

Strategies for Coping with the Pandemic at Ports

A Case Study on Bulk Carrier Operations.

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Abstract

The worldwide distribution systems experienced major interruptions due to the COVID-19 pandemic. As a result, the maritime industry faced extended delays in bulk carrier operations. This research examines the problems bulk carriers encountered during the pandemic, including challenges related to crew exchanges and operational delays and their impact on global trading activities. The research investigates the adaptive strategies used by maritime ports, such as Singapore and European ports, to tackle these challenges. A qualitative research methodology was adopted, involving semi-structured interviews with ten maritime professionals and two significant case studies of port responses. Important changes in operations, such as digital change, automation, and improved relationships with suppliers. According to the findings, future threats mean maritime operations must be open to change and adaptation, but using technology ensures the ongoing success of businesses. The findings are used by organizations to design better ways to lead during emergencies and be better prepared for problems that might interrupt their work.

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1 Introduction

The COVID-19 pandemic created extraordinary problems throughout all business sectors worldwide and significantly impacted maritime operations. This pandemic created major work issues at ports globally because people had to stay home as per the changed travel rules. While ports are essential centres for the well-being of humankind, they are also inevitable nodes in maritime supply chains (Alamouh et al., 2020) ; (Notteboom et al., 2021). Globally, 8,292 ports exist in 222 countries, 835 of which are the most active seaports and handle 99 % of seaborne trade (Exportvirginia 2014). Various emergencies require constant attention, and pandemics are no exception in the maritime industry. Firstly, long periods at sea, confined spaces, limited access to healthcare, and regulatory complexity are the main obstacles to maintaining crew health and welfare. Secondly, immediate medical help is out of reach because sometimes it is challenging to manage some restrictions. The crew members are exposed to a higher chance of contracting an infectious disease owing to close confined living and working stations, no access to adequate medical care, and proper preventive measures onboard. During the early stages of the pandemic, the maritime trade, which accounts for approximately 80% of global goods transport, experienced a significant decline in volumes. According to the International Maritime Organization (IMO), there has been a considerable delay in global container traffic management due to congested ports, which also caused difficulties with crew movements. These operational difficulties have made worldwide supply problems worse. The maritime logistics shortages exposed during COVID-19 forced organizations to implement new operating approaches to manage emergencies.

Bulk carriers play an important role in getting essential goods such as grain, coal, and iron ore to markets that need them to run their industries and keep people fed worldwide. Bulk ships transport loose bulk materials and provide strong support for the global trade economy, which helps nations thrive through constant raw material supplies. The bulk shipping industry has undergone significant changes in its operations and management since the pandemic began. Delivery operations switched to remote operations quickly because their existing digital systems fit the need. To facilitate international trade, many port authorities have implemented remote and digital approaches for conducting vessel inspections at ports. There has been a rise in the prevalence of ports where the physical

presence of port health officials is deemed unnecessary for granting free pratique to a vessel. Nowadays, also a large number of ports maintain electronic platforms to simplify customs and port authorization processes. So, the COVID-19 pandemic has positively and negatively impacted the shipping industry and global trade. This study investigates these simultaneous effects of the crisis.

1.1 Statement of the problem

During the COVID-19 pandemic, bulk carrier ports showed significant weak points in the maritime industry. The worldwide port faced difficulties from crew changes restricted by travel regulations, extended quarantines, and inadequate cargo management because of labor shortages. There were severe effects of the interruptions on delivering essential goods, disrupting supply chains in global trade, and threatening port worker's and seafarer's health and safety. This pandemic caused a worldwide crew change crisis due to significant disruption of regular crew rotations in the highly confined environment of a ship due to border closures and multiple restrictions. This situation arrise mental health issues among seafarers, as uncertainties related to crew changes—including limited shore leave and strict quarantine measures—negatively affected their well-being, (Kulke et al., 2023).The lack of standardized global responses further intensified these challenges. Port authorities worldwide implemented inconsistent measures, creating logistical inefficiencies and increasing operational risks(Notteboom et al.,2021). Furthermore, (Duru & Okan,2018) argue that maritime workers frequently occupy environments in which swift medical assistance cannot be summoned, thus stimulating a higher probability of blood-borne infections and other health hazards among them while executing their regular job tasks. Workforce deficit and shore leave limitations harden the points. Seafarers faced restricted access to health information, preventive services, and timely medical intervention, which were already limited due to the isolated nature of their work (Fjørtoft et al. 2023). Also, (Galam et al.2024) highlight that staying on the ports for a limited time was hazardous for reasons like having little opportunity for recovery and getting care that was not always the same everywhere. Therefore, good strategies are needed now, more than ever, to avoid problems and maintain the resilience of ports during worldwide crises. According to (Diskin, 2024), without consistent health screening protocols and synchronized international efforts, the maritime industry remains vulnerable to health and

operational risks that could have widespread implications for global trade and public health.

1.2 Purpose and research questions

The purpose of this research is the following

1. To investigate the biggest challenges faced by bulk carrier operations during the pandemic.
2. To identify the steps were taken to adapt cargo handling procedures that comply with the health regulations.
3. To identify the disruptions that happened in the carrier operation procedures under the altered regulations compared to normal handling processes .
4. To find any automation solutions that were implemented to ease the carrier operations and the advantages of those solutions.
5. To investigate the optimal approaches undertaken for minimizing port operation disruptions while maintaining personnel safety.

To meet the purpose of this research, this research will find the answers of the below questions:

1. What were the biggest challenges in bulk carrier operations during Covid 19 pandemic and how port authorities tackled the situation?
2. How did the modified carrier operation arrangement affect the port authorities and how the automation solutions, if any, improved the overall situation?
3. What were optimal approaches that worked best in balancing both the port operations and crew's health security during pandemic, and what recommendations can be drawn to ensure the mitigation of any such crisis in the future?

1.3 Delimitation

The research examines bulk carrier operations at ports during the COVID-19 pandemic as its specific focus within the maritime industry. While other vessel types, such as container ships and cruise liners, also experienced disruptions, the study limits its analysis to bulk carriers due to their critical role in transporting essential commodities like grain, coal, and iron ore.

The research is further constrained by:

- Focus on ports operational challenges that implemented distinct operational adaptations, not on broad financial or economic impacts.
- The study primarily covers the period from early 2020 to mid-2023, when the pandemic had significant operational impacts on global ports.
- Discuss crew mental health issues only as part of the broader operational challenges, rather than conducting an in-depth psychological analysis.
- Analyze case studies of ports that implemented automation or digital solutions.

1.4 Research method

This study employs a qualitative research approach to explore the challenges and adaptations in bulk carrier operations during the COVID-19 pandemic. Researchers use qualitative research to investigate authentic situations to discover information that numbers alone cannot reveal (Strauss & Corbin, 2008). The study uses semi-structured interviews with maritime professionals, including ship captains, cargo superintendents, and port authorities, according to (May, 1997) , to achieve flexible data collection with a structured comparison framework. The study includes case analyses about how ports in Singapore manage crew exchanges and digitization projects in European ports to demonstrate specific implementation methods.

2 Literature review

2.1 Impact of the pandemic on maritime port logistics

Worldwide supply chains suffered intense damage because of the COVID-19 pandemic, starting with port logistics operations. China reacted swiftly to the virus and established new business operations. European supply chains needed additional time to recover because of supply breakdowns and staff shortages and heightened business uncertainties. According to the analysis report on the impact of the COVID-19 pandemic on the global economy released by the United Nations Conference on Trade and Development (UNCTAD 2020) in the statement of (March et al., 2021), the epidemic will become a significant threat to the global economy. It may cause the annual growth rate of the global economy to drop to 2.5% in 2020 due to port congestion, workforce shortages, and delays caused by quarantine measures and health protocols. Ports faced challenges adapting to reduced staffing and increased health requirements, resulting in operational inefficiencies and rising freight rates. The bulk transport of essential goods, including food grains and minerals, alongside raw materials, through ports operated at lengthy delays, escalating operational expenses as per UNCTAD's 2020 report, while disrupting global trade flows. Ports introduced simplified operational protocols alongside contingency strategies to adapt to changing volumes of merchandise while overcoming access congestion issues. At that time, many ports implemented digital solutions, remote monitoring systems, and electronic documentation to automate operations while minimizing physical contact requirements (Bešković et al., 2022). Port policy and regulatory inconsistencies during the pandemic period produced additional challenges that placed extra risks upon logistics providers while making cooperation more complicated, according to (Notteboom & Rodrigue, 2022). The disruptions showed the importance of creating port systems that effectively manage unexpected disruptions. Understanding the pandemic's effects on ports and logistics suppliers creates essential knowledge to develop a stronger maritime industry framework.

