [8] mention several other aspects as predictors of employee performance, including proactivity, adaptability, skill flexibility, commitment, and skill level. To some extent, all of these factors can affect employee performance.

In conducting their duties or performing their roles in the company, there are various characters or personalities of the employees. Some of them may be passive or proactive on the job. Bakker et al. [25] stated that if employees can proactively adapt to their work environment, they manage to stay engaged and perform well. Furthermore, being proactive has a beneficial impact on employee attitudes and behavior because proactive employees identify and generate opportunities for individual or team effectiveness [26]. Several other indicators, such as adaptability [8] and flexibility or creativity [13,27], can also empirically affect employee performance.

Furthermore, Diamantidis and Chatzoglou [8] found that when compared to the other dimensions, flexibility and intrinsic motivation are the dominating factors that have an immediate effect on employee performance. Several prior studies have found a positive relationship between intrinsic motivation and performance [9,13,28]. SDT explains that someone who performs an activity (for example, job) because they find it engaging and enjoyable (intrinsically motivated) prefers to give their best effort to that work or activity. Therefore, it can direct them to perform at their optimum level.

Van der Kolk et al. [9] further explains that there are several reasons why intrinsic motivation leads to increased performance. First, employees who are intrinsically motivated tend to set challenging goals for themselves to improve their task competence and performance [28]. In addition, employees who perceive jobs to be more intrinsically motivated will put in more effort simply because they enjoy the activity [9,11]. Thus, based on the theory's explanation and some research findings, the second hypothesis of this study could be described as follows.

H2: Factors related to employee characteristics that affect the performance of Port Enterprise employees.

3. Research Method

This study employs a quantitative methodology using data collected through survey techniques. All employees in the Port Enterprose in the DKI Jakarta area, namely PT. The Tanjung Priok Port, Jakarta International Container Terminal, and Koja Container Terminal were included in this study. A five-point Likert scale was used to measure statements in the survey instrument. From one to 5, 1 represents strongly disagree and 5 represents strongly agree. The research began in 2018 and continued until 2020, before the pandemic. The pandemic temporarily halted this research because of changes in lifestyle and teaching patterns, which required a considerable time and effort to adapt to. Physical questionnaires were distributed with permission from the company management. This also contributed to a significant delay in the research because the responses from the completed questionnaires had to be manually inputted into digital form. Digital-based questionnaires may have more advantages, such as being more cost-effective and faster; however, paper-based questionnaires allow for higher response rates and validity because respondents can fill them out gradually in their leisure time [29].

There are three dimensions: employee performance, environment/company influences, and employee characteristics. Employee performance dimensions consist of 10 statements, dimensions of factors related to the environment/company as many as 20 statements, and factors related to employee characteristics as many as 20 statements. Therefore, the total number of statements in the questionnaire is 50.

The validity and reliability of the respondents' responses will be examined first. In this research dataset, indicators that do not pass will be discarded. Furthermore, the responses of each variable indicator were examined using PCFA. This PCFA technique is used to reduce the complexity of high-dimensional data while maintaining trends and patterns. This is accomplished by reducing the data to smaller dimensions that act as feature summaries [30]. Many studies have been conducted using this methodology, and they claim that using PCFA produces more accurate results than using manual methods by averaging the responses of each respondent [31].

Principal component analysis (PCA) is not the only technique for data reduction, but it has advantages over other techniques such as exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). PCA can be used to reduce dimensions in a large dataset while retaining most of the data's variability. This can be valuable in behavioral analysis involving many measurable variables, allowing researchers to focus on the most important components. In addition, PCA is relatively simple and efficient in its implementation [30,32]. However, PCA has some limitations, especially in the context of behavior. One of its limitations is that PCA does not consider the interpretation of latent factors, as is done in EFA. Because this study did not establish latent factors, PCA is more suitable for use.

Our empirical model examines whether environmental/company conditions and employee characteristics influence the performance of Port Enterprise employees. The model can be defined as follows.

$$PFM_{i} = \beta_0 Intercept + \sum_{i=1}^{j} \beta_i ENV + \sum_{i=j+1}^{k} \beta_i CHRT + \varepsilon \quad (1)$$

where the dependent variable (PFM/performance) is a performance variable, and the main independent variables are ENV (Environment) and CHRT (Characteristic). Each of these variables represents environmental/company factors and employee internal characteristics. The above regression model was conducted using STATA 16's OLS regression model. The research framework for this study is neatly illustrated in Figure 2 below.

4. Discussion

4.1. Demographics of the Respondents

We distributed a questionnaire to 264 respondents. Two survey findings cannot be used because the responses are incomplete. As a result, the total number of data points in this study was 262. The responses of the respondents are provided in Table 1 based on the data obtained from the distributed questionnaires. Male responders dominated all the observation objects, contributing to 81.68% of the total (8.32%). In terms of age, 37% of respondents were between the ages of 31 and 40, 32.06% were between the ages of 41 and 50, and only 6.11% were under the age of 30. Furthermore, 67% of respondents were bachelor graduates (S1), with 48.47% having worked for 5 to 7 years.

4.2. Principal Factor Component Analysis (PCFA)

Before proceeding to the PCFA process, we conducted

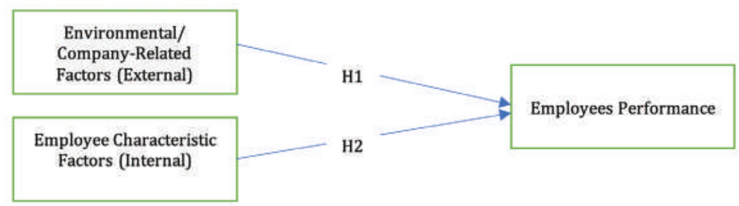

Figure 2. *Research Framework*

Table 1. *Profile of the respondents*

Demographic characteristics	Number of respondents	Percentage (%)
Gender		
Male	214	81.68%
Female	48	18.32%
Age		
21-30 years old	16	6.11%
31-40 years old	97	37.02%
41-50 years old	84	32.06%
>51 years old	65	24.81%
Educational level		
High school/Equivalent	5	1.91
Diploma (D1/D2/D3/D4)	32	12.21
Bachelor's degree (S1)	176	67.18
Master's degree (S2)	49	18.70
Work experience		
<2 years	3	1.15
3-5 years	24	9.16
5-7 years	127	48.47
>7 years	108	41.22
Total observations=262		
Source: Data processed by the researcher (2023)		

reliability and prior validity tests on all indicators of each variable. Indicators that fail these two tests will not be included. On the basis of the test findings, four indicators on employee-related factors were issued. The PCFA results for the three variables in this study are shown in Tables 2-4.

Table 2 shows that the KMO value is 0.65, with a significance value of 0.05. As a result, the existing data can be subjected to factor analysis (PCFA). Based on the same table, only one factor is formed out of the ten indicators in the employee performance variable. One component has a percentage of variance or proportion of 74.65%, which indicates that it represents 74.65% of all available variants. Furthermore, various factors with eigenvalues less than one represents the remainder. In addition, Table 3 shows the PCFA results for the "Environmental/Company-Related Factors (ENV)" variable.

Table 3 shows that the PCFA results provide five factors. The KMO value is 0.5617, and the significance level is 0.000, which is less than 0.05. This indicates that the PCFA analysis is suitable for use in a amount of the study data. The overall eigenvalue is 8.48. Keywords from the question are used to name each factor. Table 4 shows the PCFA results for factors related to employee characteristics.

On the basis of the aforementioned table, the PCFA technique condenses the components of factors relevant to employee characteristics into 3 factors. The KMO value was 1055.49, with a significance level of 0.0000. The three components are named on the basis of their respective keywords, similar to the previous factors. Six components were excluded from the variable because the validity test could not be applied to them. The definitions of each of these factors are presented in Table 5.

Table 2. *PCFA results on employee performance variables (PFM)*

Indicator code	Keyword	Performance
		Factor 1
PFM1	Meets requirements	0.3035
PFM2	Improved resolution	0.3868
PFM 3	Quantity of work	0.4389
PFM 4	Learning from more experienced individuals	0.5864
PFM 5	Be a role model	0.3856
PFM 6	Following the leader	0.5272
PFM 7	Complete work under all conditions	0.5440
PFM 8	Reached the target	0.4101
PFM 9	Unsupervised job	0.0365
PFM 10	Quality of work	-0.0847
Eigenvalue		1.67745
Proportion		0.7465
KMO		0.6497
k^2		371.43
Prob>chi^2		0.0000
Source: Data processed by the researcher (2023)		

After conducting the PCFA on all dimensions in this study, we noted that several of them were broken down into several variables. The changes made resulted in the study framework represented in Figure 2 Developed to be like the one in Figure 3 below.

4.3. Univariate Analysis

Univariate analysis is used to examine the relationship or correlation between variables alone. The results of the univariate test using the Pearson correlation technique are shown in Table 6.

According to the table, some dependent variables have significant relationships with the dependent variable. *CHRT_Skill, CHRT_Adapt, ENV_Climate, ENV_Dynamism, ENV_JobEnv,* and *ENV_Autonomy* are among these variables. These data indicate that several of the specified independent variables have significant effects on employee performance at a level of less than 1%. However, univariate testing results cannot be utilized to evaluate hypotheses because they exclude other variables as predictors in a model. This test examines the correlation between variables on its own, and if the relationship is very strong (close to 1), it must be omitted from the model because it is perfectly correlated.

4.4. Hypothesis Testing

We apply the OLS regression approach to test the hypothesis. We checked the variance inflation factor (VIF) on the study variables before performing the OLS regression to ensure that they were free of any multicollinearity problems. The test results are shown in Table 7. Based on the table, there are no values more than 10, implying that all variables in the study are free of multicollinearity problems.

