



Maritime Technology and Research

<https://so04.tci-thaijo.org/index.php/MTR>



Research Article

Ports, maritime transport, and industry: The immediate impact of COVID-19 and the way forward

Anas S. Alamoush^{*}, Fabio Ballini and Aykut I. Ölçer

Maritime Energy Management, World Maritime University, Malmö, Sweden

Article information

Received: April 13, 2021
Revised: September 1, 2021
Accepted: September 4, 2021

Keywords

COVID-19,
Ports,
Maritime transport,
Supply chains,
Impacts,
Sustainability,
Aqaba Port

Abstract

The spread of coronavirus (COVID-19) has led to the implementation of unprecedented global restrictions and strict safety measures. Countries and authorities imposed, inter alia, lockdowns, social distancing, border closing, prechecks, and personal protective equipment. Nonetheless, the restrictions had consequences for the whole transport sector. This study endeavors to investigate COVID-19's immediate impact and the ensuing issues for ports, shipping, and the maritime supply chains and industry. Therefore, we conducted an exploratory review of various sources and, in addition, utilized our findings to conduct a case study to investigate the responses to the pandemic and issues arising in the Port of Aqaba/ Jordan. The way forward for ports to follow after the pandemic was also identified. The results of the analysis of impacts were categorized into 6 different, yet interconnected, attributes. Impacts illustrated how adversely COVID-19 shocked maritime transport, supply chains, and industry, and how the consequent restrictions complicated operations. Findings indicate that ports need to maintain resilience through the pandemic- the same is true for any future shocks- by building risk management plans and expanding the circle of cooperation regionally and globally, not only within the port, but also including the maritime supply chains. Furthermore, despite its unfavorable impacts, the COVID-19 pandemic is considered as the spark for the reconfiguration of shipping and port operations, particularly by integration of smart and digital technologies and by enhancing sustainability, e.g., climate change adaptation and mitigation. Along these lines, post-COVID-19 economic recovery and the way forward should harness socioenvironmental pathways. While the study provides timely analysis, including insights and lessons learned, which can inform policymakers and practitioners on the severity of the pandemic and future pathways, it also contributes to scholarly discussions by pointing out future research agendas that could guide further academic investigations.

1. Introduction

Sea ports are drivers of, and contributors to, the growth of maritime transport. In addition, ports advance the economic development of coastal countries and, thus, provide direct and indirect employment (Roh et al., 2016). While ports are essential centers for the wellbeing of humankind, they are an inevitable node in maritime supply chains (Alamoush et al., 2020; Notteboom et al.,

^{*}Corresponding author: Maritime Energy Management, World Maritime University, Malmö, Sweden
E-mail address: asa@wmu.se

2020). Globally, there exist 8,292 ports in 222 countries, 835 of which are the most active seaports and handle 99 % of seaborne trade (Exportvirginia, 2014). Shipping is the other cornerstone in the maritime supply chain. In 2018, ships carried 11 billion tons of seaborne trade (around 108.9 trillion tons/km), which is around four-fifths of the world trade volume and 60 - 70 % of the value (UNCTAD, 2019b). In 2019, the world fleet totaled 98,140 ships of 100 gross tons and above, reaching a 2 billion deadweight tonnage (dwt) capacity (UNCTAD, 2020f). Since shipping and ports are highly interlinked and interdependent, their continuous operation is vital to the sustainable development and prosperity of nations, moving the world's food, energy, and raw materials, as well as manufactured goods and components, and should never be compromised (UNCTAD, 2020e). However, it should be always noted that, despite the importance in connecting the world and promoting trade, port and ship operations generate social and environmental externalities (Dinwoodie et al., 2012).