2.2 Crew change and health challenges

From the IMO series of circulars, among them (IMO-c, 2020; IMO-e, 2020), the seafarers' crisis of crew changes and repatriation was one of the most ongoing concerns. The disruption of regular crew exchanges due to the pandemic posed severe physical and

mental health risks for seafarers. (Baygi et al., 2021) highlight that when seafarers spend extended periods at sea and are isolated from the shore, it results in significant mental health challenges and physical fatigue. In essence, these problems not only place the health of its maritime personnel at risk but also significantly compromise overall operational effectiveness within the maritime sector. Uniform health protocols across ports prevented efficient disease control measures from being deployed, so seafarers and port personnel remained at greater risk, according to (Duru & Okan, 2018). According to (ILO,2024) seafarers cannot stay on board continuously for more than 12 months without acquiring leave. Circumstances during the pandemic required seafarers to prolong their assignments through extended periods since travel limitations and scarce crew interchange stations prevented relief. Seafarers developed extreme fatigue at the same time their mental health conditions deteriorated, which resulted in widespread operational breakdowns. Multiple ports applied different testing and quarantine rules at their facilities as a way to fulfill public health requirements; however, these regulatory approaches led to operational delays and inconsistent procedures. This period brought significant disruptions to crew return tasks and reassignment because local authorities blocked international movement and crew transfer operations. The IMO and other organizations started observing this problem, leading them to ask nations for immediate intervention. Secretary-General António Guterres of the United Nations acknowledged that seafarers endured a humanitarian crisis according to his assessment of their role in sustaining worldwide trade operations. In his message on World Maritime Day 2020 (September 24), Guterres urged nations to designate seafarers as essential workers and protect their right to unrestricted crew rotation in the maritime sector, as the humanitarian and security crises in the industry.

2.2.1 Singapore Crew Change Crisis During the COVID-19 Pandemic

The global maritime industry faced severe disruption due to the COVID-19 pandemic, with crew change challenges emerging as the most pressing issue. The port city of Singapore, as an international maritime center, found itself confronting this crisis. Millions of seafarers at sea endured extended contractual obligations because of global border closures and travel restrictions. Operational security vulnerabilities became apparent, and the maritime community's humanitarian needs emerged strongly due to this crisis, (Dolumbia-Henry 2020) .

At the time of the pandemic, Singapore, like many countries, closed its borders and restricted crew changes to prevent the spread of the virus. The pandemic affected more than 400 thousand seafarers as their contracts lasted longer than legal limits because of crew change restrictions. These restrictions violated the Maritime Labour Convention (MLC) and prompted emergency action from the International Maritime Organization (IMO) and the International Labour Organization (ILO). The prohibition of crew exchanges in Singapore at the beginning created supply-chain complications which added burden to maritime personnel through increased physical and mental challenges. The inability to change crew members caused crews to become exhausted, which reduced operational efficiency while raising concerns about crew safety alongside vessel safety (Ghaforian Masodzadeh et al. 2022). Under continuous pressure from shipping companies, unions, and international organizations, Singapore's Maritime and Port Authority (MPA) took a leadership role in crafting a structured, health-focused response. The outcome led to the implementation of the Crew Change Protocol that incorporated

- a) 14-day quarantine for arriving crew in designated facilities.
- b) Multiple COVID-19 tests (pre-departure and post-arrival PCR tests).
- c) Green Lane arrangements with selected countries to facilitate crew movements.
- d) Safe Travel Passes and pre-approved transit corridors.
- e) Digital documentation systems minimize contact and speed up immigration procedures.

These policies were supported by close coordination between the Ministry of Health, Ministry of Manpower, immigration authorities, and port operators (IMO 2020) .

2.2.2 Crewchange handbook at Singapore

During the COVID-19 pandemic, according to (MPA SINGAPORE 2020) , Singapore became one of the few locations facilitating crew changes with the following key requirements

1. Vaccination and Testing
 - Fully vaccinated crew within the Active Vaccination Travel Lane (VTL) could register without requiring a Stay-Home Notice (SHN) or VTL-specific flights.

- A negative COVID-19 PCR test, conducted within two days before departure, or a professionally administered Antigen Rapid Test (ART) within 48 hours, was mandatory for non-vaccinated crew.
- Fully vaccinated crew were exempt from pre-departure Fit-to-Travel (FTT) testing, but non-vaccinated crew still required it within 24 hours before departure.

2. Exemptions

- Fully vaccinated crew recovered from COVID-19 within 90 days were exempt from all testing and SHN with proper documentation.
- Non-vaccinated recovered crew were exempt from pre-departure testing but had to observe SHN.

3. Operational Rules

- Crew must not have gone ashore or interacted with shore personnel in the last 7 days before disembarkation.
- Ships were required to depart promptly after completing the crew change.

4. Application Process

- Initially requiring a 7-day advance submission, crew change applications could be submitted at least 3 days before departure starting March 2022.

2.3 Regulatory responses during COVID-19

The COVID-19 pandemic that began in 2019 brought unprecedented challenges to the maritime industry and highlighted the vulnerabilities faced by seafarers. The travel restrictions and quarantine measures led seafarers to remain at sea, which led to extended periods onboard and resulted in mental health issues as well as limited access to medical care (M.,A.J.& J. Brown, 2020) . The isolation, stress, and demanding nature of seafarer work can contribute to mental health issues, so mental health support for seafarers must become a priority, brought up (Nautilus shipping, 2024). During the pandemic, several industrial associations and organizations took action to address the crisis.

The IMO establishes programs to increase understanding and provide aid for mental health problems experienced by seafarers. In response, the International Maritime Organization (IMO) issued guidelines and recommendations to its member states, urging them to recognize seafarers as essential workers and to facilitate crew changes to improve working conditions at sea (IMO- c, 2020). The IMO circulated a preliminary list of recommendations for governments and relevant national authorities on facilitating maritime trade during the COVID-19 pandemic (IMO- g, 2020). The circular emphasized providing access for ships to port berths, with no restriction on loading and unloading cargoes and facilitating crew changes. The maritime supply chain and international trade received backing from the IMO via a joint statement demanding sustainable socioeconomic recovery after COVID-19 (IMO- d, 2020) . The statement highlights the importance of international legal standard usage while promoting improved regional and sectoral collaboration. The tools and measures presented clear guidelines to facilitate proper supply chain coordination throughout multiple transport modes along international borders.

The United Nations Conference on Trade and Development (UNCTAD) secretariat developed a technical note about port responses to COVID-19 through port experiences on the train for trade Network (UNCTAD -e, 2020). The note presents general requirements for implementing and observing an outbreak mitigation plan through executive protocols, providing sample guidance regarding specific actions at defined crisis levels. The review examined how the pandemic impacted maritime logistics and connections to inland areas. It included observations from port management organizations, maritime regulators, and shipping companies. UNCTAD stressed the need to maintain open ports and supply chains so maritime trade can continue without disruption, yet employees require dedicated protection measures. UNCTAD presented a report (UNCTAD.-c, 2025) showing how nations can defeat COVID-19 by enhancing trade facilitation by optimizing processes and reducing costs while increasing transparency and cooperation and leveraging technology for cross-border trade contactless operations. Treatment should enhance international trade and reduce delays by following the principles provided within the 10-Point Action Plan set by Challenges for International Trade Logistics , (2020). A special clause dedicated to the COVID-19 pandemic appears in the UNCTAD maritime transport review of 2020, (Asariotis et al., 2020).

Safe ship-to-port operations during COVID-19 received guidance from ICS (International Chamber of Shipping 2020) through their partnership with the International Association of Ports and Harbors (IAPH) so that ships could secure their crews and assets (ship agents, chandlers, inspectors, pilots, stevedores, surveyors, and service engineers) with shore personnel. The document provided a system of control measures establishing both safety protection and risk reduction methods.

The World Ports Sustainability Program created the World Ports COVID-19 Information Portal within its framework. Through its comprehensive portal system, the platform presents complete climate guidance and operational specifications for ships and ports, including worldwide port status reports, port restrictions, and operational details derived from worldwide best practices. The WPSP established an essential guide that supports ports and operators in minimizing COVID-19 impacts (Michail & Major, 2020). The frequently updated document is based on key inputs from the Port of Açú (Brazil) and other IAPH member ports' best practices and introduces a four-layer approach that covers port operation management, financial stability, stakeholder support, and resumption of port activities (Michail & Major, 2020). The WPSP and IAPH developed a comprehensive COVID-19 port economic impact barometer that revealed a detailed analysis of global port operational and economic trends. Multiple free digital platforms presented global safety rule updates from port states and information from port organizations and the Ministry of Transport Services. The International Group of P&I Clubs created an online COVID-19 digital dashboard (P&I, 2020), to help ship owners, charterers, and their counterparts track COVID-19 measures enforced by countries and ports. International Shipping Services (ISS) built a COVID-19 portal that gives maritime industry stakeholders access to pandemic-related port information and requirements alongside crew change status lists ISS., (2020). The maritime industry utilized these tools to identify market risks alongside potential threats and regulatory expectations, thus making predictions for future reactions possible. The world's port authorities created innovative guidelines that supported COVID-19 prevention efforts while facilitating recovery efforts. The Maritime and Port Authority of Singapore released its "crew change handbook" to establish protocols for safe port transitions (MPA Singapore, 2020). According to (Yang June, 2020), China's Ministry of Transport created specific prevention measures such as information collection protocols and sanitation standards as well as personnel protection practices and ventilation protocols

in addition to vehicle disinfection guidelines. Numerous ports have distributed their developed safety frameworks with onboard staff requirements to the International Maritime Organization (IMO) for frontline workers, operations, port system interface, and domestic shipping sectors. Port authorities and governmental entities established security and safety measures to defend their workforce, service providers, and users from COVID-19 threats. Adjustments of operational methods served dual functions by reducing possible dangers while sustaining maritime supply chains through safer cargo transport routes. The anti-pandemic measures produced observations, resulting in knowledge acquisition and best practice discoveries (Yang June, 2020).