Table 7 also includes the results of hypothesis testing. Column (1) is the result of the OLS regression for the influence of environmental/company factors on employee performance, Column (2) is the result of testing the influence of employee characteristics on employee performance, and Column (3) combines both factors in one model.

Column (1) shows that all environmental/company factors have been empirically shown to affect employee performance at the same time, indicating that Hypothesis 1 is supported. Once back at home, the results in Column (2) show that factors related to employee characteristics are likewise proven to influence employee performance. This evidence is provided by the probability's significance value, which is less than 1%.

Table 3. *PCFA results for variables related to environment/company (ENV)*

Code	Keyword	Company/Environmental Related Factors (ENV)				
		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
		Organizational climate	Environmental dynamism	Job environment	Job autonomy	Organizational vision
ENV1	Supporting work	-	-	0.3559	-	-
ENV2	Work comfort	-	-	0.9484	-	-
ENV3	Work planning	0.2428	-	-	-	-
ENV4	Simple and flexible work procedures	-	-	-	0.8709	-
ENV5	Organizational change	-	-	-	0.4354	-
ENV6	Effect of policies and practices.	-	0.2769	-	-	-
ENV7	Tolerance value	0.3648	-	-	-	-
ENV8	Trust value	0.9090	-	-	-	-
ENV9	Organizational vision	-	-	-	-	0.8318
ENV10	Process of achieving goals	0.3459			-	-
ENV11	Effect of organizational change	-	0.9099	-	-	-
ENV12	Practices/written regulations	0.4799		-	-	-
ENV13	Unwritten regulations	-		-	0.2069	-
ENV14	Interaction between employees and superiors	-	0.2230		-	-
ENV15	Problem solving	-	-	0.1503	-	-
ENV16	Process in finding the solution	0.9063	-	-	-	-
ENV17	Future plans for the company	-	-		-	0.8360
ENV18	Commitment and discipline	-	-	0.9637		-
ENV19	Integration	-	0.9062	-	-	-
ENV20	Organizational Goal	-	-	-	-	0.8602
Eigenvalue		2.60249	2.37292	2.28312	2.24802	1.57750
Proportion		0.2582	0.2354	0.2265	0.2230	0.1565
KMO		0.5617				
k^2		2112.01				
Prob>chi^2		0.0000				
Source: Data processed by the researcher (2023)						

Furthermore, according to Table 7 Column (3), there are 5 variables that have been scientifically demonstrated to affect employee performance. ENV_Climate (H1a), ENV_JobEnv (H1c), and ENV_Autonomy (H1d) are variables that describe environmental/company factors. CHRT_Skill (H2a) and CHRT_Adapt (H2b) are the variables that describe employee characteristics. Column (3) results are consistent with the results of testing Columns (1) and (2). The difference is that the level of significance of variables related to the environment/company has decreased. This indicates that when predictor variables from employee personal characteristics are added to the model, the influence of environmental/company factors reduces. This research also implies that employee characteristics have a greater effect on their work performance.

4.5. Analysis and Discussion

In the port industry, dedicated and motivated workers are required to provide the best service and maintain competitive advantage [10]. This study aims to examine the internal and external influences on port industry employees in Indonesia that can enhance their performance. External factors refer to those originating from outside of employee motivation, such as working conditions, management, colleagues, and so on. Internal factors, on the other hand, pertain to factors that originate from within the employee, such as adaptability and other abilities possessed by the employee [8].

The results of testing the hypothesis proposed in this study can be seen in Table 7 above. The table shows that the two hypotheses in this study have been empirically accepted.

Table 4. *PCFA results on factors related to employee characteristics (CHRT)*

Code	Keyword	Factors related to employee characteristics (CHRT)		
		Factor 1	Factor 2	Factor 3
		Skill development	Adaptability	Intrinsic motivation
CHRT1	Meeting life needs	-	-	0.8320
CHRT2	Provide for the family	-	-	0.4284
CHRT3	Adaptation to the workplace	-	0.2520	-
CHRT4	Work tranquillity	-	-	-
CHRT5	Guaranteed	-	0.2830	-
CHRT6	Security	-	-	-
CHRT7	Respect between employees	-	0.4370	-
CHRT8	Acceptance of other employees	-	0.7646	-
CHRT9	Appreciation	-	-	-
CHRT10	Giving performance-based bonuses	-	0.3802	-
CHRT11	Attend seminars	0.8916	-	-
CHRT12	Further study	0.2455	-	-
CHRT13	Pleasure based on knowledge	-	0.1002	-
CHRT14	New insight	-	-	-
CHRT15	Work-life balance	0.2985	-	-
CHRT16	Bonus	-	-	0.7725
CHRT17	Training	-	-	-
CHRT18	Discussion with managers or seniors	-	0.7640	-
CHRT19	Moral support	-	-	-
CHRT20	Support from coworkers	0.8554	-	-
Eigenvalue		2.02626	1.86550	1.70391
Proportion		0.3726	0.3430	0.3133
KMO		0.5751		
k^2		1055.49		
Prob>chi^2		0.0000		
Source: Data processed by the researcher (2023)				

Columns (1) and (2) show how each aspect affects employee performance at the same time. Column (3) also shows the test results of the two components together to see which variables in the two factors affect employee performance. These two criteria are inextricably linked since they are significant indicators of employee performance [15].

According to Table 7 Column (3), not all identified factors have significant effects on the performance of Port Enterprise employees. Job environment (*ENV_JobEnv*) and job autonomy (*ENV_Autonomy*) were determined to have the greatest influence in the group of environmental/company factors, followed by organizational climate factors. The work environment factor has a coefficient value of 0.114 and the job autonomy factor has a coefficient value of 0.113 (*ENV_Climate*). Both of these variables have a significance level of less than 0.05 (<0.05). Meanwhile, the effect of organizational climate is smaller with a coefficient value of 0.111, although it is still significant (<0.1). In other words, it has been empirically proven that the organizational climate, job autonomy, and job environment all positively influence employee performance in the Port Enterprise, nevertheless to varying degrees. The findings of this research support the findings of earlier studies [8,21,22,33].

A conducive work environment, in the sense that it can create the perception that the work performed by employees is unique and valuable to the company, can have a positive impact on employees (especially in achieving higher job performance). Port companies rely heavily on their employees to carry out their operations. Employees in the port industry play a key role in performing various tasks necessary to efficiently manage the port, such as in port operations, management and administration, security and compliance, ship maintenance, logistics and distribution, and in serving their customers [23,24]. Therefore, employees

Table 5. *Definition of PCFA factor results*

Factor	Code	Operational Definition	Total items	Reference
Organizational climate	*ENV_Climate*	How an employee perceives the company's culture, particularly the quality of relationships between superiors and co-workers.	6	Suliman and Al Harethi [33]; Cherian et al. [21]
Environmental dynamism	*ENV_ Dynamism*	Management's perception of the stability of the business environment in which the organization works.	3	de Hoogh et al. [34]; Diamantidis and Chatzoglou [8]
Job environment	*ENV_JobEnv*	The degree to which the work environment promotes comfort, meets social needs, and fosters the belief that skills lead to high levels of work performance	4	van der Kolk et al. [9]; Chen et al. [19]; Imam et al. [22]
Job autonomy	*ENV_ Autonomy*	The degree to which the company allows employees to work flexibly or spontaneously in various aspects of their work while yet keeping mindful of the responsibilities and objective of their job	3	Dysvik and Kuvaas [35]; Diamantidis and Chatzoglou [8]
Organizational vision	*ENV_Vision*	How employees perceive the company's vision and mission as motivation to improve their performance	3	Cerasoli and Ford [28]
Skill development	*CHRT_Skill*	Concerned with the development of skills needed by employees in order to improve their performance	4	Elnaga and Imran [4]; Ibrahim et al. [36]
Adaptabilty	*CHRT_Adapt*	How employees can adapt to their working environment and achieve comfort at work	7	Pulakos et al. [37]; Diamantidis and Chatzoglou [8]; Jnaneswar and Ranjit [13]
Intrinsic motivation	*CHRT_Motiv*	Related to internal motivation such as meeting needs and bonuses got by employees	3	Dysvik and Kuvaas [35]; Cerasoli and Ford [28]
Source: Data processed by the researcher (2023)				

