ORIGINAL RESEARCH (AR) DOI: 10.4274/jems.2023.04900

Journal of ETA Maritime Science 2023;11(4):251-258

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

Ender Yalçın[1,2], Serap Göksu[3], Can Taş[4]

[1]Bandırma Onyedi Eylül University Faculty of Maritime, Department of Maritime Transportation Management Engineering, Balıkesir, Türkiye
[2]Newcastle University Faculty of Engineering, Newcastle, United Kingdom
[3]Recep Tayyip Erdoğan University Faculty of Maritime, Department of Maritime Transportation Management Engineering, Rize, Türkiye
[4]İskenderun Technical University, Maritime Higher Vocational School, Maritime and Port Management Programme, Hatay, Türkiye

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.

Address for Correspondence: Ender Yalçın, Newcastle University Faculty of Engineering, Newcastle, United Kingdom
E-mail: ender.yalcin@newcastle.ac.uk
ORCID ID: orcid.org/0000-0001-5898-3191

Received: 26.08.2023
Last Revision Received: 04.10.2023
Accepted: 09.10.2023

To cite this article: E. Yalçın, S. Göksu, and C. Taş. "A Contemporary Analysis for COVID-19 Pandemic Related Port Congestion in Gemlik Region of Türkiye." *Journal of ETA Maritime Science*, vol. 11(4), pp. 251-258, 2023.

• 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

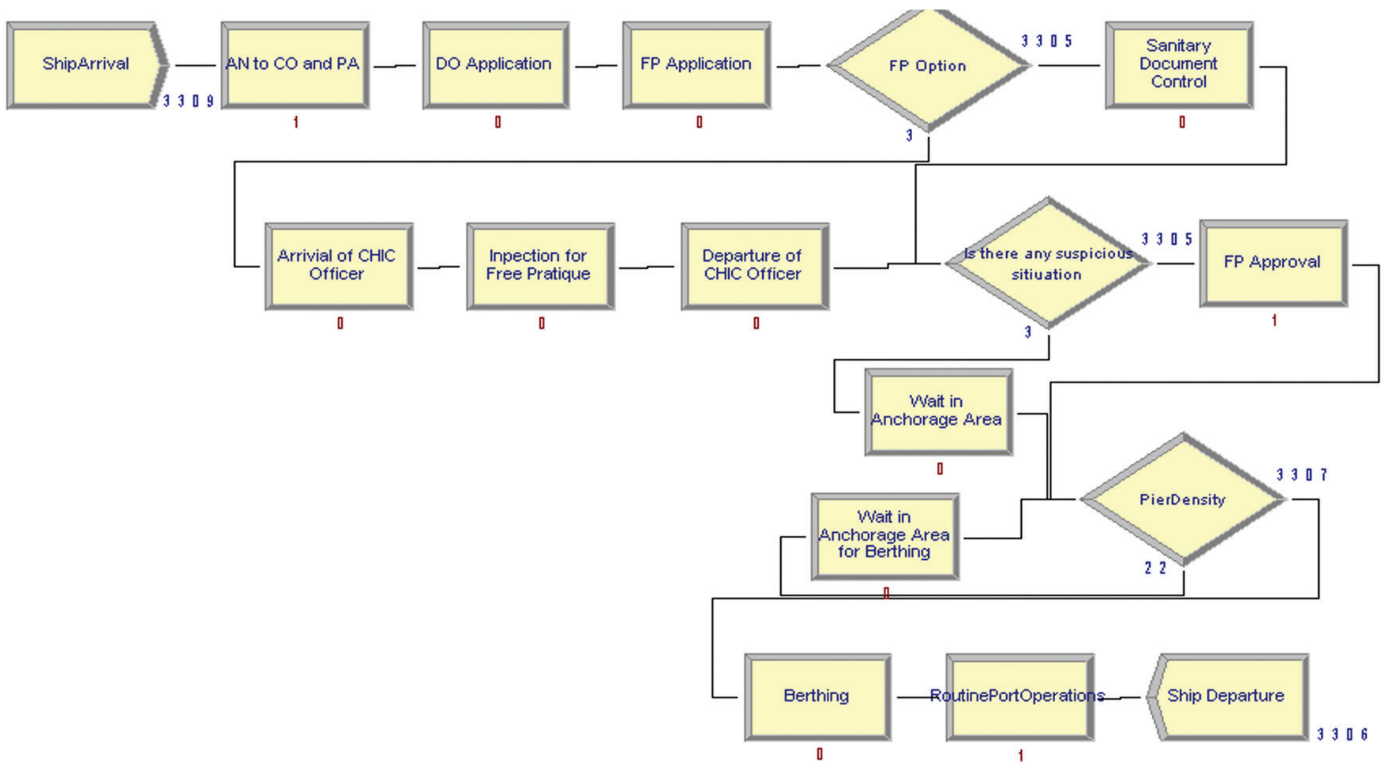

Figure 1. *System simulation model for port operations of ships under the effect of COVID-19 pandemic*