As general guidelines, safety measures can be summarized as follows: Measures of port safety depend on essential hygiene practices combined with radio-telephone communication with a stated aim of minimum contact among humans. They can enforce a two-meter guideline and ensure the supply and protective equipment for medical personnel. Moreover, ports are involved in area sanitation, and entry into ports is regulated by temperature screening and symptom checking. Disinfection protocols are used across at-risk port areas and trucking routes, and digital procedures are used to decrease personnel interaction, (IMO-a,2020).

2.4 Facilitation of port entry for uninterrupted delivery of essential goods

Ports adapted to pandemic challenges by maintaining operations to ensure the continuous flow of essential goods. Trade information should be available in trade information portals to make trade more transparent and undertakings less complicated and more assured De, (2020). Accelerated customs clearance and release of daily necessary goods, along with simplification of export and import procedures, and leading towards paperless trade, were accounted to combat the spread of the pandemic. Additional measures included the exemption of customs duties on the import of essential goods, the introduction of a 24/7 Telemedical Assistance Service (TMAS) help desk, the relaxation of demurrage fees, and the exemption from interest charges that can mitigate the effects of the crisis (Bernard Hoekman, 2020).

Development of comprehensive emergency response plans

Maritime emergency response depends on implementing all evacuation plans and contingency plans, and resource mobilization stands correctly. Emergency management typically does not figure as part of these plans, although it remains essential to establish pandemic-related guideline connections.. The planning process should also be clearly explained, especially regarding the partnership between emergency management and public health. All emergency management agencies should develop a transparent planning process and make response plans publicly available,(Crawley et al., 2024). These plans can be regularly drilled and simulated so that all stakeholders can practice for actual real-life scenarios. The maritime industry can avoid the impact of health emergencies and safeguard the health and safety of those aboard by having well-prepared response plans.

To ensure the safety and effectiveness of Emergency Medical Services (EMS) personnel during the COVID-19 pandemic, the focus should be on the proper use of Personal Protective Equipment (PPE). EMS personnel should be trained about appropriate PPE selection, use, and disposal. This training must be regularly updated to reflect the evolving understanding of the pandemic and any changes in recommended injury mitigation guidelines (Fateme Mohammadi et al. 2021).

EMS personnel experience high stress from their COVID-19 case management alongside prolonged PPE usage, creating adverse effects. Mental health programs, counselling sessions, and stress management training must be accessible to healthcare providers. Scheduled staff surveys about mental health and emotional status will help teams identify the first signs of workforce exhaustion or fatigue. Additionally, personnel should be encouraged to report any issues related to PPE, such as discomfort or fit, to ensure that equipment meets the needs of all EMS staff, (Cash, R.E, et al., 2021).

EMS workers must be familiar with all the equipment, including masks, gloves, gowns, face shields, and eye protection. Training should focus on how to avoid contaminating PPE and ensure that PPE is not broken or damaged. EMS personnel can simulate and go through practical drills of using PPE in a safe environment. This allows the staff to get used to the equipment and establish protocols so that there is minimal risk to themselves as they reach out to patients. It will be beneficial if simulations include emergencies to test the effectiveness and comfort of PPE (Cash, Rivard, et al., 2021). This paper also highlights that

the organization must explain PPE protocols and their requirements to personnel while teaching them about the guidelines' purpose and effects. Access to PPE protocols must be simple, and staff members should receive supervision for clarification and practical guidance during PPE implementation.

2.5 Ships responsibilities

2.5.1 Regular disinfection and sanitation standards

According to the CDC(Centers for Disease Control and Prevention) recommendations, ship companies need to develop a complete operational plan that offers a practical and detailed strategy for COVID-19 prevention and response on ships. Shipboard operations should apply complete sanitization practices that require special attention to access points and public zones. This includes routine sanitization of cabins, dining areas, and workspaces to minimize the risk of virus transmission. Staff surveys about mental health plus emotional status will enable teams to recognize early signs of workforce exhaustion or fatigue. The reporting system should enable personnel to inform the organization about PPE issues, including fit problems or equipment-related discomfort. At the same time, it addresses worker needs (CDC & Epa, 2020). Adherence to established sanitation guidelines is essential. Providing crew members with appropriate personal protective equipment (PPE) and training them on its correct usage ensures effective infection control. Challenges include donning and doffing PPE in tight spaces, PPE degradation due to exposure to saltwater and environmental conditions, and limited resupply options during extended missions, (WHO 2020) .

2.5.2 Quarantine and isolation requirements

During the COVID-19 pandemic, quarantine and isolation requirements on ships were crucial to prevent the spread of the virus. The establishment implemented these procedures following guidelines provided by the CDC, the World Health Organization (WHO, 2020), and the maritime health organization. According to (Schumacher et al., 2024),single-occupancy cabins should be used by persons who need private bathrooms with door closures when possible. People should wear a high-quality mask or respirator outside of isolation. Isolated persons should have no direct contact with other persons

except for medical designee. Designated ship medical personnel or the Captain should communicate with each person in isolation at least once daily to check their status. Shipboard medical staff and telemedicine providers must consult COVID-19 information from the CDC's site under Information for Healthcare Professionals to receive the current details about infection control, clinical management, specimen collection, and patient evaluation and contact identification.

2.6 Collaboration with authorities and stakeholders

The planning and implementation process builds a complete solution because shipping companies and health authorities, and international organizations collaborate from beginning to end. Participation by stakeholders brings collective commitment to health measures, which improves their effectiveness according to (Van der Wal 2020). The author points out that good health outcomes are supported by the partnership of government-funded bodies and international organizations. A good amount of resources is important to run and maintain comprehensive health initiatives to ensure the ongoing vitality of the maritime industry.

2.7 Leveraging technology and digital solutions

The COVID-19 pandemic intensified workforce shortages, supply chain breakdowns, and safety risks, so EMS agencies were required to modify their training and support methods. The pandemic accelerated the adoption of digital technologies, emphasizing the need for more robust and flexible port management systems to handle future crises (Myrskykari & Nordquist, 2024). Strategic delivery through technological systems integrated with digital solutions became fundamental for managing these matters. The maritime industry has transformed the integration of digital tools, including port automation systems, blockchain cargo tracking solutions, and AI-powered logistics optimization tools Smith et al., (2021).

The COVID-19 restrictions damaged port operations to the extent that bulk carriers operated at 20% below their optimal efficiency because of workforce shortages (Moros-Daza & Jubiz-Diaz, 2024)). Remote monitoring tools ensured compliance with PPE protocols during emergency responses, addressing operational inefficiencies caused by workforce shortages and health risks (P. Brown & Simmons, 2021). Contact limitations

from pandemic measures disrupted supply chain logistics and port functionality, resulting in slower transport of essential medical materials. The mental health impact of the pandemic on EMS personnel cannot be understated. Constant exposure to high-risk situations, long working hours, and the physical strain of PPE contributed to widespread burnout (Moros-Daza & Jubiz-Diaz, 2024).

Bulk carrier operators who adopt IoT protocols combined with AI systems and implement data analytics gain enhanced ability to resist pandemic interferences while keeping their crews intact and necessary maritime functions operational. During the pandemic, bulk carriers maintained operations through remote operational technologies, including unmanned cranes and digital monitoring (Clemente et al., 2023). Integrating digital health solutions, including temperature scanning systems and contactless documentation processes, ensured crew safety and reduced operational risks (Wang et al., 2021).

AI-driven logistics systems improved the coordination of PPE shipments and reduced the impact of cargo delays on EMS operations. Using digital technologies and innovative solutions enabled Emergency Medical Services (EMS) to keep their operations functional through proper Personal Protective Equipment (PPE) management. Virtual training systems using e-learning modules became essential to expand PPE education while avoiding the need for additional staff. EMS agencies used these training solutions to speed up their ability to bring on new staff members while teaching them promptly for service continuity purposes. The combination of mobile applications and AI-enabled inventory management systems enables purposes of PPE supply tracking while making predictions about usage patterns, and redistributing systems. EMS agencies used these modern technologies to handle their scarce assets with precision by prioritizing high-risk zones and averting essential supply shortages. Telemedicine systems with mobile applications delivered mental health care and counseling platforms, ensuring EMS staff members got the emotional support they needed. Staff well-being assessments through virtual appointments enabled supervisors to assist their teams better. These innovative changes in EMS operations will strengthen how the system handles future crises by proving its capacity to adapt during emergencies (Modgil et al., 2022).