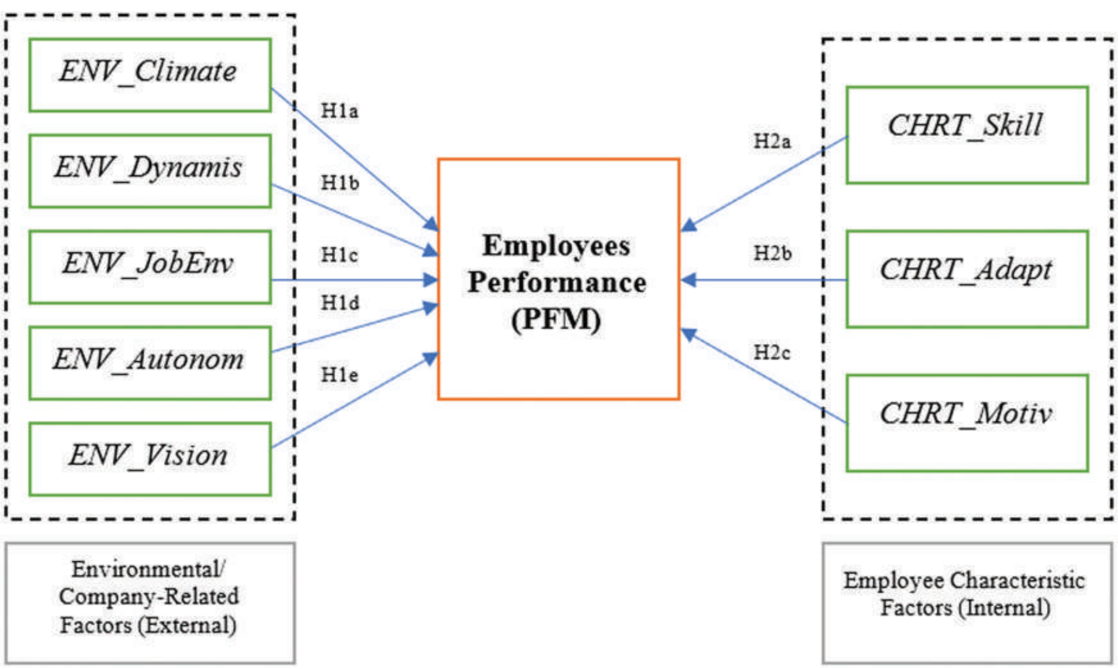

Figure 3. *Research Framework after PCFA*

require a comfortable environment to work optimally [10]. According to Cherian et al. [21] stated that the work environment and organizational climate serve as mechanisms that influence the behavior of each individual inside them. If the work environment is competitive, every employee will be selfish rather than concerned with the overall goals of the company. As a result, managers and supervisors play a crucial role in maintaining and improving the behavioral aspects of employee ownership and affirmation in the work environment. Job autonomy is also essential. Employees will be able to increase their performance by carrying out their jobs in more effective

***Table 6.** Univariate analysis results*

Variabel	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) PFM	1.000								
(2) CHRT_Skill	0.441***	1.000							
	(0.000)								
(3) CHRT_Adapt	0.409***	0.445***	1.000						
	(0.000)	(0.000)							
(4) CHRT_Motiv	0.015	0.100	-0.197***	1.000					
	(0.808)	(0.104)	(0.001)						
(5) ENV_Climate	0.295***	0.369***	0.220***	0.213***	1.000				
	(0.000)	(0.000)	(0.000)	(0.001)					
(6) ENV_Dynamism	0.161***	0.289***	0.231***	0.067	0.437***	1.000			
	(0.009)	(0.000)	(0.000)	(0.280)	(0.000)				
(7) ENV_JobEnv	0.331***	0.464***	0.247***	0.054	0.279***	0.268***	1.000		
	(0.000)	(0.000)	(0.000)	(0.385)	(0.000)	(0.000)			
(8) ENV_Autonomy	0.317***	0.351***	0.322***	0.006	0.346***	0.381***	0.287***	1.000	
	(0.000)	(0.000)	(0.000)	(0.929)	(0.000)	(0.000)	(0.000)		
(9) ENV_Vision	0.056	0.043	0.037	0.090	0.046	0.077	-0.003	-0.009	1.000
	(0.364)	(0.485)	(0.551)	(0.146)	(0.458)	(0.216)	(0.956)	(0.883)	

PFM: Employee performance, *CHRT_Skill*: Skill development, *CHRT_Adapt*: Adaptability, *CHRT_Motiv*: Employee motivation, *ENV_Climate*: Organizational climate, *ENV_Dynamism*: Environmental dynamism, *ENV_JobEnv*: Job environment, *ENV_Autonomy*: Job autonomy, *ENV_Vision*: Organizational vision.
***: Significance level less than 1%, **: Significance level less than 5%, *: Significance level less than 10%

***Table 7.** Hypothesis testing results*

Variable	(1) Perform	(2) Perform	(3) Perform	VIF
ENV_Climate	0.165*** (2.81)		0.111* (3.07)	1.44
ENV_Dynamism	-0.061 (2.81)		-0.086 (-1.53)	1.37
ENV_JobEnv	0.209*** (3.94)		0.114** (2.13)	1.33
ENV_Autonomy	0.195*** (3.36)		0.113** (2.00)	1.35
ENV_Vision	0.052 (0.99)		0.037 (0.75)	1.02
CHRT_Skill		0.284*** (5.11)	0.188*** (3.06)	1.65
CHRT_Adapt		0.267*** (4.46)	0.236*** (3.87)	1.44
CHRT_Motiv		0.036 (0.69)	0.015 (3.06)	1.17
Intercept	0.0002	0.0003	0.0023	
Obs	262	262	262	
Adj. R2	0.1761	0.2437	0.2749	
F value	12.16	29.24	13.37	
Prob>F	0.0000	0.0000	0.0000	

PFM: Employee performance, *CHRT_Skill*: Skill development, *CHRT_Adapt*: Adaptability, *CHRT_Motiv*: Employee motivation, *ENV_Climate*: Organizational climate, *ENV_Dynamism*: Environmental dynamism, *ENV_JobEnv*: Job environment, *ENV_Autonomy*: Job autonomy, *ENV_Vision*: Organizational vision. ***: Significance level less than 1%, **: Significance level less than 5%, *: Significance level less than 10%

ways if they feel free to do so [8]. Meanwhile, too much pressure to follow text-book-based procedures will prevent employees from reaching their full potential [35].

Following that, the environmental dynamism and company vision factors show insignificant values. This suggests that employee understanding of the company's vision and objective, as well as environmental changes, have no effect on Port Enterprise employees' performance. This contradicts prior research findings and research predictions that demonstrated a positive relationship between these factors and employee performance [8]. One explanation for why both of these factors have no effect on performance is that the work environment at Port Enterprises is static (particularly the output/products provided in the form of services). This means that a company's ability to update equipment and production procedures and identify ways to strengthen its competitive position is extremely limited. As a result, environmental changes have less of an impact on employee performance.

Employee performance is also extremely likely to be influenced by individual variables. According to the test results in Table 7 Column (3), self-development (*CHRT_Skill*) and adaptability (*CHRT_Adapt*) have an impact on employee performance. Both of these variables have a significance value of less than or equal to 0.01 (<0.01), with coefficient values of 0.188 and 0.236, respectively. The findings of this study are consistent with those of Diamantidis and Chatzoglou [8], Elnaga and Imran [4], Ibrahim et al. [36], and Pulakos et al. [37].

In recent decades, many innovations have been introduced in the port industry, highlighting the importance of innovation in this sector, such as digitization and the introduction of new tools. Port industry employees around the world have faced new challenges in adapting to such rapid changes. They are driven by companies to undergo various training programs to enhance performance, which will result in increased company profits [38]. Both the desire to develop or the ability to adapt encourages better employee performance [8]. Employees who can quickly adapt to unexpected situations or new workplaces/environments and complete new duties efficiently are more likely to have a positive effect on their performance [37]. In contrast, employees who find it difficult to adapt or use new skills, knowledge, and techniques in performing tasks or work, will provide minimal support for their job performance. Companies must therefore give training and self-development programs for employees in order to achieve high performance. This training is intended to inculcate necessary attitudes such as integrity, work ethic, as well as effective work methods [4]. Furthermore, training helps to change corporate culture by changing the attitudes and/or behaviour of all employees in the organization [36].

5. Study Limitations

There are several limitations to this study. First, a research sample was collected from Jakarta Port Enterprises for this study. Despite the fact that it has represented the majority of the Port Enterprise s in Indonesia, future research can include research samples from other Port Enterprises. Due to its more case-study-oriented nature, research is needed that can generalize findings by expanding the sample. Research in other fields in the future can also use the same methodology as this study. Second, future studies can include additional characteristics that are believed to influence employee performance. The addition of this factor can improve the model's accuracy for prediction. These factors can also be used to moderate or mediate the relationship between environmental factors and employee characteristics and employee performance. Third, the adjusted R-square (R2) in this study indicates that the independent variables in the model only influence employee performance by 27.49%, meaning that the remaining 72.51% is influenced by other variables not included in the model. Subsequent research may consider incorporating other variables to increase the R2 value.

6. Conclusion

This study examines the effect of environmental/company factors and individual characteristics on the performance of Port Enterprise employees. In contrast to many previous research, this one utilizes of the PCFA method to provide more specific evidence on the factors that influence employee performance. The findings of this study support our research hypotheses. Five of the eight identified variables (5 related to the environment/company and 3 related to individual characteristics) had significant effects on employee performance. In particular, for environmental/company factors, the performance of Port Enterprise employees is influenced by the job environment, job autonomy, and organizational climate in this study. Furthermore, adaptability and self-development are among the most important characteristics that managers must consider, particularly in order to attain optimal company performance. This study contributes to the literature on employee performance, which infrequently samples shipping enterprise. By using the SDT theory, this research makes a theoretical contribution by providing empirical evidence that the performance of Port Enterprise employees is influenced by intrinsic and extrinsic factors. Furthermore, the practical contribution of this research is that companies must prioritize an enjoyable working environment and job autonomy for their employees. This comfort and autonomy will help them to maximize each other's capabilities to boost company performance. In terms of internal employees' characteristics, adaptability, and capacity building are also major factors of performance improvement. As a result, the company has a responsibility to provide employees with suitable training on a regular basis.

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Risk Assessment for Maritime Container Transportation Security

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Abstract

Container shipping is the backbone of the global supply chain, and its security is directly linked to the global economy. Disruptions in container transportation could have severe consequences, such as an increase in transport and insurance costs and damage to the environment and cargo. The first aim of this study is to identify, assess, and prioritize the security risks associated with maritime container transportation using the Delphi technique and to draw a risk map accordingly. The second aim is to identify the strengths, weaknesses, opportunities, and threats to using SWOT analysis from a security perspective. Maritime container transportation between Türkiye and the Far East serves as a case study for this purpose. As a conclusion of the first part of the study, the risk of cyber-attacks has one of the highest probability factors scored first, war and warlike conditions having the highest impact factor scored second, and piracy and armed robbery scored third in general. In the second part, the SWOT factors are determined and prioritized using the Analytic Hierarchy Process. Strengths scored the highest among the main SWOT factors, which indicates that it is more prominent than other factors. Weaknesses, opportunities, and threats to. The overall conclusion drawn is that security risk assessment has become essential given recent technological changes, such as the increasing risk of cyber-attacks on electronic navigational aids, and geopolitics, such as tensions in the Middle East and the South China Sea.