The year 2020 held various surprises that negatively shocked whole maritime supply chains, including ports and shipping, and reached the whole maritime industry's essential core. The coronavirus (COVID-19) pandemic, which spread from China in the last quarter of 2019, had dire consequences all over the world, and the maritime industry and transport were no exception. The world faced, and is still facing, an unprecedented global crisis that is unfolding in several levels of severity, seen as leading to a second global crisis, following the 2009 financial crisis (Notteboom & Pallis, 2020a). COVID-19 has swept through 192 countries and territories, infected more than 120 million persons, and caused the deaths of around 2.6 million, with the United States ranked top for infected cases and death rates, as of March 2021 (ISS, 2020). Accordingly, reflecting the critical role the maritime industry plays in world trade, and the complexity of trade and supply chains, the necessity to continue transport, including maritime transport of the most-needed items such as crucial medical supplies and equipment was the one of world's primary focuses (UNCTAD, 2020e).

To curb the spread of the pandemic, many countries employed measures and restrictions affecting international trade and transport. Examples include: entire and partial lockdowns, the closure of borders, and restrictions on mobility (curtailed travel), coupled with various safety measures for human interactions. However, the restrictions have interrupted and disrupted the flows of international trade, supply, and value chains, including maritime transport (shipping and ports), and of essential aids and technical supports, which has led to negative socioeconomic consequences (UNCTAD, 2020d). Economically, port demand is a derived demand (similar to shipping), and an unexpected decline in demand has had an instant impact on port activity levels. The restrictions, particularly lockdowns and semi-lockdowns, have led to a global decline in derived demand (Notteboom & Pallis, 2020a).

Nonetheless, through keeping ships moving and ports open (UNCTAD, 2020a), shipping and ports' undisrupted operations have turned out to be an indispensable part of the remedy to cope with the COVID-19 crisis (WPSP, 2020a). Consequently, to revive the global economy, and to continue fighting the outbreak, concerted efforts have been made by governments, border authorities, port authorities, and customs administrations to advocate and press for reforms that aim to keep trade flowing while undertaking safety measures to protect populations, transport workers, and border officers (UNCTAD, 2020d). The same is true with respect to efforts from global bodies, governmental and nongovernmental organizations, and industrial associations, which all called for the avoidance of unnecessary interference in maritime supply chains, and which proposed measures to deal with emerging implications (see Section 3). A high and unparalleled level of global unanimity and harmonized actions was needed to minimize devastation and stop the domino effect of the COVID-19 pandemic, while remembering to note that ports will always be endangered by the resurgence of pandemics, among other crises. Notable examples are hazardous respiratory diseases, the Influenza A (H1N1) pandemic, Ebola virus disease (EVD), Middle East respiratory syndrome, coronavirus (MERS-CoV), and Severe Acute Respiratory Syndrome (SARS) (UNCTAD, 2020e).

Given that COVID-19 generated severe consequences and ensuing impacts on ports and the maritime supply chains and industry, this study aims to investigate- by means of exploratory review, and case study- these immediate impacts, and to suggest the way forward for sustainable recovery and better preparedness for similar shocks. This study, therefore, contributes to port and maritime transport management by identification of the influence of the pandemic, while highlighting the importance of managers and policymakers taking measures to enable adaptation and resilience to get through present and future situations of uncertainty. While this study contributes to port sustainability (economic, environmental, and social dimensions), it also has implications for scholarly discussions and future research.

The study is structured in seven main parts: Section 2 shows materials and methods, Section 3 summarizes global responses and best practices, Section 4 analyzes the immediate impacts and implications, Section 5 is the case study, Section 6 details the way forward post-COVID-19, and Section 7 comprises a discussion and some conclusions.