2.8 Digital transformation in European ports during the pandemic

Port operations and supply chains experienced rigorous evaluation due to the global spread of COVID-19. European ports, particularly Finland, Rotterdam (Netherlands), Antwerp (Belgium), and Hamburg (Germany), demonstrated resilience and innovation by accelerating their digital transformation efforts to address workforce shortages, health regulations, and disruptions in cargo flow. Due to their leadership in modern port infrastructure, these ports served as essential network points in European and global maritime logistics systems. Their ability to adapt rapidly to these challenges sets a benchmark for modern port operations during crises (Bocayuva, 2021).

According to (Huňady et al., 2024) When the pandemic hit, European ports encountered a few challenges. Drastic reduction in available manpower due to lockdowns and quarantines. Surge in demand for contactless procedures and remote operations. Increased congestion and delays due to inconsistent international health protocols.

European ports accelerated digital initiatives in development to address these challenges (Bocayuva, 2021). These included remote vessel inspections and cargo documentation via IoT-based sensors. Blockchain technology for tamper-proof, paperless customs clearance. All the information entered in this system is split across many computers, so it remains indelible because each document is directly linked to the one before, and the entire network must agree to any changes. In this way, the data kept on the system remains trustworthy and clear. Ports in Europe now use blockchain to set up accurate and immutable processes for customs clearance, tracking cargo, and overseeing supply chains. AI-driven berth and traffic planning systems to optimize turnaround times. Cloud-based platforms for real-time data sharing among port authorities, shipping lines, and logistics firms. Contactless gate entry systems for truck drivers using QR codes and facial recognition.

Specific examples include (Bocayuva 2021):

- i) Port of Antwerp's "Certified Pick-Up" system, which replaced PIN-based container retrieval with secure digital authentication.
- ii) Port of Hamburg's integration of Port Community Systems (PCS) for seamless data exchange across stakeholders.

3 Methodology

3.1 Research design

The chosen research approach for the study is qualitative. Qualitative research aims to understand phenomena as they naturally occur by simultaneously examining a variety of their facets. The authors in the paper, (Strauss & Corbin, 2008) argue that qualitative methods can be used to examine new phenomena, gain new perspectives on existing issues, or gain more in-depth information that may be difficult to convey quantitatively. According to (Bogdan & Biklen, 1982) qualitative interviewing utilizes open-ended questions that allow for individual variations and can evoke meaningful cultural responses.

3.2 Qualitative data collection

Semi-structured interviews with open-ended questions were selected to carry out this research study. Semi-structured interviews occur somewhere in between unstructured interviews and free-form interviews. This study will employ the use of interviews to extract information that may not be accessible using the structured interview format (Levitt et al. 2018). It allowed the participants to elaborate and, with that provided more flexibility, range, and therefore the capacity to elicit more information from the participant. Semistructured interviews permit scope for individuals to answer questions more on their terms than the standardised interview permits, yet still provide a good structure for comparability over that of the focused interview (May 1997) The participants typically include ship captains, cargo superintendents, port authorities, and teachers to gather pandemic response insights directly at their sites. Examine port-specific adaptations, such as Singapore's crew change policies and the digitalization efforts at European ports studied, to find the answers to the research question.

3.3 Data analysis

Once the data had been transcribed, it was coded with categorized responses into themes such as challenges faced, adaptation strategies, and long-term impacts. After that, it was analyzed, interpreted, and verified. The transcription process helped to gain a deeper understanding of the subject by repeatedly reading and reviewing the transcripts. Coding began once all the data had been fully transcribed. According to (Braun, 2006) thematic

analysis is a flexible and valuable tool for analyzing qualitative data, allowing for detailed exploration of participants' perspectives. The analyzed data was organized into themes alongside key findings from the coding process. Each theme received an identified specific code. We followed data interpretation by identifying repeated themes while noting similarities as well as differences. The verification process consists of repeating the transcript and code assessments to verify their precision. This process was allowed to confirm or refine initial conclusions. Due to seafarers' mobile nature and access constraints, the survey was distributed electronically via email and professional networks of maritime professionals.

3.4 Ethical considerations

This is unethical to accumulate information without the knowledge of the participants noted (Kumar, 2005) , as well as their expressed willingness and informed consent. The ten individuals who were known to my previous professional career, interviewed for this study, were contacted through their email. All participants had experience in bulk carrier operations and had worked during the COVID-19 pandemic. Therefore, it made clear to all participants that confidentiality and anonymity would be assured during data collection. Their participation was voluntary, and they were free to withdraw from the study at any time. Every participant had the right to depart at any point during the process. They were also advised that they were under no obligation to answer any questions they may not have felt comfortable with. Each participant received a briefing both before and after their participation. Also, the participants were provided with a summary of the process of the interview to be sure that they were completely prepared and comfortable with the pattern of the interview, explained reasons for conducting the research, and how the data would be used. This ensured that they were fully prepared for the process. Information was cut up into manageable chunks, and the recorded interview data was stored in a safe place with backup data preserved separately. File transfers are encrypted, and files are password-protected. After the analysis was finished, files were removed and destroyed using destruction software.

Respondent selection and research interview questions

These semi-structured interviews were conducted via Google Forms, allowing participants to respond at their convenience. Respondents were selected through a combination of purposeful sampling, which was used to ensure that participants had direct experience or professional involvement in maritime operations, particularly concerning bulk carrier logistics and port management during the COVID-19 pandemic. This ensured that the data collected would be relevant and informative. At the same time, convenience sampling was employed by reaching out to known contacts within the maritime industry or professional networks. They were identified based on their relevance to the research topic, and invitations to participate were sent out via email or social media platforms. The interviews were conducted asynchronously, with participants completing the Google Form at their own pace. Since the interviews were conducted through Google Forms, there was no need for in-person meetings or phone calls. The survey was designed to accept both structured and open-ended responses from participants whose input was captured directly within the form. The procedure delivered secure data collection alongside ease of use.

Qualitative Interview Questions

1. What were the biggest challenges faced by bulk carrier operations during the pandemic?
2. How did ports adapt cargo handling procedures to comply with health regulations?
3. What specific changes were made to facilitate safe crew changes during the pandemic?
4. How did automation and digitalization play a role in sustaining port efficiency?
5. Can you describe any unexpected operational hurdles caused by COVID-19?
6. What lessons have been learned from managing bulk carriers in a pandemic scenario?
7. How do you think ports should prepare for future global crises?

8. Would you like me to refine any specific sections further?

4 Results and data analysis

The research conducted qualitative data analysis procedures systematically by categorizing the responses into significant themes such as the main challenge faced by bulk carrier operations, adaptation Strategies and recommendations. Each theme was then broken down into Key points, which were more specific, smaller categories that provide deeper insights into the data. For example, under the theme of as main challenge faced by bulk carrier operation, key points include issues like crew change crisis, operation delay, etc. After then it evaluated participant responses through the relevant key points they had identified during analysis. It acquired more precise comprehension of each participant's subjective experiences and perceptions about the principal themes through this approach. The research approach reveals common features from participant experiences in addition to distinct variations within their viewpoints. These studies enable researchers to discover important industry knowledge related to how the business addressed these atypical situations. A variety of maritime professionals with extensive expertise participated in the research through a diverse group of participants. Participant 1, a Nautical Teacher with 18 years of experience in various positions on ships, holds a Master Mariner qualification. Participant 2, a Master onboard a ship, boasts 34 years of experience in various roles, also holding a Master Mariner qualification. Participant 3, a Port Superintendent, brings 10 years of experience in port management with a Master Mariner background. Participant 4, a Shipping Director specializing in Port Operations, has 22 years of experience and is also a Master Mariner. Participant 5, a Master onboard a ship, has 24 years of experience in various roles and holds a Master Mariner qualification. Participant 6, a Cargo Superintendent and expert in port operations, has 23 years of experience in various port operations and a Postgraduate qualification. Participant 7, a Technical Superintendent of a shipping company, has 25 years of experience and holds a Master Mariner qualification. Participant 8, another Nautical Teacher with 22 years of experience, has a Postgraduate qualification. Participant 9, a Master onboard a ship with 20 years of experience in various roles, is also a Master Mariner. Finally, Participant 10, a Master onboard a ship, has 25 years of experience in various roles and is a Master Mariner. All

participants were experienced maritime professionals holding diverse positions in bulk carrier operations who shared their expert knowledge during and after the pandemic.

4.1 Interview results

All interviewees shared their experiences in response to the interview questions. In this section, the insights concerning each of the questions are discussed individually.

4.1.1 Biggest challenge

In the first question, when asked about the biggest challenges faced by bulk carrier operations during the pandemic, the responses focused heavily on crew change crises. One captain reported that repeated travel restrictions onboard led to mental health problems and tiredness for the crew. It was made worse when vaccine supplies for crew members were inconsistent, and their crew sign-offs were still unclear. Even so, a master remarked that the introduction of new health and safety requirements had made it difficult for operations at the port to flow smoothly. The lockdowns created challenges at sea, causing delays in managing cargo and disrupting how port activities were planned. More adjustments to expenses and freight rates made the crisis less certain for five respondents.