Keywords: Transportation security, Risk assessment, Delphi, SWOT, AHP

1. Introduction

"Transportation security" is defined as "the combination of preventive measures and human and material resources intended to protect transport infrastructure, vehicles, systems, and workers against intentional unlawful acts" [1]. Transport security is concerned with the security of cargo transported by various modes of transportation. The need for security during transportation stems from the desire to avoid unwanted negative disruption in the flow of goods. Such disruption, whether physical (terrorist attacks, piracy) or virtual (cyber-attacks), may result in fatalities-the primary concern-as well as delays and cancelations among other problems. In this context, "security risk" refers to the likelihood that an individual or organization may encounter a negative consequence because of a security breach.

The perception of transportation security has significantly changed over recent decades, particularly in the wake of the 9/11 terrorist attacks. The concepts of security, resilience, and systemic vulnerabilities must be reexamined and rediscovered in a new political, economic, social, and technological environment [2]. The first of the changes is the necessity to take measures not only against cargo theft but also against terrorism. The other is the shift in the field of interest from national to global issues. The last one is that security has emerged as an issue that interests all actors in the supply chain rather than being a problem only on the basis of companies [1].

Nowadays, the container trade takes center stage in transportation security concerns because of its evolution as an ideal means to smuggle drugs, weapons, and

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people. Technological developments and recent changes in geopolitics are another factor affecting transportation security. For instance, blockchain technology can completely transform maritime security by improving accountability, traceability, and transparency in the sector. It offers a decentralized, unchangeable ledger that securely documents and validates transactions, making it the perfect solution to problems such as fraud, smuggling, and piracy [3]. Geopolitical tensions such as those in the Black Sea, Middle East, and South China Sea negatively affect shipping trade either directly by affecting merchant ships and their crew or indirectly by increasing insurance premiums.

Terrorist attacks on container transportation include the 2013 attack on China's COSCO Asia, at al-Qantarah, 30 miles south of Port Said, after it had departed Suez at the southern entrance to the Canal [4] - an attack that prompted China to consider alternative routes bypassing the Suez Canal-and recent assaults carried out against merchant traffic off the coast of Yemen or at ports along the Gulf of Aden [5].

For the past 20 years, the major illicit activity that threatens the security of the world's maritime transport routes has been piracy and armed robbery. In particular, in the Gulf of Aden, the Indian Ocean, the Straits of Malacca and Singapore, the South China Sea, and the Gulf of Guinea, dozens of merchant ships have been hijacked, with hundreds of seafarers held and even injured or killed, and tons of cargo forcibly detained.

Containers can be used to smuggle people, narcotics, weapons, and radioactive, chemical, and biological materials. This can be accomplished by altering cargo paperwork or by concealing the presence of unlawful people or substances in any area of the transportation without the consent of transportation authorities, carriers, consignees, and cargo owners.

Unlawful smuggling of people into shipping containers endangers both seafarers' and national security. Stowaways outnumbering crew members or behaving violently is a risk that could result in injury to crew members; one recent incident was the Turkish cargo ship, sailing from Türkiye to France, which was attacked by armed stowaways off Naples and secured by Italian special forces [6].

Many incidents of cyber risks in maritime transportation can be cited. In addition to the cyber-attack carried out against the Danish shipping company AP Moller-Maersk, in which their IT systems were completely shut down for ten days in 2017, several incidents have been reported of unauthorized persons gaining access to conventional ship control systems [7]. Since Automatic Identification System (AIS) spoofing scenarios can disrupt maritime traffic and interfere with a vessel's ability to navigate safely [8], dependable precision navigation is more important than ever because of the increase in the size and number of vessels at sea.

Another risk area in transportation security includes war and warlike conditions, internal conflicts, and geopolitical instabilities through maritime routes. In recent years, several incidents originating from the civil war in Yemen, including assaults on ships off the Yemeni coast, tensions between Iran and the US in the Persian Gulf, and between China and the US in the South China Sea and off the coast of Taiwan and the Eastern Mediterranean after the Israel-Hamas war, are regions of crises that may impact merchant traffic between Türkiye and the Far East. The Russian-Ukrainian war that began in February 2022 also had direct and indirect impacts on the structure of the global supply chain.

Moreover, the coronavirus disease-2019 pandemic- although not a security but a safety risk, because it was not a deliberate incident, which is a prerequisite for a security risk [9] - also had indirect security effects due to its impact on the global supply chain. These effects include increasing risks from container shortages, blank sails, delays, and lay times, in addition to the increase in cargo theft of medical equipment (masks, suits, sanitizer, etc.) [10]. The pandemic also expedited digitization and created new digital opportunity structures that increased cyber risks [11].

In this study, no safety-related risk factors are examined because additional issues around security are gradually taking center stage in terms of technological advancements as new types of security risks emerge (e.g., cyberattacks, autonomous transport etc.) [12]. Another reason for dealing purely with security issues is that security breaches are considered more dangerous than safety issues because their results are far more severely damaging than safety issues, despite arguably occurring less frequently. Additionally, the occurrence of security breaches is associated with a high level of uncertainty and is frequently beyond the company's control.

Hence, the primary objective of this study is to examine the security risks associated with container trade, focusing specifically on the trade between Türkiye and the Far East. The objective of this study is to address three research questions: Research Question 1: What are the security risk factors associated with container trade between Türkiye and the Far East? Research Question 2: Among the identified risk factors, which ones hold relatively greater significance in terms of security? Research Question 3: What are the strengths, weaknesses, opportunities, and threats of container trade between Türkiye and the Far East? To address these questions, a comprehensive examination of existing literature, followed by four iterations of Delphi surveys, and a thorough SWOT analysis are employed as the chosen methodological approach.

The following section presents a review of the literature. Section 3 discusses the methodology, data collection, and calculation of risk and SWOT factors. Section 4 presents the results and a discussion of the study. The last two sections provide concluding thoughts on the study and recommendations for future research.

2. Literature Review

It is imperative to define risk and risk assessment before discussing research in that area. "The combination of the frequency and severity of the consequence" is the definition of "risk" in the IMO circular [13], while risk assessment is "the process of gathering data and synthesizing information to develop an understanding of the risk of a particular enterprise" [14]. Many risk assessments have the primary goal of identifying the dangers associated with a certain process or system and developing appropriate measures to prevent or mitigate undesirable consequences.

Various safety and security risk assessment studies have been conducted that could help to manage the corresponding threats [14-25]. Different methodologies were used when conducting this research, such as quantitative risk assessment (QRA), failure mode and effects analysis (FMEA), and risk mapping. The examined studies on risk assessment are summarized in Table 1.

Mousavi et al. [14] provided a brief introduction to risk analysis methods and emphasized the importance of identifying hazards before conducting risk analysis techniques or risk-reducing measures. Zhang [15] introduced two case studies in the Yangtze River-China's largest and the world's busiest inland waterway-to illustrate the application of several approaches in maritime risk assessment. Jiang et al. [16] analyzed the risk factors influencing maritime supply chains along the Maritime Silk Road, and their assessment results revealed that fuel price is the most significant risk factor.

Goerlandt and Montewka [17] studied and analyzed risk definitions, views, and scientific risk analysis methodologies in maritime transportation, with a focus on applications addressing the accidental risk of shipping. Cieśla et al. [18] analyzed foundations associated with risk management for a company performing multimodal transportation services of intermodal transport units (ITU). Among the 24 threats, they concluded that the two most important threats were overturning the ITU stack on the terminal yard and collision or accident involving the ITU during its shipment process

Table 1. *Literature review*

Author/Year	Subject	Method	Country/Case study
Mousavi et al. [14] (2017)	Risk assessment in the maritime industry	Literature review	Iran
Zhang [15] (2014)	Challenges and new developments in marine risk assessment	Combined AHP with discrete fuzzy sets	China/Yangtze River
Jiang et al. [16] (2022)	Risk assessment of maritime supply chains in the context of the Maritime Silk Road (MSR)	QRA	China/The 21st Century MSR
Goerlandt and Montewka [17] (2015)	Maritime transportation risk analysis: Review and analysis considering foundational issues	Literature Review	Finland
Cieśla et al. [18] (2017)	Multimodal transport risk assessment with risk mapping	Risk Mapping	Poland/Intermodal Transport Units
Roh et al. [19] (2018)	Risk assessment of maritime supply chain security in ports and waterways	Risk/loss exposure matrix	Malaysia/ Malaysia's ports and waterways
Nguyen et al. [20] (2022)	Methodological framework for quantitative risk analysis in container shipping operations	QRA	Vietnam/Three Container Shipping Companies
Nguyen and Wang [21] (2018)	Prioritizing operational risks in container shipping systems using cognitive assessment techniques	FMEA and its integration into a fuzzy rules Bayesian network	Vietnam: An Anonymous Container Shipping Company
Wan et al. [22] (2019)	Analysis of the risk factors influencing the safety of maritime container supply chains	Delphi	China/Selected Maritime Stakeholders in China
Chang et al. [23] (2015)	Risk analysis for container shipping from a logistic perspective	Risk scale average likelihood and consequence and average risk scale	Taiwan/Taiwan Container Shipping Industry
Zhou et al. [24] (2022)	Holistic Risk Assessment of Container Shipping Services based on Bayesian Network Modelling	Hybrid Method Comprising FMEA, Evidential Reasoning, and Rule-Based BN	China/Maritime Experts from China
Wan et al. [25] (2019)	Advanced fuzzy Bayesian-based FMEA approach for assessing maritime supply chain risks	Fuzzy Belief Rule Approach using Bayesian Networks	China/Container Shipping Company
AHP: Analytical hierarchy process, QRA: Quantitative risk assessment, FMEA: Failure mode and effects analysis			

[18]. Roh et al. [19] analyzed the risk to Malaysia's maritime supply chain security in ports and waterways using piracy and terrorism, government intervention, cyber security, and facility as risk assessment factors and concluded that Malaysian ports are vulnerable to attacks and crime due to various factors.