2. Materials and methods

The impact of the COVID-19 pandemic on maritime transport will continue to unfold in years to come. Up until now, existing research on this emerging topic has been neither broad enough nor mature enough and, thus, looking at such issues demands a holistic exploration. Therefore, this study applies an exploratory literature review to provide a wide-ranging analysis of directions in the field and to facilitate identification of underlying issues (Thomas, 2003). While it can be argued that a systematic literature review entails solid scientific rigor and generalization, in addition to identification of past and confirmed work (Palmatier et al., 2018), it is not highly preferred, particularly when researchers aim to explore and discover emerging ideas taking into consideration that the literature does not lend itself to a more thorough systematic literature review. Thus, an exploratory review is not meant to follow a repeatable systematic method, or be an all-inclusive summary, as it starts with reviewing research close to the scope of the study, and normally delivers a broad overview of work that has been implemented in a certain area, utilizing an open-ended approach toward data collection (Stebbins, 2001).

According to Swedberg (2020), there exist two common forms of exploratory reviews: i) giving a tentative analysis for a topic that has not been highly researched before, and ii) exploring an already existing topic to produce new ideas and hypotheses without further verification. This study belongs to the first category. The study is guided by the United Nations' 17 Sustainable Development Goals (SDGs) (United Nations, 2015), and investigates the port as a central node in the maritime supply chain. In the light of this, to achieve the main goal, this study follows the exploratory review approach (as in Arksey & O'Malley, 2005), thereby answering 3 questions: **Q1:** What are the global responses and best practices required to minimize the pandemic effects in the maritime industry? **Q2:** What are the immediate impacts and implications of the COVID-19 pandemic on ports, and on maritime supply chains and industry? **Q3:** How can ports be resilient to future pandemics and crises, and what are the best ways forward? This exploratory review includes 3 steps: identification of relevant literature; structuring of the review by building typologies of impacts; and utilization of findings to investigate issues in a case study and to develop the way forward. **Figure 1**, below, illustrates the study's research outline, including the steps and methods taken.

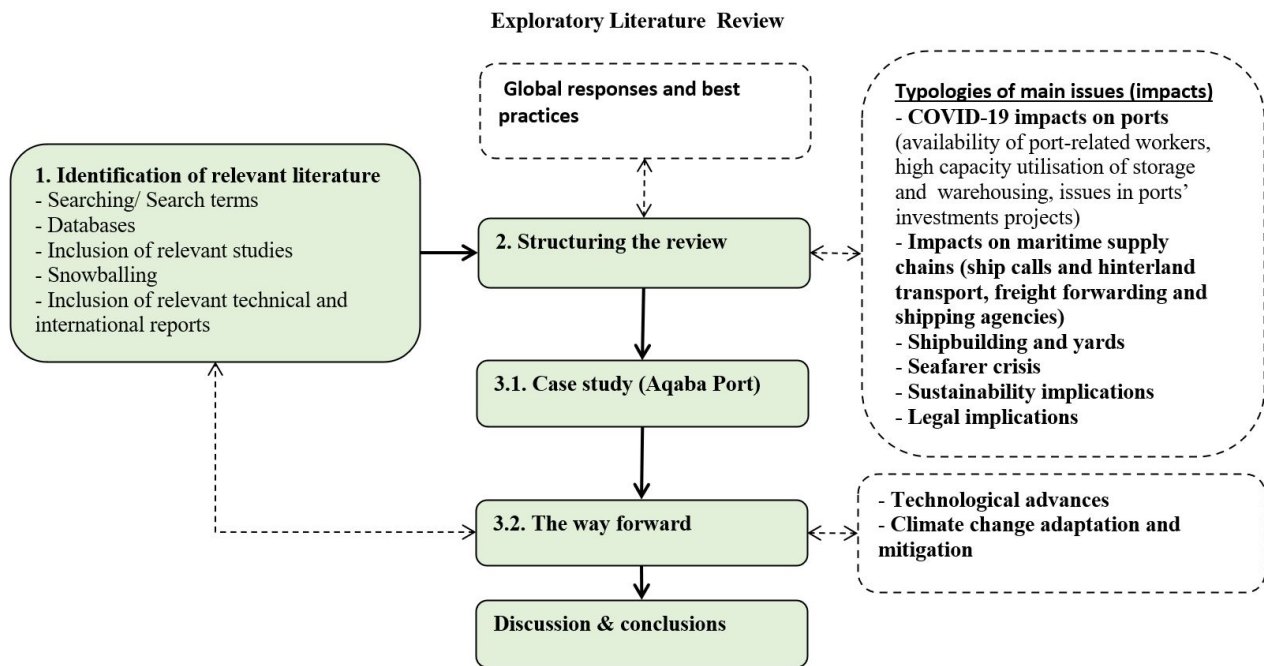


Figure 1 Research outline.