4.1.2 Health regulations

On the second question, it was asked how ports adapted cargo handling procedures to comply with health regulations. In response to the question, six participants explained that automation and digital technology improve safety and efficiency. A master explained that several ports now handle most operations through the internet and have made their procedures contactless, lowering physical contact between staff. Automation and using remote control devices helped speed up offloading, as social distancing was required. In addition, technical super shared how enhanced sanitization and the use of PPE are required for port workers. Several ports carried out temperature checks and screenings for illness to help stop the virus from spreading. Additionally, cargo super pointed out that several ports create areas for quarantining high-risk cargo and ships. Moving customs clearance and cargo paperwork online was seen as an important way to avoid delays during the pandemic.

4.1.3 Facilitate safe crew changes

The question of how crew changes were facilitated during the pandemic revealed a significant emphasis on testing and quarantine protocols. One master shared that ports like Singapore and Rotterdam established crew change safe zones, where strict health protocols, including PCR tests and quarantine, were followed. Technical super highlighted the importance of dedicated transport for crew members to minimize exposure, as well as the use of contactless procedures for documentation. He also mentioned that staggered crew changes were implemented to reduce the number of crew members on-site at any given time, which helped maintain safe social distancing practices. Overall, all participants emphasized the need for collaboration between ports, shipping companies, and health authorities to ensure safe and efficient crew changes despite the ongoing challenges.

4.1.4 Automation and digitalization

All participants agreed that the fourth question was vital when thinking about digitalization and automation for port efficiency. Among them, one master explained how ports could lower the number of people working in the facility by using automated cranes and electronic surveillance. Digital platforms for real-time shipment tracking and document management were also key to improving operational efficiency during the pandemic. Technical super further described how AI is used in traffic and berth management to avoid delays, and IoT sensors are key to better understanding the supply chain. Many ports also implemented cloud-based systems that allowed for better coordination among stakeholders, ensuring a smoother flow of goods despite the challenges. In summary, each participant noted that digitalization and automation not only helped ports navigate the pandemic but also laid the groundwork for more resilient and efficient operations in the future.

4.1.5 Unexpected operational hurdles

In the fifth question, when asked about any unexpected operational hurdles caused by COVID-19, all participants described several unexpected operational hurdles caused by the pandemic. One master shared a personal experience of being stuck in China for 31 days due to COVID-19 infections onboard, which caused serious supply chain disruptions. Similarly, a nautical teacher described a situation where a crew member tested positive for

the virus, forcing the vessel to go into isolation and causing delays in operations. Technical super also highlighted the issue of supply shortages, particularly for spare parts and fuel, due to lockdowns and restrictions in various countries. These unforeseen challenges forced many bulk carrier operations to adapt quickly and find innovative solutions to maintain continuity during the pandemic.

4.1.6 Lessons learned from managing bulk carriers during the pandemic

Seven participants speaking about pandemic-related challenges highlighted its importance in terms of adaptability and respect for crew well-being when dealing with bulk carriers. Another important statement mentioned by a master was the great effect of digitalization and cooperation with global stakeholders in solving the problems. Similarly, another master stressed the need for teamwork and planning to handle disruptions effectively. Cargo super highlighted the importance of health and safety measures and ensuring that seafarers' mental health is supported. Technical super added that the pandemic demonstrated the value of proactive contingency planning and having the flexibility to adjust quickly to changing conditions.

4.1.7 Strategies for port preparation in future global crises

Analyzing the prospects of future challenges and struggles, the participants encouraged the ports to invest a larger share in the realms of automation, digital infrastructure, and risk management over the wide areas. A nautical instructor stressed the need to reduce manual effort and apply digital technology for the purpose of remote controlling and self-operating processes. Technical super advised that ports should enlarge the supplier networks and include backup systems in their logistics to increase its ability to withstand disruptions. He also stressed the importance of training the workforce and adopting sustainable practices to make ports more adaptable to future crises. One master reflected on the unpredictable nature of pandemics and emphasized the need for efficient crew change policies and global cooperation to ensure smooth operations during such events.

4.1.8 Refinement of specific sections

Lastly, when asked if any specific sections should be refined, all participants generally agreed that the sections on supply chain disruptions, crew management, and regulatory

challenges could benefit from more clarity and depth. One master also suggested that the impact of geopolitics on international shipping should be given more focus, as it can have far-reaching effects on global shipping operations.

4.2 Thematic analysis of interview data

A systematic approach was employed in the qualitative data analysis procedures by first categorizing the responses into significant themes, such as major challenges and adaptation strategies, among others. Within each of these broad themes, key points were identified, which are more specific, smaller categories that provide deeper insights into the data. The key areas were categorized into themes based on the responses received from the participants and analyzed. After that a comparative analysis was conducted based on the responses provided by the participants, to systematically compare similarities and differences across the themes.

Identification code and Theme	Key points inside each theme	Participant
1. Big challenges faced by bulk carrier operations during the pandemic.	Crew change crisis	2(Master), 4(Shipping director), 5 (Master), 7 (Tech. Super), 10 (Master)
	Operational delays	2 (Master), 5(Master), 7 (Tech. Super)
	Health & safety challenges	1 (Teacher), 2 (Master), 4 (Shipping director).

2. Adaptation strategies implemented by ports.	Health & safety protocols	4 (Shipping director), 5(Master), 6 (Cargo Super).
	Automation and technology Integration.	4(Shipping director), 7(Tech. Super), 6 (Cargo Super).
3. Lessons Learned and future preparedness..	Adaptability	2(Master), 4(Shipping director) , 7(Tech. Super).
	Digital transformation	2(Master), 4(Shipping director) , 7(Tech. Super).
	Supply chain resilience	4(Shipping director), 7(Tech. Super), 10 (Master).

Table 1. The participants who responded under each theme.

4.2.1. Theme 1: Big challenges Faced by bulk Carrier operations

From the below figure, we find the key points inside theme 1, now discussing participants thoughts under this theme. Here, three masters, the shipping director, and the technical superintendent all pointed out that travel restrictions became the biggest challenge when trying to change crews.

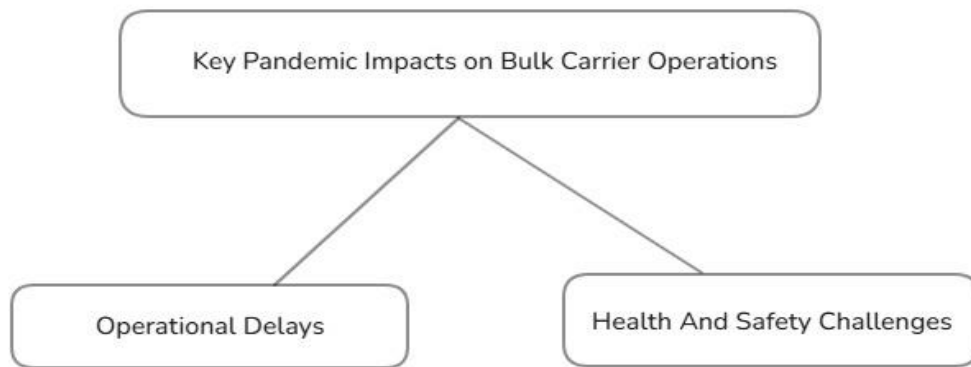


Figure 1: Key points under theme 1

The extended time crew members spent at sea led to mental and physical exhaustion, as shared by the participants, which also caused violations of labor laws and called for humanitarian intervention. Two master and a technical super also noted that during the COVID-19 period, most port authorities implemented several port restrictions, health checks, and quarantine measures, which created significant delays in cargo handling, especially when ports imposed mandatory quarantines or reduced workforce capacity. The major challenge highlighted by all participants was the pandemic, which presented various challenges in ensuring the safety and health of our crew members and port personnel. It required us to adapt to ever-changing global regulations while managing personal protective equipment (PPE) and quarantine procedures to keep everyone safe.

Similar points of view

All participants highlighted that the crew change crisis was a significant challenge during the pandemic and mentioned travel restrictions and quarantine protocols as barriers to crew rotation. They also talked about the crew's extended periods at the ship during the pandemic, creating great mental and physical fatigue for them. All of them noted the significant delays in port operations due to health and safety checks (e.g., temperature screenings and PCR testing), where everyone highlighted port congestion and reduced workforce capacity as key contributors to operational delays. Finally, they mentioned the need for health protocols (e.g., PPE, social distancing, health screenings). Ensuring crew and worker safety was prioritized, with the varying regulations creating operational challenges.