Different authors examined container-specific works. Nguyen et al. [20] proposed a methodological framework to strengthen the quality and reliability of the QRA of container shipping in Vietnam in diverse risk scenarios. Nguyen and Wang [21] identified container shipping operational risks using multivariate risk evaluation mechanisms such as the fuzzy rules Bayesian network and FMEA. Wan et al. [22] identified the primary risk factors of substantial safety concerns using a Delphi survey and a risk matrix approach from different viewpoints. Chang et al. [23] investigated the hierarchical classification of risks in container shipping operations from a logistics standpoint.

Zhou et al. [24] examined container shipping service risks using a hybrid method and found that economic, political, and technical risks pose the greatest threats to resilient container shipping service. Wan et al. [25] created a novel model to assess the risk factors of maritime supply chains and investigated a container shipping company, revealing that the most significant risk factors are "transportation of dangerous goods, fluctuation of fuel prices, fierce competition, unattractive markets, and change of exchange rates," in that order.

The above papers shed important light on the safety and security risks facing container transportation businesses. While safety studies focused on hazards related to transportation systems, security studies focused on threats that have a negative impact on transportation systems. Little research has strictly discriminated between safety and security [19] because of the nature of those two concepts, which are indivisible in many ways [26]. Apart from the conceptual papers on risk assessment [14,17], while most studies focused solely on safety issues [15,18], some studies discussed both safety and security together [16,20-25].

This research is one of the pure security risk assessments among the literature examined. Although some studies have made an integrated analysis of safety and security, which is called "Safety and Security Co-Analysis (SSCA)" [27], modeling security risk using safety analysis approaches is difficult because security is an activity involving a higher level of uncertainty and is influenced more by external factors. Therefore, this study may help fill the research gap in this area. Moreover, the results of this study can also contribute to the idea that safety and security studies can be divided in some cases or for specific patterns of container transport different from traditional risk assessment studies.

A risk assessment is the foundation of a comprehensive risk management strategy, and a risk analysis is a component of the assessment process in which the likelihood and criticality of each risk are calculated and a score is assigned to each risk based on the findings. A risk assessment is a more comprehensive process that involves conducting assessments, determining the choices for risk mitigation, and informing stakeholders. To improve corporate strategy development against risks and simplify complicated problems, another approach is SWOT analysis [28,29]. SWOT analysis with an analytical hierarchy process (AHP) helps rank and prioritizing risks; several studies have been conducted in this area.

Amin et al. [30] used a SWOT matrix to identify the strengths, weaknesses, opportunities, and threats to different transportation modes in Cape Breton Island, Nova Scotia, Canada, while evaluating and ranking the factors based on pairwise comparisons in the AHP. Chang and Huang [31] used major container ports in East Asia as a case study and compared them with different criteria using the quantified SWOT analytical method and obtained the weights of key factors using the AHP method. They concluded that the quantified values of the SWOT would help enterprises learn about themselves and can be used as the foundation for developmental strategies. Şenol et al. [32] investigated the strategies associated with autonomous shipping and proposed a strategy based on SWOT-AHP analysis.

3. Research Methodology

The Delphi technique was used for data gathering, whereas QRA/mapping and SWOT AHP were used to analyze the data. The Delphi technique is a method used in complex problems where uncertainty exists and expert opinion is needed to overcome this uncertainty and reach a consensus on the likelihood and consequences of future events by identifying risks, threats, and opportunities with positive and negative consequences.

The fact that SWOT analysis cannot be expressed numerically makes it difficult to access solid and reliable information in strategic management planning. Therefore, SWOT analysis gains a quantitative meaning when integrated with multi-criteria decision making (MCDM) techniques such as AHP. For this reason, the SWOT-AHP method was chosen as the best fit for our research.

To accomplish the goals of the research, analysis processes were structured using the risk management framework. The next sections go into further detail on the steps involved in putting these methods into practice.

3.1. Design of the Methodology

In this study, transportation security risks were identified by content analysis of academic papers and books on transportation security. As a second step, a Delphi survey was conducted with twelve experts from shipping companies and academia to confirm the security risks found in the literature review. In the third step, a second tour Delphi survey was conducted to determine the likelihood and impacts of the risk areas by eliminating one risk area (smuggling of drugs, weapons, and weapons of mass destruction) with a consensus rate below 70% [33]. The average percentage of majority opinions (APMO) formula is used with the formula [34]:

$$APMO = \frac{Majority\ Agreements + Majority\ Disagreements}{Total\ opinions\ expressed} \quad (1)$$

As a fourth step, risks were calculated by multiplying likelihoods and impacts, prioritized, and a risk map was drawn. In the fifth step of the study, another Delphi was conducted to collect input for a draft SWOT table indicating the strengths, weaknesses, opportunities, and threats of container transportation risks from Türkiye to the Far East. The final SWOT table was formed with experts' input. In the last step, the SWOT AHP technique was used to prioritize SWOT's main and sub-criteria with a fourth round of Delphi survey. The stages of the methodology are shown in Figure 1.

3.2. Data Collection

A comprehensive data collection process is necessary for valid data analysis. The Delphi technique is a useful tool for determining the expert panel's most reliable consensus for a set of sequential questions or rounds separated by controlled feedback [35]. Participants in an expert panel in a Delphi study are seasoned experts who can offer a knowledgeable viewpoint or expert opinion on problems in their particular field [36]. Therefore, 12 experts in container transportation with at least five years of experience were chosen; and contacted by phone/e-mail/in person conversation. The list of experts is given in Table 2.

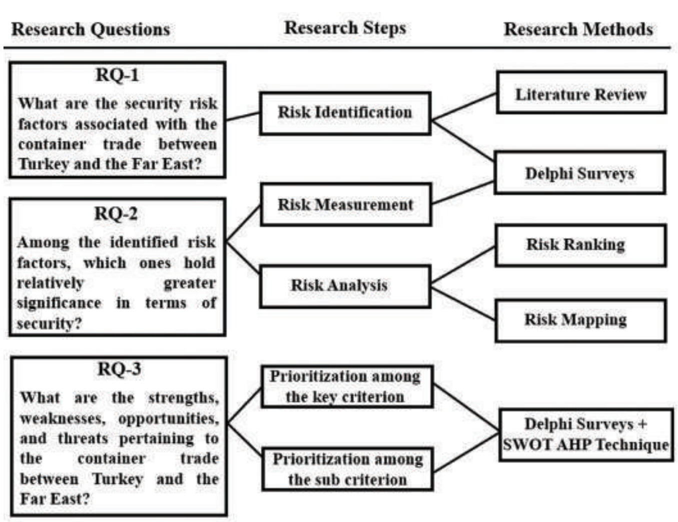

Figure 1. *Methodology for the study*

Source: Authors

3.3. Calculation of Risk Factors and Risk Mapping

The filtered risk area's likelihood and impact factors (Tables 3 and 4) were calculated using the linguistic assessments of the experts (Table 5).

Based on the data acquired through the aforementioned techniques, the risk scale for each risk factor was evaluated, and their relative weights were determined. The following notations are introduced before going into the mechanics of how risk scales are calculated:

- R: the total number of risk areas.
- E: the total number of experts.
- l_{re}: the likelihood of risk area r by the expert, e, $1 \leq r \leq R$ and $1 \leq e \leq E$; and
- i_{re}: the impact of risk area r by the expert, e, $1 \leq r \leq R$ and $1 \leq e \leq E$.

Note that the risk scale's elements are a risk area's likelihood and impact. One of the two methods can be used to determine the risk scale. In the first strategy, the average likelihood across all experts is multiplied by the average consequence across all experts. This method is known as risk scale average likelihood and impact (RSALI). The formula is as follows:

$$RSALI = \bar{l}_r \times \bar{i}_r \quad (2)$$

where:

$$\bar{l}_r = \frac{1}{E}\sum_{e=1}^{E} l_{re} \text{ and } \bar{i}_r = \frac{1}{E}\sum_{e=1}^{E} i_{re} \quad (3)$$

In the second method, the risk scales for each respondent on each risk component are first obtained, and then the risk scales for all respondents are averaged to create a risk analysis for container transportation. This methodology is known as the Average Risk Scale (ARS). The formula is as follows:

$$ARS_r = \frac{1}{E}\sum_{i=1}^{E}(l_{re} \times i_{re}) \quad (4)$$

For each risk factor, the first technique offers three results: average likelihood, average impact, and risk scale. It is simple to use, and the outcomes can be displayed right in the risk map that calls for them all. However, the fact that the RSALI results include those components derived by multiplying one respondent's likelihood by another respondent's impact could skew the statistical findings.