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,

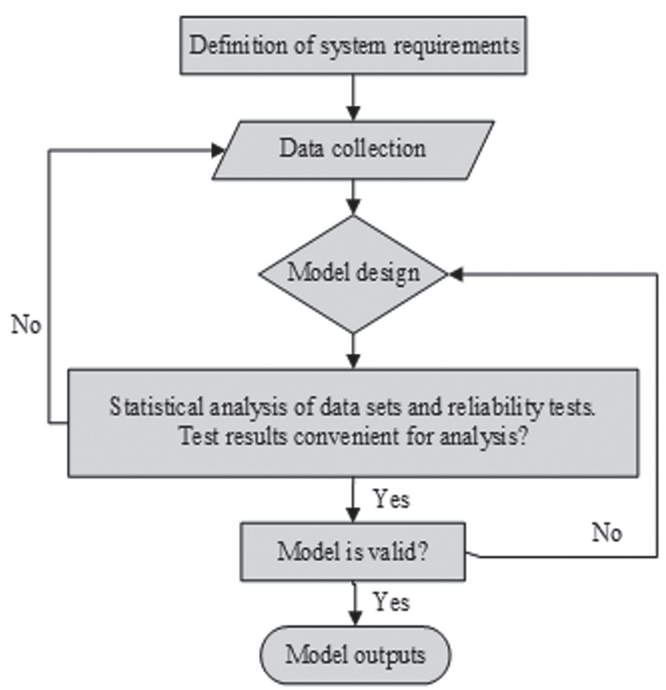

Figure 2. *The modelling procedures in system simulation approach [14]*

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.

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 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.

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

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.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept design: E. Yalçın, S. Göksu, and C. Taş, Data Collection or Processing: E. Yalçın, and C. Taş, Analysis or Interpretation: E. Yalçın, Literature Review: S. Göksu, and C. Taş, Writing, Reviewing and Editing: E. Yalçın, and S. Göksu.

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

[1] J. J. Wang, and M. C. Cheng, "From a hub port city to a global supply chain management center: a case study of Hong Kong," *Journal of Transport Geography*, vol. 18, pp. 104-115, Jan 2010.

[2] P. T. Narasimha, P. R. Jena, and R. Majhi, "Impact of COVID-19 on the Indian seaport transportation and maritime supply chain," *Transport Policy*, vol. 110, pp. 191-203, Sep 2021.

[3] J. Shan, M. Yu, and C.Y. Lee, "An empirical investigation of the seaport's economic impact: Evidence from major ports in China," *Transportation Research Part E: Logistics and Transportation Review*, vol. 69, pp. 41-53, Sep 2014.

[4] UNCTAD, "Trade and Development Report", [Online]. Available at: https://unctad.org/tdr2022. [Accessed: August 14, 2023].

[5] M. Lind, et al. "Maritime Informatics for Increased Collaboration," *Maritime Informatics*, Progress in IS. Springer, Cham, pp. 113-136, Nov 2020.

[6] M. Mańkowska, M. Pluciński, I. Kotowska, and L. Filina-Dawidowicz, "Seaports during the COVID-19 Pandemic: The Terminal Operators' Tactical Responses to Disruptions in Maritime Supply Chains," *Energies*, vol. 14, pp. 1-22, Jul 2021.

[7] T. N. Cuong, H. S. Kim, S. S. You, and D. A. Nguyen, "Seaport throughput forecasting and post COVID-19 recovery policy by using effective decision-making strategy: A case study of Vietnam ports," *Computers & Industrial Engineering,* vol. 168, Jun 2022.

[8] J. Jeevan, N. H. Mohd Salleh, I. M. Mohd Zaideen, M. R. Othman, M. N. S. Menhat, and L. Divine Caesar, "Application of geoeconomics in seaport operations: a theoretical proposal for post Covid-19 recovery strategy," *Australian Journal of Maritime and Ocean Affairs*, vol. 12, pp. 217-242, Oct 2020.

[9] A. S. Alamoush, F. Ballini, and A. I. Ölçer, "Ports, maritime transport, and industry: The immediate impact of COVID-19 and the way forward," *Maritime Technology and Research*, vol. 4, Jan 2020.

[10] J. Y. Chua, R. Foo, K. H. Tan, and K. F. Yuen, "Maritime resilience during the COVID-19 pandemic: impacts and solutions," *Continuity & Resilience Review*, vol. 4, pp. 124-143, 2022.

[11] D. Russell, K. Ruamsook, and V. Roso, "Managing supply chain uncertainty by building flexibility in container port capacity: a logistics triad perspective and the COVID-19 case," *Maritime Economics and Logistics*, vol. 24, pp. 92-113, 2022.