Different points of view

A shipping director and another master testify that this situation has brought about serious humanitarian problems, especially regarding seafarers who have been left behind. The shipping director stressed that the crisis had serious logistic and economic impact, pressing the timetable of operations and increasing costs. Another shipping leader touched the idea of long processes of staying at sea that caused significant psychological difficulties to the seafarers, as well as primarily to the seafarers' mental health. Another master and shipping director reported that use of remote operations and digital technology has been instrumental in curbing such delay impacts. A master mentioned that specific ports imposed longer waiting times, while a technical super emphasized that inconsistent regulations across ports caused confusion and logistical challenges. Moreover, a nautical teacher discussed the difficulty of implementing consistent health protocols across different ports. At the end, a master and shipping director emphasized the technological solutions adopted (e.g., remote health checks), while others focused on the practical operational challenges.

4.2.2 Theme 2: Adaptation Strategies by ports

Referring to the figure presented, the themes discussed in theme 2 are now evaluated according to the input and perspective of the participants. Major concern was expressed by the Shipping Director, a Master, and the Cargo Superintendent about the port adaptation measures during the pandemic, with a high emphasis on the need for progressive changes so that continuity in operations can be preserved.

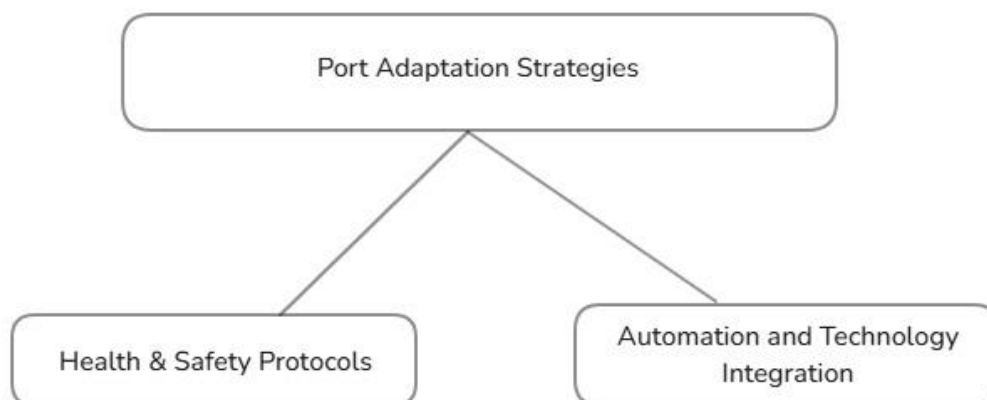


Figure 2: Key points under theme 2

Major port authorities introduced several quick protocols, such as touchscreen cargo handling and digital documentation backed by personnel and crew member health checks. Also, technical super, cargo super, and one master highlighted that the pandemic underscored the necessity of digital solutions and automation to sustain operational performance across all port activities. Contactless technologies, together with automated cargo handling systems and remote monitoring, helped ports minimize interactions between people while reducing waiting times and improving operational efficiency.

Similar points of view

There was no second opinion from participants that ports must implement health and safety protocols promptly and in full. Adoption of these protocols – with elements such as PCR testing, temperature checks and sanitization procedures – was identical and there was an agreement in general that automation and the adoption of new technologies were paramount to keeping the operations efficient throughout the pandemic. IoT devices, AI systems, and cloud-based platforms for remote monitoring and cargo management were mentioned as vital solutions.

Different points of view

The shipping director focused more on the staffing limitations imposed by these protocols, while others, like one master, emphasized the digital transformation aspect of port operations during the pandemic. Technical super pointed out that improved facilities at ports would help ports apply these protocols, even if there are still concerns about them in some big regions. Both the master and the shipping director recognized that automation would help greatly in the future, so they made it a worthy investment for better efficiency. Technical super, however, was more cautious, highlighting automation's costs and integration challenges.

4.2.3 Theme 3: Lessons learned

The figure below outlines the key points within Theme 3, which will now be explored through the insights and reflections shared by the participants. Among participants, one master, shipping director, and technical super noted that the pandemic accelerated the adoption of digital platforms for documentation, along with communication systems and tracking methods, to enhance the safety and efficiency of their operations.

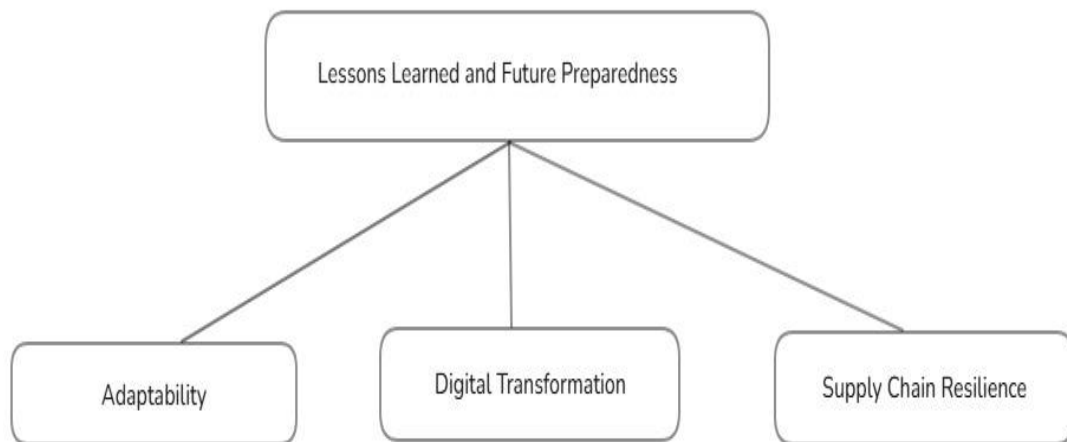


Figure 3: Key points under theme 3

Participants emphasized the significance of remote monitoring systems and management platforms that enabled oversight of ship operations without the need for physical workers, while also improving operational effectiveness. Shipping director, one master, and technical super brought up that the pandemic highlighted the vulnerabilities in global supply chains and underscored the need for greater resilience. With a pandemic facing organizations, their supply chains must be diversified to have various suppliers and channels to reduce the risks and enhance the capability to endure disruptions. Strategic stockpiling of essential items occurred to protect organizations against possible supply chain interruptions and running out of products. Completion of operational supply chains required reinforcing supply routes with backup systems and creating backup plans for dealing with disruptions. It's essential for organizations to focus their attention on building resilience by strengthening supplier partnerships while increasing planning accuracy and buying systems that monitor supply chains and manage risks.

Similar points of view

All the participants described how adaptability was necessary to respond to new rules and uncertainty at that time. Port operations were recognized as being widely transformed with digital technology. During the pandemic, key tools for running ports included remote inspection, AI in logistics, and systems hosted on the cloud. Eight participants agreed on the importance of building resilient supply chains. Diversifying trade routes and investing in technology were key to ensuring future preparedness.

Different points of view

According to a master and a shipping director, digital readiness is essential for future crisis management because technology plays a central role. The discussion of technical super highlighted that organizations require resilient employees to manage unpredictable situations. Another master views digital tools as a critical long-term investment, while another master expressed concerns about technological dependency and the associated implementation costs. One experienced master highlighted the importance of better coordination and communication systems to strengthen supply chain resilience, and a technical super pointed out the importance of long-term planning to prevent future disruptions. A master and a shipping director discussed LNG-powered ships as one of the options for the future, following the trend to move to greener fuels. However, one master raised worries about the profitable implications of embracing such technologies, particularly under the influence of financial pressure caused by the pandemic. The technical superintendent identified possible issues of scaling up green practices. However, due to their position as master and shipping director, committed to directing their industries to a more eco-friendly level, both believed in the potential of cooperative climate action.

4.2.4 Discussion on Key Insights from the analysis

Crew welfare and mental health concerns were emphasized across all responses, highlighting the human aspect that should be addressed in future crisis management strategies. There is a positive outlook about automation and digital tools in improving operational efficiency, but some participants made concerns regarding costs and integration challenges. Adaptability and digital transformation were identified as key factors for future resilience, with varied perspectives on how these should be implemented. While green fuel adoption and ethical tourism were less explicitly discussed, there was recognition of the importance of sustainability in the long-term future of the maritime industry.

4.3 Integration of Real-World Case Studies

Two specific port authorities were chosen for the study to offer real-life examples of how they have addressed the issue of the pandemic. The choice of Singapore and the examination of the crew change protocol and digital trends in the European ports were

based on the ways they tackle operational dilemmas caused by the pandemic. Singapore was singled out for how it dealt with the crew-change crisis, while European harbours offered a spectrum of automation and digital solutions to demonstrate various ways in which operations can be sustained amid the COVID-19 restrictions. To complement the data obtained through the interviews, this study describes these case studies, which outline the challenges and adaptation measures expounded under various themes. Such examples support the need for the themes that have been deemed relevant in participant feedback responses.