Table 2. *Profile details of maritime experts*

No	The type of organization	Year of employment	Department/professional area	Position
1	Shipping Industry	8	Intermodal, Railway, and Maritime Transport	Marketing and Sales Manager
2	University*	23	Port Management	Dean
3	Shipping Industry	23	Maritime Transportation	Senior Manager, Port and Terminals
4	University*	14	Logistics and Container Transportation	Lecturer
5	Shipping Industry	11	Dangerous Cargo Transportation: Port Operations	Line Manager
6	Shipping Industry	14	Container-Ship-Port Operation	Operation Manager
7	Shipping Industry	10	Container and maritime transportation	Cargo Operations Officer
8	University*	14	Foreign Trade	Lecturer-General Manager
9	Shipping Industry	18	Equipment and Ship Operation Management	Türkiye Operation Manager
10	Shipping Industry	17	Shipping and Logistics, Training and Development, Project Management	Learning Partner: Global Commercial Team
11	Shipping Industry	5	Export	Customer service assistant specialist
12	University*	22	Management and Strategy	Vice dean
*All of them also had working experience in the shipping industry Source: Authors				

Table 3. *Definitions of the likelihood of risk factors*

Likelihood	Scale	Definition	Numerical value
It is unlikely to happen (High)	5	It didn't happen, or at least once every ten years.	0.85
The probability is very low (Moderately high)	4	It only happens in some extreme environments, or it can happen every few years.	0.70
Less likely (Medium)	3	The probability of occurrence is not high, or at most once a year.	0.50
It can happen (Low)	2	It can happen in some cases or every few months.	0.25
The probability is higher (Very low)	1	It happens in most cases, or every month.	0.10
Source: Adapted from [22]			

Table 4. *Definitions of the impact of risk factors*

Impact	Scale	Definition	Numerical value
Catastrophic	4	Cause complete and irrecoverable failures, long-term environmental damage, or death.	1.00
Severe	3	Cause some disruptions, or sometimes failures with severe impacts such as major cost increase and major environmental damage injuries.	0.70
Moderate	2	Cause some disruptions with medium impacts, such as moderate cost increase, delay, and minor environmental damage.	0.50
Minor	1	Cause some inconvenience with minor impacts, such as a small cost increase/schedule change.	0.25
Source: [22]			

Since the risk scales are derived by first multiplying the risk likelihood by the risk impact provided by each respondent and then averaged over all respondents, it is concluded that the second method-ARS-is more acceptable in generating risk scales. Consequently, both techniques were employed to assess the risk scale for each risk factor, and both results did not change the overall order (Table 6).

Finally, a security risk map for maritime transportation is created using the risk rankings given above. In Figure 2, red denotes critical risks, orange indicates severe risks, yellow indicates moderate risks, and green indicates sustainable risks.

3.4. SWOT and the AHP Model

Risk assessment is necessary for a shipping company when defining the potential impact of each risk, but it is not enough. For "risk management" which is used to assess, analyze, prioritize, and formulate a strategy for mitigating threats and managing risks to a company's resources and revenue, SWOT is a widely applied tool in strategic

***Table 5.** Linguistic assessment of maritime transportation security risks*

Maritime transportation security risks	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-10	E-11	E-12
	Likelihood/impact											
Terrorism and sabotage	L/S	VL/C	M/Mr.	L/S	L/C	L/S	L/C	L/S	L/S	VL/S	M/S	M/C
Piracy and armed robbery	L/M	MH/S	M/Mr.	L/S	M/S	M/S	M/S	L/S	M/M	L/S	M/S	H/S
Human trafficking and stowaways	H/Mr.	MH/Mr.	MH/M	MH/S	MH/Mr.	MH/M	MH/M	M/M	L/M	MH/S	M/Mr.	H/M
Cyber attacks	H/C	M/M	H/S	M/M	VL/Mr.	MH/M	MH/C	M/S	H/C	MH/S	H/C	M/M
War and warlike conditions	H/C	L/M	MH/S	M/S	VL/M	M/M	MH/C	L/S	L/C	L/C	M/C	M/C
Cyber theft	MH/Mr.	H/M	MH/M	L/C	H/Mr.	MH/M	MH/Mr.	M/M	M/Mr.	MH/M	MH/Mr.	H/M
Source: Authors' Delphi survey inputs												

***Table 6.** Maritime transportation risk rankings*

Maritime transportation	Risk scale calculated using RSALI	Risk scale calculated by ARS	Ranking
Cyber-attacks	0.440	0.484	1
War and warlike conditions	0.346	0.368	2
Piracy and armed robbery	0.290	0.291	3
Human trafficking and stowaways	0.280	0.258	4
Cargo theft	0.277	0.254	5
Terrorism and sabotage	0.219	0.210	6
Source: Authors' calculations RSALI: Risk scale average likelihood and impact, ARS: Average Risk Scale			

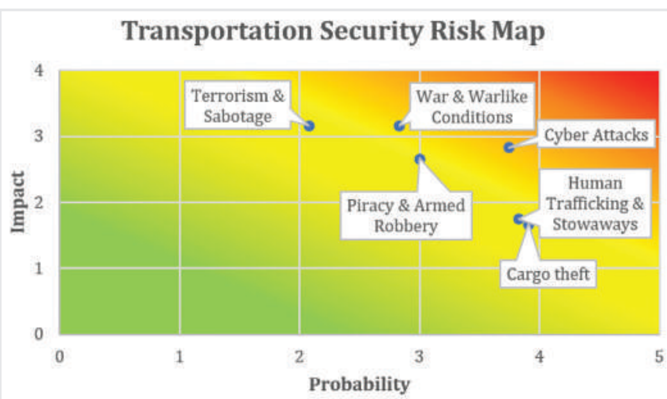

***Figure 2.** Risk mapping of container transportation security from Türkiye to the Far East*

Source: Authors

decision support. Therefore, a SWOT matrix is drafted, and another Delphi tour is conducted to collect experts' input to fine-tune the matrix. The final SWOT matrix (Table 7) is disseminated again to experts for prioritization of the main and sub-criteria using the SWOT AHP technique.

The basic goal of a SWOT analysis is to subjectively identify and assess an organizational and operational system's strengths, weaknesses, opportunities, and threats. By identifying these elements, new constitutive strategies based on strengths, weakness, eradication, exploitation of opportunities, and threat to can be devised. Opportunities and threats are identified as external factors, whereas strategies and weaknesses are identified as internal system elements [37].

AHP, a decision-making technique that considers both qualitative and quantitative factors aimed at using professional consultation to derive relative priority on absolute scales from discrete and continuous paired comparisons [38], helps to conduct SWOT more analytically and to elaborate the study. Moreover, the combined use of AHP and SWOT analysis is a promising approach for supporting strategic decision-making processes [39].

Three steps are involved in applying the SWOT AHP technique [38]. The first stage in conducting a SWOT analysis for strategic planning is to make a list of the significant internal (strengths and weaknesses) and external (opportunities and threats) variables. The weights of each SWOT group are captured in the second stage, which employs pairwise comparisons. To determine the relative importance of each element within the SWOT categories, the third phase employs AHP. The local weights of the factors are multiplied by the particular group weight to arrive at the overall factor weight rank.

By selecting a number from a standardized comparison scale of nine levels (Table 8) created by Saaty [40] to indicate the relative relevance of the criteria, the prioritization method is carried out. Pairwise comparison matrices provided the means for calculating the importance of these factors.

Table 7. *SWOT matrix of transportation risk between Türkiye and the Far East*

Strengths (S)	Weaknesses (W)
S1 Need for maritime expertise to perform terrorist attacks or sabotage against sea targets. **S2** Strict rules such as ISPS Code and CSI exist in IMO frameworks. **S3** Regional/international naval support against piracy and human trafficking. **S4** Use of technology enhancing the security of containers (AI, IoT, RFID, etc.).	**W1** Additional risks compared with other transportation modes such as piracy and stowaways. **W2** Increased reliance on communication and information networks renders shipboard power systems more susceptible to covert cyberattacks. **W3** A more potential space for smuggling. **W4** Risk of blocking choke points in case of terrorist attack/sabotage on a container ship, which will have a greater impact on the global economy.
Opportunities (O)	**Threats (T)**
O1 China's policy to bypass sea routes by alternative transport routes and pipelines. **O2** Existence of alternate routes, such as the Arctic route.	**T1** Existence of high-risk areas (HRA) through routes from Türkiye to the Far East. **T2** Increasing cyber-security risks with recent developments in technology. **T3** Territorial disputes in the South China Sea and the Taiwan problem.

Source: Authors' interpretation, including Delphi survey inputs

IoT: Internet of Things, RFI: Radio frequency identification

Table 8. *Pairwise comparison scale*

Importance	Explanation
1	Equally important or preferred.
3	Slightly more important or preferred.
5	Strongly more important or preferred.
7	Very strongly more important or preferred.
9	Extremely more important or preferred.
2,4,6,8	Intermediate values to reflect compromise.
Reciprocals	Used to reflect the dominance of the second alternative as compared with the first.

Source: [40]

Let $C = \{ C_j | j = 1, 2, ..., n\}$ be the collection of requirements. An (n x n) evaluation matrix A, in which each element is a_{ij} ($i, j = 1, 2, ...,$ n) is a quotient of the weights of the criteria (relative importance for i to j in each SWOT group), can be used to summarize the results of a pairwise comparison of n criteria. A square and reciprocal matrix can be used to illustrate this pairwise comparison (see Equation 5).

$$A = (a_{ij}) = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & & a_{nn} \end{bmatrix} \quad (5)$$

Each matrix is normalized, and the relative weights are determined in the last step. The right eigenvector (w) corresponding to the largest eigenvalue (λ_{max}) as follows:

$$A_W = \lambda_{max} \times \mathrm{w} \quad (6)$$

Matrix A has rank 1 and $\lambda_{max} = n$, if the pairwise comparisons are entirely consistent. Any of the rows or columns of a can be normalized in this scenario to yield weights.