[12] A. Sharifi, A. R. Khavarian-Garmsir, and R. K. R. Kummitha, "Contributions of smart city solutions and technologies to resilience against the covid-19 pandemic: a literature review," *Sustainability*, vol. 13, pp. 1-28, Jul 2021.

[13] A. Shahpanaha, A. Hashemia, G. Nouredinb, S. M. Zahraeea, and S. A. Helm, "Reduction of ship waiting time at port container terminal through enhancement of the tug/pilot machine operation," *Jurnal Teknologi*, vol. 68, pp. 63-66, May 2014.

[14] E. Yalcin, O. Arslan, and M. Aymelek, "A multilayer stock level recommendation for a ship inventory system: a system simulation approach," *V. International Scientific and Vocational Studies Congress - Engineering (BILMES EN 2020)*, pp. 12-15, Dec 2020.

[15] J. Cong, L. Cui, G. Ding, and B. Ren, "Simulation on aviation maintenance support system based on goal-driven," *Journal of System Simulation*, vol. 33, pp. 2157-2165, 2021.

[16] R. Feng, et al. "Improvement pathways of vehicle fuel energy conversion based on energy flow experiment and system simulation," *Case Studies in Thermal Engineering*, vol. 39, Nov 2022.

[17] X. Bai, H. Wu, S. Yang, and Z. Li, "Probabilistic production simulation of a wind/photovoltaic/energy storage hybrid power system based on sequence operation theory," *IET Generation, Transmission & Distribution*, vol. 12, pp. 2700-2706, Jun 2018.

[18] M. Elnour, N. Meskin, K. Khan, and R. Jain, "Application of data-driven attack detection framework for secure operation in smart buildings," *Sustainable Cities and Society*, vol. 69, Jun 2021.

[19] F. C. Chien, and Y. C. Chiu, "Assessing the impact of dropsonde data on rain forecasts in taiwan with observing system simulation experiments," *Atmosphere*, vol. 12, pp. 1-23, Dec 2021.

[20] K. W. Belcher, M. M. Boehm, and M. E. Fulton, "Agroecosystem sustainability: a system simulation model approach," *Agricultural Systems*, vol. 79, pp. 225-241, Feb 2004.

[21] L. Xiong, P. Hu, and H. Wang, "Establishment of epidemic early warning index system and optimization of infectious disease model: Analysis on monitoring data of public health emergencies," *International Journal of Disaster Risk Reduction*, vol. 65, Nov 2021.

[22] M. C. R. Leles, E. F. Sbruzzi, D. O. M. P. Jose, and C. L. Nascimento, "A MatLabTM computational framework for multiagent system simulation of financial markets," *SysCon 2019 - 13th Annual IEEE International Systems Conference*, 2019.

[23] L. Ziyan, T. Ke, X. Qing, X. Chengrong, and X. Yuhua, "Finite-time impulsive control of financial risk dynamic system with chaotic characteristics," *Complexity*, pp. 1-8, Jun 2021.

[24] B. Dragović, E. Tzannatos, and N. K. Park, "Simulation modelling in ports and container terminals: literature overview and analysis by research field, application area and tool," *Flexible Services and Manufacturing Journal,* vol. 29, pp. 4-34, 2017.

[25] J. Liu, X. Wang, and J. Chen, "Port congestion under the COVID-19 pandemic: The simulation-based countermeasures," *Computer & Industrial Engineering*, vol. 183, Sep 2023.

[26] S. Park, S. Yun, and S. Kim, "Autonomous vehicle-loading system simulation and cost model analysis of roll-on, roll-off port operations," *Journal of Marine Science Engineering*, vol. 11, pp. 1-20, Jul 2023.

[27] Y. Keceli, S. Aksoy, and V. A. Aydogdu, "Simulation model for decision support in Ro-Ro terminal operations," *International Journal of Logistics Systems and Management,* vol. 15, pp. 338-358, Jun 2013.

[28] R. Iannone, S. Miranda, L. Prisco, S. Riemma, and D. Sarno, "Proposal for a flexible discrete event simulation model for assessing the daily operation decisions in a Ro–Ro terminal," *Simulation Modelling Practice and Theory,* vol. 61, pp. 28-46, Feb 2016.

[29] I. S. Manoy, W. Djafar, and A. H. Djalante, "Simulation of utilization rate of loading/unloading of equipment in Makassar container terminal by using ARENA," *AIP Conference Proceeding,* vol. 2543, Nov 2022.

[30] Y. Tang, L. Li, and X. Liu, "State-of-the-art development of complex systems and their simulation methods," *Complex System Modeling and Simulation*, vol. 1, pp. 271-290, Dec 2021.

[31] J. A. Sokolowski, and C. M. Banks, "Principles of modeling and simulation: a multidisciplinary approach," *John Wiley & Sons, Inc.,* 2008.