2.1. Identification of relevant literature

To identify relevant literature, combinations of search terms were utilized: (COVID-19 OR Corona Virus OR Pandemic) AND (Impact OR Influence) AND (Maritime Transport OR Port OR shipping OR Maritime Supply Chain OR Maritime Industry). Searching for keywords and titles was conducted in December 2020 using broad databases, i.e., Scopus and ScienceDirect. The search yielded 57 articles. After duplicates were removed, the studies were scanned and included only if they answered the study questions, verified as being relevant, in addition to a qualitative assessment of the rigor. Very few articles were included (15). However, through snowballing, 4 new articles were added.

While peer-reviewed studies of the investigated literature are inadequate, this study entailed a review of global technical and industrial reports, governmental reports, official correspondence, and governmental and intergovernmental reports published in the period of the study, e.g., those from the IMO, UNCTAD, IAPH, and WPSF, in addition to credible websites. Therefore, a search using a combination of the same abovementioned search terms was conducted using Google Scholar. The use of Google does not pose a challenge, contrary to systematic reviews, thereby allowing access to a larger number of sources including grey literature. The search resulted in the identification of more than 200 studies and reports; thus, several reports were considered relevant to the review (14).

2.2. Structuring the review

It is very important to build concepts and typologies (Jaakkola, 2020) in which all key findings from studies can be pooled. This assists in limiting the scope of the review. While reading the papers and reports, we applied concept mapping, which is a key tool to identify, organize, and collate key concepts of research areas, and to make sense of different knowledge. Concept mapping usually ends up with visual presentation (illustration) of identified various concepts (Torres & Marriott, 2009). Once all studies were compiled, 6 main typologies of impacts were constructed based on pre-exploration of the literature (**Figure 1**).

2.3. The case study and development of the way forward

After structuring the review and presentation of findings, results were utilized to investigate identified impacts in a case study. Many exploratory reviews have exploited case studies (or a single case study) which incorporate the review's findings (Swedberg, 2020). Accordingly, considering the importance of case studies as sources of a variety of information (Yin, 2014), we have incorporated a case study of the Jordan Maritime Commission (the maritime administration) and the Port of Aqaba as part of our investigation of developing countries' responses to the pandemic and the impacts felt. The six identified issues in the review were investigated in the case study.

In parallel, the studies and reports identified as relevant (included for the review) were scanned to establish an outline of the way forward for ports post COVID-19, i.e., what ports need to focus on for better recovery and to be resilient in the face of expected future shocks. Two main ways forward were identified, i.e., technological advances and climate change adaptation and mitigation. Following the same searching approach used in the exploratory review, we explored additional relevant studies that addressed these topics. Such a bringing together of the case study and identification of the way forward will contribute to policy and decision makers in the field by highlighting areas of focus beyond the pandemic.