Note that the consistency of the pairwise comparison judgments has an impact on output quality of the AHP. The relationship between the entries of

$A: a_{ij} \times a_{jk} = a_{ik}$ serves as the basis for determining consistency. The following formula can be used to compute the consistency index (CI).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7)$$

The assessment levels of consistency can be determined using the final consistency ratio (CR). According to Equation 8, the CR is determined by dividing the CI by the random index (Table 9).

$$CR = \frac{CI}{RI} \quad (8)$$

The generally acknowledged top limit for CR is 0.1. To increase consistency, the review process must be repeated if the final CR is higher than this.

3.5. Application

AHP is applied to the SWOT matrix. First, pairwise comparisons of the SWOT groups were performed using a comparison scale from 1 to 9 developed by Saaty [40]. Second, each SWOT group is considered while comparing the components of SWOT matrices. The expert team performs all pairwise comparisons in the application. Five of the 12 experts used in the first part of the study made up the expert team, and the first expert's prioritization scores are given below as an example (Table 10).

Table 9. *Random index*

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49
Source: [39] RI: Random index										

Table 10. *Pairwise comparisons of the SWOT factors for E1*

SWOT Groups	S	W	O	T	Importance degrees of SWOT groups
Strength (S)	1	3	1/3	1	0.223
Weaknesses (W)	1/3	1	1/3	1	0.129
Opportunities (O)	3	3	1	3	**0.485**
Threats (T)	1	1	1/3	1	0.161
CR=0.05	Source: Authors' calculations				

Table 11. *SWOT rankings of the main criteria based on pairwise comparisons*

SWOT/Expert	E1	E2	E3	E4	E5	Average	Rank
Strengths	0.223	**0.387**	0.183	**0.463**	0.161	**0.283**	**1**
Weaknesses	0.129	0.179	**0.316**	0.272	**0.424**	0.264	2
Opportunities	**0.485**	0.128	**0.316**	0.168	0.044	0.228	3
Threats	0.161	0.304	0.183	0.095	0.369	0.222	4
Source: Authors' calculations							

Table 12. *Comparison matrix of strength groups*

Strengths	S1	S2	S3	S4	Importance degrees
S1 Need for maritime expertise to perform terrorist attacks or sabotage against sea targets.	1	1/3	1/5	1/3	0.076
S2 Strict rules such as ISPS Code and CSI exist in IMO frameworks.	3	1	1/5	1	0.172
S3 Regional/international naval support against piracy and human trafficking.	5	5	1	3	0.559
S4 Use of technology enhancing the security of containers (AI, IoT, RFID, etc.).	3	1	1/3	1	0.191
CR=0.04 Source: Authors' calculations IoT: Internet of Things, RFI: Radio frequency identification					

The procedure is repeated and the results based on the opinions of five experts (E1, E2, E3, E4 and E5) are depicted in Table 11.

Subcriteria are then prioritized based on the same technique (Table 12).

Table 13. *SWOT rankings of strengths based on pairwise comparisons*

Strengths/ Experts	E1	E2	E3	E4	E5	Average	Rank
S1	0.076	0.055	0.061	0.073	0.065	0.066	4
S2	0.172	0.182	0.111	0.234	0.119	0.163	3
S3	**0.559**	0.238	**0.635**	**0.603**	**0.574**	**0.521**	**1**
S4	0.191	**0.522**	0.190	0.087	0.239	0.245	2
Source: Authors' calculations							

The procedure is repeated and the results based on the opinions of five experts (E1, E2, E3, E4 and E5) are depicted in Table 13.

Subcriteria are then prioritized based on the same technique (Table 14).

The procedure is repeated and the results based on the opinions of five experts (E1, E2, E3, E4 and E5) are depicted in Table 15.

Subcriteria are then prioritized based on the same technique (Table 16).

The procedure is repeated and the results based on the opinions of five experts (E1, E2, E3, E4 and E5) are depicted in Table 17.

Subcriteria are then prioritized based on the same technique (Table 18).

The procedure is repeated and the results based on the opinions of five experts (E1, E2, E3, E4 and E5) are depicted in Table 19.

4. Results and Discussion

There are different criteria for transportation mode selection, and safety/security is one of them. Other criteria for mode selection are cost, transport time, product characteristics (type of freight), service quality, market considerations (customers' demand), and carrier considerations [41]. Although there are initiatives such as the ISPS Code [42], which regulates the ship security analysis that must be performed by ship owners and operators, additional tools are needed to assess the security for a specific route, time period, or conditions. For example, the waters off the coast of Somalia were the world's most dangerous maritime channels between 2008 and 2011. During this time period, hundreds of attacks were conducted against ships, numerous seafarers were taken captive by pirates, and billions of dollars were spent by governments as hijacking costs.

Among the identified maritime transportation security risks, cyber-attacks had the maximum score -which is understandable-, considering the dependance on Global Navigation Satellite Systems and their vulnerability to jamming and spoofing. The second scored risk factor is

Table 14. *Comparison matrix of the weakness group*

Weaknesses	W1	W2	W3	W4	Importance degrees
W1 Additional risks compared with other transportation modes such as piracy and stowaways.	1	5	1	1	0.323
W2 Increased reliance on communication and information networks renders shipboard power systems more susceptible to covert cyberattacks.	1/5	1	1/3	1/3	0.082
W3 A more potential space for smuggling.	1	3	1	1/3	0.218
W4 Risk of blocking choke points in case of a terrorist attack/sabotage on a container ship, which will have a greater impact on the global economy.	1	3	3	1	0.375
CR=0.06 Source: Authors' calculation					

Table 15. *SWOT rankings of weaknesses based on pairwise comparisons*

Weaknesses/ Expert	E1	E2	E3	E4	E5	Average	Rank
W1	0.323	0.302	**0.418**	0.110	0.115	0.253	2
W2	0.082	**0.365**	0.217	0.173	0.085	0.184	4
W3	0.218	0.183	0.283	0.056	0.226	0.193	3
W4	**0.375**	0.148	0.080	**0.659**	**0.572**	**0.366**	**1**
Source: Authors' calculations							

Table 16. *Comparison matrix of the opportunities group*

Opportunities	O1	O2	Importance degrees
O1 China's policy to bypass sea routes by alternative transport routes and pipelines	1	5	1
O2 Existence of alternative routes, such as the Arctic route	1/5	1	2
CR=0.00 Source: Authors' calculations			

Table 17. *SWOT rankings of opportunities based on pairwise comparisons*

Opportunities/ Expert	E1	E2	E3	E4	E5	Average	Rank
O1	**0.833**	0.500	**0.833**	**0.833**	**0,866**	**0,773**	1
O2	0.166	0.500	0.166	0.166	0.129	0.225	2
Source: Authors' calculations							

Table 18. *Comparison matrix of the threats group*

Threats	T1	T2	T3	Importance degrees
T1 Existence of high-risk areas (HRA) through routes from Türkiye to the Far East.	1	3	5	0.655
T2 Increasing cyber-security risks with recent developments in technology.	1/3	1	1	0.186
T3 Territorial disputes in the South China Sea and the Taiwan problem.	1/5	1	1	0.157
CR=0.02 Source: Authors' calculations				

Table 19. *SWOT rankings of threats to on pairwise comparisons*

Threats/ Expert	E1	E2	E3	E4	E5	Average	Rank
T1	**0.608**	0.199	**0.607**	**0.655**	0.259	**0.477**	**1**
T2	0.242	0.199	0.302	0.186	0.106	0.207	3
T3	0.101	**0.600**	0.089	0.157	**0.634**	0.313	2
Source: Authors' calculations							

war and warlike conditions, including territorial disputes. Territorial disputes in the South China Sea have not yet had a significant effect on merchant traffic as in the Black Sea, although that may change if the situation worsens. Piracy and armed robbery, the third scored risk factor, are perceived by experts as not as high a risk factor as the first two risk factors because of the modus operandi of the pirates in the Malacca Strait, which generally occurs as petty theft instead of hijacking.

Therefore, policy recommendations for the first part of the study could be to ensure that cyber awareness protocols, including IMO recommendations [43,44], are followed in addition to some basic precautions, such as the segregation of vessel networks, frequent password changes, or software updates. Another countermeasure could be switching off the AIS in high-risk areas (HRA) upon the lawful decision of the ship's captain [45].

There is not much that can be done about the risk of war and warlike conditions other than to take appropriate security measures, such as staying away from HRAs or taking necessary precautions in ports with ISPS Security Level 3. For piracy risk, complying with IMO and Best Management Practices (BMP) recommendations would be the best option apart from a detailed threat and risk assessment to be conducted by the companies and ships prior to transit through the HRA, as stated in BMP-5 [46].

When analyzing the results of the prioritization of the main SWOT criteria, "strengths" had the highest score, which indicates that existing tools such as regulatory legislation, naval support, and use of technology together with the need for maritime expertise to perform a terrorist attack are recognized enough for the experts to choose strength as the highest scored SWOT criterion. This can be interpreted as indicating that although there are some hurdles, maritime container transportation's strengths are higher than its weaknesses, which makes it a preferred mode of transportation compared to other modes, in terms of security aspects.

Among the subcriteria within the main SWOT factors, the highest scored "strength" factor is "regional/international naval support against piracy and human trafficking". Operations that help decrease piracy incidents off the Somali coast, such as NATO's Operation Ocean Shield (terminated end 2016), the EU's Operation Atalanta, and Combined Task Force-151 led by the United States, are examples of how this option works. A similar operation, named MALSINDO, has been carried out in the Malacca Strait since 2014 by the Malaysian, Indonesian, and Singaporean navies to manage piracy in the region.