4.3.1 Case Study 1

Results and Impact on Singapore Crew Change Crisis During the COVID-19 Pandemic

According to Sea Trade Maritime News (2021) We can see in the graph how the number of

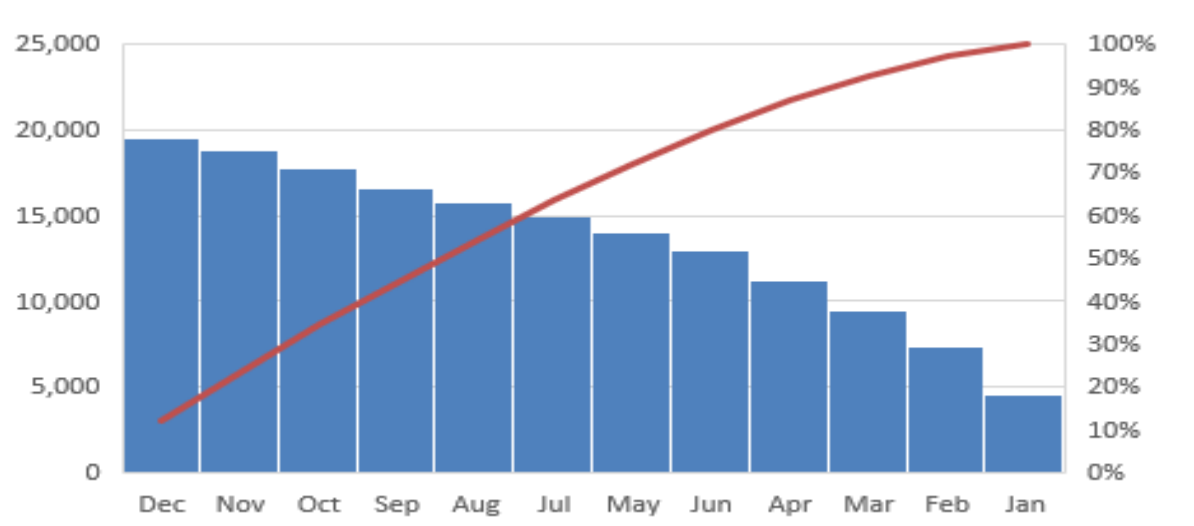


Figure 4: Crew change process in Singapore,2021 (“Sea Trade Maritime News,” 2021)

crew changes increased gradually, reflecting Singapore’s adaptive measures to overcome COVID-19 challenges. Initially, crew changes were slow due to the stringent health checks and quarantines. However, by mid-2021, the system became much more efficient, handling larger volumes of crew changes every month. This shows the country's agility in refining its protocols and adapting quickly to the situation, ensuring that bulk carrier operations could continue smoothly without compromising the health of crew members. By following this protocol, Singapore successfully finished the year of 2021 with more than 1,20,000 completed crew changes (Sea Trade Maritime News 2021). At this period the MPA regularly issued instructions with transparent messaging, which established Singapore as a model for

how to adapt port operations during global crises. Through this protocol, the MPA successfully reduced stress for trapped seamen while it also restored crew exchange process to normal conditions, showing how technological platforms with multi-agency collaboration enable running busy operations while upholding stringent disease prevention standards.

Insights and Solutions from the Case Study for Research Questions

The big challenges in bulk carrier operations during the pandemic included crew change crises, port restrictions, and operational delays. In response, Singapore's Maritime and Port Authority (MPA) included measures such as implementing the crew change protocol, including quarantine procedures, COVID-19 testing, and creating green lane arrangements with select countries to facilitate the safe movement of crews. Through digital documentation, shipboard operations became more efficient, which simultaneously cut down crew change interactions, reducing delays and improving pandemic workflow. The Crew Change Protocol in Singapore shows that coordination between port operators, immigration authorities, and health officials makes an effective process for operational efficiency and crew safety possible. The information gathered through the case study supports research questions by explaining the role of port authorities, automation, and health security protocols in sustaining bulk carrier operations during crises.

4.3.2 Case study 2

Impact and performance of digital transformation in European ports during the pandemic

By the impact and performance of digitization strategies, European ports successfully achieved high operational volume through digital programs maintained during peak pandemic times. Automation resulted in ports experiencing faster operations and reduced expenses for paperwork management. Remote operations demonstrated the essential function of digital infrastructure during the pandemic because they permitted workers to stay safe while preserving international logistics networks (PORT CYBERSECURITY, (2019)). European countries were classified by their digital readiness, with Belgium, Denmark, Finland, Sweden, Malta, and the Netherlands forming a leading cluster, particularly in customer-facing digital innovations. Conversely, Spain, Portugal, France, Italy, Poland, Slovakia, and Lithuania demonstrated strengths in internal digital processes like

robotizationHuňady et al. (2024).Despite differences, the overall gap between clusters narrowed slightly during the pandemic, suggesting that COVID-19 acted as an accelerator for digital transformation across Europe.

Insights and Solutions from the Case Study for Research Questions

According to European port case studies, the biggest challenge for bulk carriers throughout pandemic operations involved crew rotation management alongside health safety protocols. Ports like Rotterdam successfully implemented crew change protocols to enable safe personnel exchanges that smoothly preserved bulk carriers' operations. Numerous essential details in the case study illustrate the digital transformation within European ports. IoT sensors in European ports enable remote cargo inspections for contact-free operations, which decreases inspection times. Cloud-based platforms and blockchain technology allowed stakeholders to advance customs clearance operations and increase inter-business coordination. The implementation of touchless entry protocols, remote health verification, and personal protective equipment guidelines offered security measures to reduce direct person-to-person contact. The European port system adopted IoT sensors to enable automated cargo documentation and perform inspections from a distance, eliminating contact and minimizing delays. In supporting cloud-based platforms and blockchain technology and cloud-based platforms allows stakeholders to enhance their customs clearance operations and improve inter-business coordination. Contactless entry systems, remote health checks, and PPE protocols were introduced to ensure safety and minimize human interaction. Ports operated continuously for worker health protection by implementing these technologies and automated berth traffic planning systems powered by AI that reduced resource strain. These systems effectively managed vessel operations and cargo handling activities so ports could increase their cargo loading speed and minimize port congestion. The Port of Antwerp's "Certified Pick-Up" system adopted secure digital authentication to replace PIN-based container retrieval, thus speeding up operations for cargo handling and improving efficiency. Blockchain technology and cloud-based platforms increased data exchange at ports to establish greater transparency, making health and safety management smooth and operational continuity possible. Safe and efficient operations relied heavily on implementing digital tools that consisted of blockchain technology mixed with AI systems and IoT-based solutions. The analyzed case demonstrates that ports have opted for automation and digitization as their primary

defensive strategies against future crises. Ports need to commit funds for acquiring AI-based logistics systems and remote vessel controls, which use blockchain to establish secure cargo processing capabilities.

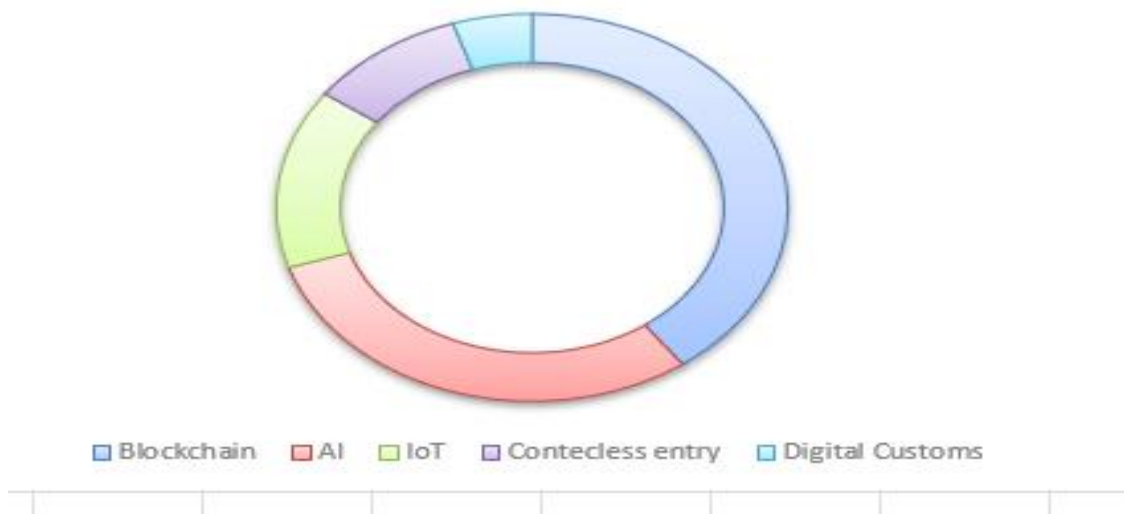


Figure 5: Digital tools adaptation in European ports (post-pandemic) (Bocayuva, 2021)

According to Bocayuva (2021) looking at the pie chart, we can see the extent to which digital tools have been implemented across various ports. Blockchain led the way with 40% of ports adopting it to streamline and secure cargo documentation. AI and IoT also played significant roles, representing a large proportion of digital adoption. These technologies helped European ports minimize physical contact, increase efficiency, and speed up customs processes during periods of reduced staffing