3. Global responses and best practices

The restrictions to contain the pandemic disrupted the maritime supply chains. Thus, during the pandemic, global efforts, including those of the maritime industry and entities in port and shipping, had an important role in framing responses to the pandemic. The International Maritime Organisation (IMO) exerted rigorous efforts and distributed several circular letters of the series "NO.4204", often jointly with other maritime stakeholders. The series provided guidance to member states and their ports and shipping industries to ensure resilient shipping and maritime trade and the safety and security of seafarers. The IMO circulated a preliminary list of recommendations for governments and relevant national authorities on the facilitation of maritime trade during the COVID-19 pandemic (IMO, 2020g). The circular emphasized the provision of access for ships to port berths, with no restriction on the loading and unloading of cargoes, in addition to the facilitation of crew changes. The seafarers' crisis, in respect of crew changes and repatriation, was one of the primary concerns in the IMO series of circulars (e.g., IMO, 2020b, 2020c, 2020e). Similar concerns were raised by the IMO as regards the issue of cruise shipping and, thus, a joint statement (IMO, 2020f) was circulated to buoy and support the safe resumption and recovery of cruise ship operations following the COVID-19 pandemic. Additionally, in contribution to the maritime supply chain and international trade, the IMO circulated a joint statement calling on all member states for a sustainable socio-economic recovery post COVID-19 (IMO, 2020d). The statement emphasized both greater utilization of international legal instruments and standards and strengthened regional and sectoral cooperation. It comprised tools and measures for proper and effective supply chain coordination and cooperation for all transport modes and across borders.

Additionally, the United Nation Conference on Trade and Development (UNCTAD) secretariat produced a technical note on port responsiveness to the COVID-19 pandemic, based on various experiences received from ports in the TrainForTrade Network (UNCTAD, 2020e). The note contains broad guidelines to implement and observe a sequence of measures to mitigate the impact of the outbreak, with an example of a crisis protocol that can be used as a guide on actions that should be implemented in relation to strictly defined crisis levels. UNCTAD emphasized the importance of keeping supply chains, including ports, open and, thus, allowing continuous maritime trade flows, while taking additional measures to protect the working staff and employees. In addition, UNCTAD produced a report on how countries can leverage trade facilitation to defeat the COVID-19 pandemic (UNCTAD, 2020c), i.e., through process optimization, cost reduction, transparency and cooperation enhancement, and the full display of technology to ensure cross-

border trade while reducing face-to-face interaction. UNCTAD's 10-Point Action Plan (UNCTAD, 2020a) to strengthen international trade and transport facilitation in times of pandemic was similar. Furthermore, the recent UNCTAD review of maritime transport 2020 included a special chapter on the COVID-19 pandemic (UNCTAD, 2020f). The review considered the pandemic's influence on maritime transport and hinterland connections, and concluded with lessons learned from first-hand experience, e.g., port authorities, small island developing states, maritime authorities, and shipping companies.

Industrial associations and organizations responded to the pandemic. The International Chamber of Shipping (ICS) led an initiative, in cooperation with the International Association of Ports and Harbors (IAPH), which provided guidelines for safe ship-port interface during COVID-19 (ICS, 2020), i.e., for ship's crew and shore personnel (ship agents, chandlers, inspectors, pilots, stevedores, surveyors, and service engineers). A hierarchy of control measures for effective safety control and risk reduction was presented. The World Ports Sustainability Program (WPSP), on the other hand, established the World Ports COVID-19 Information Portal (WPSP, 2020a). The portal contains full-fledged information and guidelines for ports and ships related to pandemic issues, e.g., current operational status, regulations and restrictions of world ports, and operational guidance based on global port best practices. Importantly, the WPSP developed a guidance document to assist port authorities and operators in the implementation of actions to alleviate the impact of COVID-19 (WPSP, 2020b). The frequently updated document is based on key inputs from the Port of Açu (Brazil) and other IAPH member ports' best practices and is structured in 4 layers: a) immediate measures addressing port operations, governance, and communication, b) measures to protect business and financial returns, c) measures to support customers, stakeholders, and community, and d) measures for getting back to work. Further, the WPSP and IAPH established the COVID-19 port economic impact barometer, which provided detailed analysis of the operational and economic impacts on world's ports (Section 4, among other sources, provides further details and results gleaned from the barometer).