The highest scored "weakness" is "risk of blocking choke points in case of a terrorist attack/sabotage to a container ship that will have a greater impact on global economy". Although the Ever Given accident in 2021 in the Suez Canal was a safety incident, attacks that disrupt choke points can easily be organized by terrorists using remote controlled "kamikaze" unmanned surface vehicles (USV) packed with explosives. It should be remembered that until the stuck ship was rescued, the blockage of the Suez Canal -through which 30% of the world's container ship traffic passes- cost $9 billion per day [47], with hundreds of ships waiting at both entrances of the canal or some preferring the Cape of Good Hope by extending their route by at least 4,000 extra miles, or 6 more transport days (minimum).

Within the subcriteria "opportunities", "China's policy to bypass sea routes by alternative transport routes" is the preferred choice between the two criteria, such as the China-Pakistan Economic Corridor and/or Kra Canal. The former aimed to secure and reduce passage through the Malacca Strait for China's energy imports, and the latter planned to connect the Andaman Sea across southern Thailand. The second opportunity, namely Arctic routes bypassing the Suez route, has recently increased in importance with the expanded time window in which the passage could be accomplished throughout the year without the assistance of icebreakers, as a result of global warming. Furthermore, it is shorter than the Suez route. Although Turkish shipping companies have not yet begun to use that route, they may do so in the future.

Within the "threats" subcriteria, "the existence of HRA through the routes from Türkiye to the Far East" had the highest score. When checking the *International Bargaining Forum's list of designated war risk areas [48] as of September 1, 2023, 12 nm. off the Yemeni Coast including all ports, excluding the Maritime Security Transit Corridor in the Red Sea, is designated as the risk area and the recommendation is to operate at ISPS Level 3. Additionally, considering the developments in Israel, the security level of Turkish flagged ships that will call at Israeli ports and sail off the coast of these ports has been increased to three by the Ministry of Transport and Infrastructure [49].

Although not an HRA, the Straits of Malacca and Singapore (72 incidents), South China Sea (4 incidents), and Arabian Sea (1 incident) are areas of concern in terms of piracy and armed robbery, constituting 58% of all piracy incidents in 2022 throughout the world (131 incidents). In the same year, out of 77 incidents en route to the Far East, 6 were against container ships, in two of which the crew's belongings were stolen, without any injuries [50]. In the first six months of 2023 -for which monthly reports were published by the IMO- of a total 89 incidents, 7 were against container ships in the Straits of Malacca and Singapore, the South China Sea, and the Arabian Sea, 6 were at anchor and 1 was drifting, no crew members were injured, and all resulted in stolen equipment. Most of the attacks in those regions were conducted against bulk carriers and tankers, whose low speed and freeboard compared with container ships make them easier for pirates to board [51].

5. Conclusion

The aim of this study was to understand the perception of security risks in the container trade by choosing the Suez route from Türkiye to the Far East as a case study based on three research questions. The 12 experts selected from shipping companies and academia concluded that among the six identified risk factors, cyber-attacks were the most dangerous. Additionally, SWOT factors are identified and prioritized. Strengths were the highest scored main criterion, and each subcriteria was prioritized as explained above. Although "strengths" scored highest among the SWOT prioritization, recent incidents in the Black Sea could occur in the South China Sea if the situation worsens; if so, they could impact merchant traffic and hence the global supply chain.

The merging of hitherto standalone operational technology (OT) systems -which physically operate several systems

*The International Bargaining Forum (IBF) brings together the International Transport Workers' Federation (ITF) and the international maritime employers that make up the Joint Negotiating Group (JNG).

onboard the ship-with information technology (IT) systems deployed both onboard and ashore has made the marine industry extremely vulnerable to cybersecurity threats today. Cloud computing, the Internet of Things, and autonomous technologies will continue to be adopted by the maritime industry, which will boost the interconnectedness between OT and IT and raise cybersecurity threats. Moreover, maritime pirates can exploit cybersecurity breaches to track ship movements and gather intelligence about possible weaknesses in defenses.

Therefore, more strict legal implications are needed to tackle both cyber security and piracy risks from the viewpoint of governments and international maritime security governance. Creating courts with specific jurisdiction, such as the ones established for piracy crimes in West Africa, may help prevent cybercrimes as well.

On the other hand, climate change affects maritime transportation and its security. The increasing time window for the use of the Arctic route will not only decrease transit time and cost but also eliminate security risks in the Suez route, which increased recently after the Israel-Hamas war.

Finally, the main conclusion is that additional risk assessments are needed by shipping companies for a specific route or a period to increase transportation security.

6. Suggestions for Further Research

Most research in this area takes both safety and security into account, which in a way is understandable because of their close link, but security-specific research assessing a designated route or transportation mode such as intermodal transport could contribute to the literature. Additionally, considering the fast-growing digitalization and automation in our era, recommendations for future research could include a security risk assessment for autonomous ships and security concerns against unmanned underwater vehicles (UUVs) or USVs.

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Marine and Technical Superintendent Training Programs: A New Step for Marine Engineering, and Maritime Transportation and Management Engineers

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Abstract

In pursuit of elevating the standards of technical management within the maritime industry, UCTEA, the Chamber of Turkish Marine Engineers (GEMIMO), has instituted the "Marine and Technical Superintendent Training Programs". This document provides an overview of these programs, their objectives, content, and significance within the maritime sector.

Keywords: Marine, Technical, Superintendent, Training

1. Introduction

As the UCTEA, the Chamber of Marine Engineers, we organized the "Marine and Technical Superintendent Training Programs" to enhance the quality and standard of technical management in the maritime industry. This training program aims to strengthen the professional competence of marine engineering officers (both engine and deck) and enable them to play an effective role in technical inspection processes.

2. Training Objectives

The primary objective of the Superintendent Training Program is to provide comprehensive training to marine engineering and Maritime Transportation and Management officers on ship emerging technologies, safety standards, and international regulations. This program aims to equip participants with essential technical management skills and enhance their abilities to keep up with technological advancements, comply with safety protocols, and efficiently manage ship machinery operations.

3. Training Content

The Superintendent Training Program is designed to cover a wide range of topics. Throughout the training process, participants acquire detailed knowledge of ship technologies, machinery systems, energy management, maintenance strategies, emergency planning, and international inspection standards. The program also emphasizes the roles, responsibilities, and ethical standards of marine engineering officers. Practical applications and case studies are integral to the program.

4. Training Process

The Superintendent Training Programs follows a modular structure and spans a total duration of 60 h. The program comprises theoretical lectures, interactive workshops, hands-on exercises, and practical applications. During the training process, participants receive lessons from industry-leading experts and academicians and share their experiences. In addition, opportunities for collaboration and networking among participants are provided.

5. Conclusion

The "Superintendent Training Programs" is a comprehensive training program aimed at enhancing the professional competence of marine engineering and maritime transportation and management engineers. It equips participants with in-depth knowledge of ship technologies

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and safety standards, enabling them to play an active role in inspection processes. The program aims to help marine engineering officers become significant contributors to a safer, more efficient, and sustainable maritime industry.

In the training, various topics are covered, including the role and responsibilities of inspectors, quality management systems, maritime customs and traditions, ethics, budgets and cost control, quality assurance, reporting and record-keeping, information technologies, monitoring ship performance, dry-docking and repairs, certification and surveys, the role of classification societies, ship purchase, sale, and delivery, port state control, corrosion protection and paint systems, emergency response, marine insurance, maritime law, and many more.

These training programs hold paramount importance because they will elevate the competence of marine superintendents in the industry, ensuring their ability to meet the evolving demands of the field. By equipping inspectors with comprehensive knowledge and skills, these programs will enhance the quality and reliability of technical inspections. Furthermore, these training initiatives are designed to adapt to the ever-changing landscape of the maritime industry by incorporating up-to-date data, emerging technologies, and industry best practices. This commitment to staying current and relevant will ensure that inspectors remain well-equipped to address the challenges and complexities of the future. With the continuous development and refinement of these training programs, the industry can look forward to a highly qualified and proficient workforce of inspectors who will play a vital role in ensuring safety, compliance, and efficiency in maritime operations.

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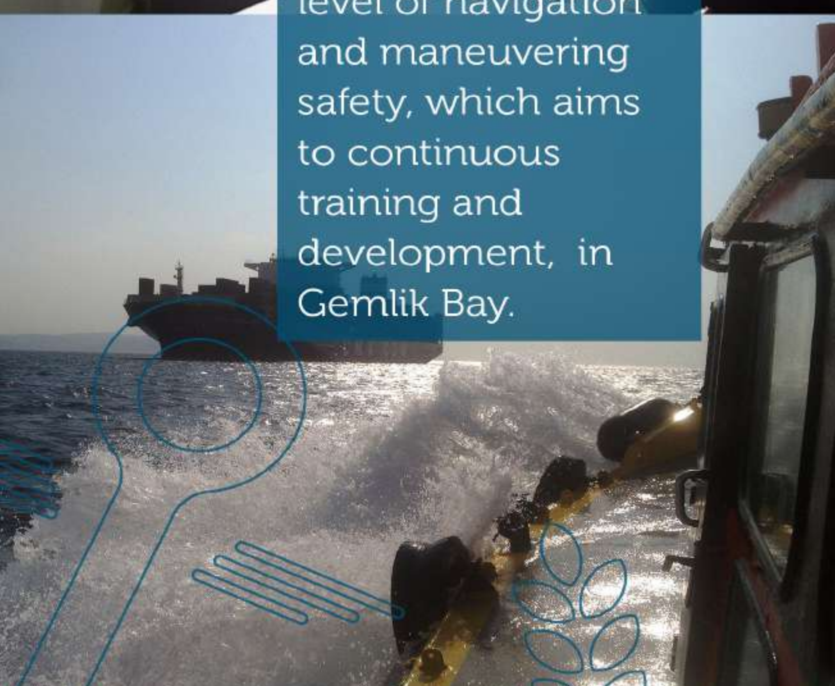

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