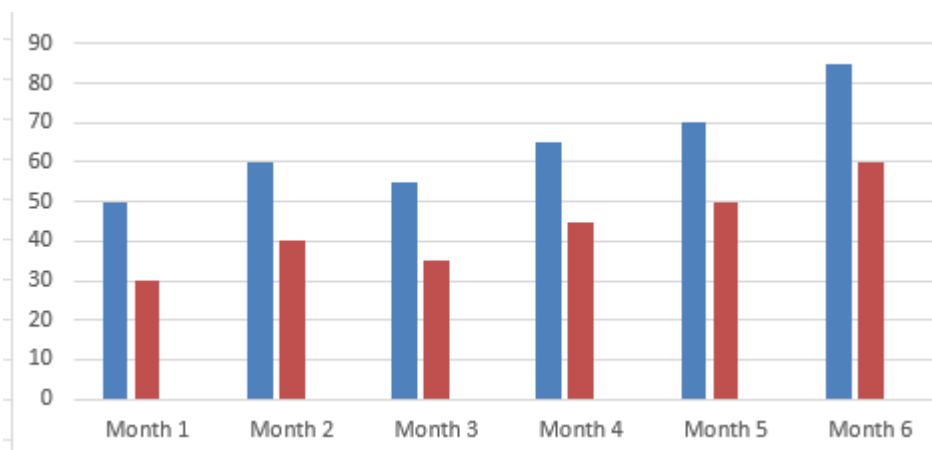


Figure 6 : Cargo flow efficiency before and after digital tools (Bocayuva, 2021)

As we can see from the bar chart, cargo flow times were significantly reduced in ports that adopted these technologies. In Month 1, clearance times were around 50 hours; however,

by Month 6, digital solutions had reduced this time to 30 hours, Bocayuva (2021). This dramatic improvement was key to maintaining supply chain fluidity and preventing disruptions during a challenging period.

5. Conclusion

The COVID-19 pandemic has exposed significant vulnerabilities within the maritime industry, particularly regarding the health and safety of seafarers and passengers, with medical evacuations at sea highlighting the urgent need for comprehensive emergency measures. Through thematic analysis, valuable insights were gained on the challenges faced by bulk carrier operations during the pandemic and the industry's adaptive strategies.

5.1 Summary of key findings

The study of the impact of the Covid-19 pandemic on the bulk carrier operations, maritime professionals' responses highlighted both immediate issues and long-term changes that contribute the industry's future direction. One major finding was the critical concern over crew welfare and health, as the pandemic significantly impacted seafarers' well-being, with extended stays at sea leading to fatigue and highlighting the need for better mental health support. Another crucial adaptation was the adoption of automation and digital solutions, with remote monitoring, automated cargo handling, and contactless technologies proving essential in maintaining operations while minimizing human interaction. These technological advancements are expected to continue driving operational efficiency and reducing vulnerabilities during future disruptions. The importance of supply chain resilience also emerged, as disruptions underscored the need for more flexible logistics and better collaboration across the maritime sector to handle unforeseen challenges.

5.2 Recommendations

In order for enhancing the efficiency and sustainability of bulk carrier operations in the post-pandemic world, several measures can be considered for implementation. International standards for crew change procedures together with health safety measures need development while seafarers require mental health support. A combination of national and port authority agreements will enable proper execution of these policies to achieve operational stability and elevated crew safety measures. The

implementation of AI-driven cargo management systems along with automated investment opportunities leads to superior supply chain operation performance and maximum supply chain optimization and decreased human interactions. Maritime emergency response depends on successful implementation of response plans that include detailed evacuation procedures together with contingency strategies and resource preparedness protocols. The improvement in operational performance can be achieved by integrating automation with remote monitoring and real-time data processing on cloud-based platforms, which can predict delays and provide seamless coordination between port authorities, shipping companies, and logistics providers. Besides, the integration of green fuels like LNG and hydrogen, alongside energy-efficient infrastructure, should be prioritized to reduce emissions and enhance environmental performance. The adoption of renewable energies (e.g., solar, wind) and sustainable port practices, including waste reduction and recycling, will help the maritime industry recover while ensuring long-term sustainability and improved operational resilience for future global crises, Huňady et al.,(2024) .

5.3 Future research directions

Several directions for future research emerge from the limitation and findings of this study. Research should examine how mental health programs assist seafarers during prolonged maritime travel and what benefits these programs offer to their welfare. Further evaluation is needed on the financial viability of digital solutions for smaller ports as they study the automation process across various port scales and operational settings. This research assesses the implementation of green fuel and the economic aspects of sustainable maritime energy transitions across industries. A study explores the use of AI alongside blockchain technology to enhance supply chain resilience as well as port facility operations during potential global emergencies.

6 Discussion and critical review

This study explored the major operational challenges that bulk carriers faced during the COVID-19 pandemic, along with the adaptations made by maritime ports to maintain the flow of bulk cargo. The findings highlight how the pandemic impacted key areas such as port logistics, crew welfare, health and safety protocols, and the accelerated use of digital technologies in port operations. The section summarizes the

study results in detail by responding to research questions through data comparison with case studies and participant input and by assessing research methodology validity and reliability. It also outlines suggestions for future research that can build on the current study's contributions.

6.1 Review of findings and discussion

This section reviews the study's main findings, linking each research question to interview insights and case studies. It also includes a reflective discussion of what these findings mean for the maritime industry, especially bulk carrier operations, during and after the COVID-19 pandemic.

Research Question 1: What were the biggest challenges in bulk carrier operations during the COVID-19 pandemic, and how did port authorities respond?

The most pressing challenge from the participants and the literature was the crew change crisis. With international travel bans and inconsistent port regulations, many seafarers remained on board for months longer than their contracts allowed. Participants described this situation as mentally and physically draining. It became clear that this wasn't just an operational issue but a humanitarian concern. This data highlights that global maritime governance faces a critical problem because international procedures lack unified coordination, leading to reduced crisis management effectiveness. Unstandardized international procedures lead to this problem. Seafarers lacked fundamental rights even after the Maritime Labour Convention (MLC) became effective. Singapore demonstrated that national leadership working with defined health protocols is an effective solution for addressing this gap. However, such examples were the exception rather than the rule. The evidence suggests it would improve efficiency and crew welfare in future crises.

Research Question 2: How did carrier operation change affect port authorities, and how did automation help improve the situation?

Interviewees agreed that operational performance was heavily impacted by health and safety rules, which created delays, required more planning, and stretched available resources. However, ports already invested in digital infrastructure and automation coped much better. The case studies of Antwerp and Hamburg illustrated how innovative technologies, like AI-based traffic systems, contactless gate entries, and

blockchain customs, helped ports stay efficient despite a reduced workforce. Digital tools became more than a short-term answer because they offered permanent strategic benefits. Digital tools confer enduring strategic benefits across extended periods.

From a critical view, this highlights a digital divide. While large, well-funded ports adapted quickly, smaller ports or those in developing regions struggled. The technical super noted that even where digital tools were available, lack of training or integration made them hard to implement effectively. Automated processes prove beneficial but require investments and training along with scalable solutions to work effectively as a general solution. This study shows that digital changes in maritime logistics should include everyone. If some ports are left out, the gap between advanced and less advanced ones will only grow.

Research Question 3: What worked best for balancing port operations and crew health, and what can be done to better prepare for future crises?

The interviews and case studies revealed that remote operations, health-focused digital protocols, and inter-agency collaboration were the most successful strategies. Remote temperature scanning, digital crew databases, and virtual health check systems allowed ports to continue operations while protecting worker safety. The study clearly recognizes mental health demands as its central lesson. Emotional exhaustion became widespread among crew members because technical innovations did not solve the staff shortage problems during the pandemic. Study participants recognized the advantages of telemedicine platforms and online counseling services, although these solutions were not accessible to everyone. From a broader perspective, this speaks to the importance of seeing seafarers not just as laborers but as essential frontline workers, similar to healthcare staff. Crisis readiness in the future should include both technological preparedness and emotional support systems. Regarding sustainability, the findings suggest that ports must look beyond efficiency to environmental responsibility. The case study literature and interviews frequently mentioned integrating green fuels (like LNG and hydrogen) and investing in eco-friendly infrastructure.

6.2 Validity and reliability

The research method used qualitative interview data from maritime experts who possess practical experience in bulk carrier activities and port logistics operations to determine the study's validity and reliability aspects. Through semi-structured interviews, researchers obtained detailed insights into the job perspectives which helped their study match genuine industry reports. The thematic analysis method confirms the study's validity because it structurally breaks down interview responses into core concepts and subgroups to make the research findings applicable between different respondents.

The study sample consisting of ten participants fulfills the requirements for qualitative research yet the limited number hinders general application of the results. The research examined professionals who work in bulk carrier operations together with those in port logistics management while their answers stem from both their specific expertise and faced challenges. Future research requires a wider variety of stakeholders with an extended sample size to verify present findings and enhance result's generalizability. The study findings gained additional validity from practical assessments on Singapore's Crew Change Protocol and European port digitalization through case studies. The information gathered from case study examinations proves valid since it mirrors statements made by interviewed participants who stressed the significance of digital tools for operational continuity maintenance throughout the pandemic.

7 Reference

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