Also, numerous free online resources were set up to provide updates on safety regulations and restrictions initiated globally by port states, port authorities, port administrations, and ministries of transport. The International Group of P&I Clubs introduced its online COVID-19 digital dashboard (IG P&I, 2020) to assist shipowners, charterers, operators, and other stakeholders to pursue countries' and ports' measures against COVID-19. Inchcape Shipping Services (ISS) established a COVID-19 portal that provides information about the pandemic's implications for ports and countries and lists of ports' local conditions, requirements, and crew changes status (ISS, 2020). Other industrial groups and associations presented updates about global ports' restrictions and regulations, e.g., the Wilhelmsen group online map (Wilhelmsen, 2020) and BIMCO[†] (BIMCO, 2020). Such tools allowed the maritime industry to discover commercial risks, threats, and other expected restrictions and, hence, prepare for reactions in advance.

In a similar fashion, port authorities around the world made available innovative guidelines for prevention and recovery from COVID-19. For example, the Maritime and Port Authority of Singapore issued its "crew change handbook" for safe and organized changes (MPA, 2020). Furthermore, the China Ports and Harbours Association (CPHA) developed the "Guidance on the Prevention and Control of COVID-19 for Ports and Its Front Line Staff", which contained measures to prevent virus transmission (e.g., information gathering, sanitation and personnel protection, ventilation, vehicle disinfection, etc.) (CPHA, 2020). Many ports followed suit and circulated to the IMO the protection measures and requirements they had established for frontline staff, work, port operations, ship-port interface, and national flagged and calling ships.

To this end, governments and/or port authorities adopted measures in response to COVID-19 for the safety and security of the port workforce, providers, and users. Additionally, operations

[†] Baltic and International Maritime Council - independent international shipping organization

were adjusted to minimize and mitigate risks and to secure cargo flow along the maritime supply chains. The measures taken against the pandemic have generated observations, knowledge, and lessons learned (best practice). Thus, as generic guidelines, safety measures can be summarized into: preventive hygiene measures (handwashing), limitation of physical interaction and contact using radios and telephones, social distancing (2 meters), provision of personal protective equipment (PPE), sanitation of surfaces, control points to monitor temperature/symptoms, fumigation and disinfection of vulnerable port areas, cargo, and trucks, and boosting the use of digital documentation and other digital technologies in order to reduce human contact.

4. COVID-19 impact on maritime transport and industry

It goes without saying that countries' generalized lockdowns, port safety requirements such as the wearing of PPE (masks, gloves), social distancing, monitoring of personal temperatures (check-ups), pre-reporting requirements, fumigation and sanitation, and remote working to minimize and mitigate the pandemic contagion resulted in disruption to ports, which impacted other aspects of the maritime supply chain and industry. It may be said that the analysis of such immediate impacts is of great importance and serves as a basis for the construction of post pandemic recovery and the establishment of future resilient measures. In this study, the impacts are addressed through the lens of ports, considering ports as the central node of the whole supply chain.

4.1. COVID-19 impacts on global ports

After the COVID-19 breakout, the IAPH-WPSP COVID-19 port economic impact barometer provided a weekly detailed analysis of trends observed in the world's ports compared to previous weeks, based on a survey that started weekly, then bi-weekly, and is now monthly. The report has been active since the 6th of April 2020. The barometer has become a vital monitoring tool for current port situations. According to the numerous reports published, and the volume of regional ports represented in the reports, this section takes the barometer report as one of the pillars to provide analysis. According to a November 2020 report (Notteboom & Pallis, 2020b), 73 world ports participated in the survey, with the highest responses from EU ports (developed countries), and to a lesser extent, American (North, Central, and South) and Asian ports. Developing countries' ports, such as those of Africa and the Middle East[‡], were not highly represented, due to a lack of responses. This trend continued in further reports. Information was gathered on four primary port issues compared to normal conditions, i.e., decline in vessel calls, hinterland transport delays, the shortage of port-related workers, and high capacity utilization of warehousing and storage facilities (i.e., capacity constraints due to high cargo dwell times). Recent questions were added dealing with crew changes, investment in port infrastructure/sustainability, and cargo throughput compared to the same period last year. Overall, in the last quarter of the year 2020, it seems that ports have increasingly resumed regular operations, motivated by the sharp decline in ships blank sailing (cancellation and rescheduling of some services as a countermeasure), increase in cargo throughput, and relaxed lockdowns[§]. In **Table 1**, based on data retrieved from the IAPH-WPSP COVID-19 port impact barometer reports (Notteboom & Pallis, 2020b, 2020a, 2020c), a summary is presented of the percentage of ports (low, moderate, and high) that reported issues in port operation and supply chain aspects in the last three quarters of 2020 compared to 2019. A further analysis referring to findings in **Table 1** follows.

[‡] This fact serves as one of the motivations in this study, i.e., to investigate the port of Aqaba/Jordan as a case study, thus shedding light on the COVID-19 response in and impact on Middle Eastern ports.

[§] Similar findings were included in a February 2021 report (Notteboom & Pallis, 2021b)

Table 1 The percentage of ports reporting COVID-19 issues in relation to port operation and supply chains aspects in the last three quarters of 2020.

Issues	Second quarter	Third quarter	Fourth quarter ^a
Availability of port-related workers			
Dock worker shortages	High (22 % peak)	Low (5 % nadir)	Moderate (8 %)
Technical-nautical service delivery worker shortages	Moderate (12 % peak)	Low (7 % nadir)	Moderate (12 %)
Harbor master services personnel shortages	Moderate (10 % peak)	Moderate (10 % peak)	Moderate (9 % peak)
Port authority personnel shortages	High (30 % peak)	Moderate (21 %)	Low (4 % nadir)
Truck driver shortages	High (21 %)	Low (3 % nadir)	Moderate (12 %)
High capacity utilization of warehousing and storage			
Food stuffs and medical supplies	High (35 % peak)	Moderate (15 %)	Moderate (20 %)
Consumer products	High (28 % peak)	Low (9 % nadir)	Moderate (20 %)
Liquid bulk	High (22 % peak)	Moderate (17 %)	Moderate (14 %)
Dry bulk	Moderate (17 %)	High (18 % peak)	Moderate (16 %)
Hinterland transport delays			
Cross-border trucks	High (43 % peak)	Moderate (23 %)	Low (0 % nadir)
In/out port trucks	High (37 % peak)	Moderate (15 %)	Low (6 % nadir)
Rail services	High (28 % peak)	Moderate (19 %)	Low (5 % nadir)
Inland barge services	High (41 % peak)	Moderate (20 %)	Low (4 % nadir)
Decline in container ships calls	High (53 %)	High (48 %)	Moderate (36 %)
Decline in other cargo ships calls	High (47 %)	High (51 % peak)	Moderate (41 %)
Decline in passenger ships calls	High (77 %)	High (85 % peak)	High (83 % peak)

Source: (Notteboom & Pallis, 2020b, 2020a, 2020c).

^a Up to November 8th, week 45.

4.1.1. Availability of port-related workers

Workers in technical-nautical services and harbor master services, port authority workers, and truck drivers were affected by the measures taken to fight the COVID-19 outbreak (Notteboom & Pallis, 2020b, 2020a, 2020c). In the second quarter, the impact on the availability of port-related workers was high compared to a limited impact in the last quarter of the year. At the beginning of the pandemic, many had to stay home, and several industries were closed; thus, there was less cargo transport. The shortage of dockworkers has relaxed in the third quarter, although it was relatively high in the last quarter of the year. The same is true with respect to the shortage of technical-nautical service personnel (pilot, towing, mooring). In the fourth quarter, 12 % of ports reported a shortage, yet this percentage was as low as 4 % in October and November. Harbor master service personnel, including VTS operators, were never highly affected; only 10 % of ports reported shortages, and in November, only 4 % of ports perceived shortages (**Table 1**).

On the other hand, port authorities experienced high shortages in personnel in the second quarter, which became moderate in the third, and low in the fourth. Government lockdowns, remote working, key staff only working restrictions, and the one person per room policy influenced the shortages in the beginning, noting that adjustment to teleworking and social distancing took time until it became the new norm. Port truck drivers were initially in short supply; 21 % of ports reported shortages, which then smoothly improved in the third quarter and continued to be stable in

the last quarter of the year, despite a slight high point (12 %) in September. All percentages of shortage were fluctuating, seemingly because some workers became sick or isolated and, in the beginning, the lockdown influenced personnel commuting. Until adaptation improved, shortages were minimized. However, recently, most lockdowns have been lifted, and as the virus second wave picked up again, shortages slightly increased.

The key findings are that teleworking (remote working) became a regular practice, especially in administration, and working in shifts was another adopted practice, in order to avoid infection of a whole department if any one worker contracted the virus. Operational workers continued attending work, with safety measures and social distancing (to prevent contact) imposed.

4.1.2. Capacity utilization issues

Typically, high capacity utilization is not an issue which adversely affecting port performance as it indicates effective utilization of ports' warehouses and storages, but this is far from being the case during the COVID-19 pandemic. Rather, the high capacity utilization during the pandemic indicates congestion, which resulted from higher cargo dwell times, since there were demand issues in addition to full lockdown measures that kept cargo held in ports. Thus, it is likely that such issues led to an increase in ship waiting times at anchor until space was available for their cargo, which is a higher cost to both shippers and shipping lines. Ports, therefore, need to take necessary steps to reduce the dwell times and expedite cargo clearance. According to the WPS reports, the capacity utilization of warehouses and storage, including distribution activities, were impacted during the pandemic (**Table 1**) (Notteboom & Pallis, 2020a, 2020c, 2020b). In the second quarter, the utilization of warehousing and distribution facilities for food and medical supplies highly increased. Despite it being relatively low in the third quarter, ports reported an increase in utilization in the fourth quarter (20 % of ports). The same is true regarding consumer products, although some ports reported underutilization. At the other end of the spectrum, dry bulk storage utilization has been going through ups and downs: 10 to 20 % of ports reported increased utilization. Further, liquid bulk storage utilization was low in the last quarters, since oil products volume dropped in addition to the lockdowns, which lowered fuel consumption and, thus, demand. It should be noted that the capacity utilization was not uniform in many ports due to a variety in restrictions (either partial or full lockdowns), closure of some factories, market dynamics, exporters' and importers' new practices (stockpiling), and the fall in demand and production of commodities and products, among others. Notably, capacity utilization issues, in addition to the port worker availability issue and safety restrictions, aggravated by accumulative delays in processing and clearance, may result in an increase in cargo dwell time and ship waiting time as well.

4.1.3. Issues in ports' investments projects

The reverberating shock of the pandemic left things uncertain, particularly port profitability and revenues, which had an obvious effect on ports' future investment plans. According to the WPSP-IAPH barometer midterm report (Notteboom & Pallis, 2020a), 69 % of surveyed ports stated that the majority of their investment plans had either been delayed or even amended. The delay reported was minor in 41 % of ports, at least until September 2020, taking into account that ports predominantly needed to remain operational and serve countries' trade. Another 19 % of ports reported that major investments were postponed, and 4 % abandoned or shelved whole projects. Delays happened because of inconveniencies in securing authorization from regional, federal, and national administrations and third party contractors' issues (e.g., availability of work forces). In view of the fact that cruise and passenger ports lost business (dues, services, restaurants, etc.), while workers on docks and in restaurants were badly affected by COVID-19 (IMO, 2020f), ports will take a long time to adjust and, thus, will reassess investment projects. Although the repercussions of the pandemic seem not to be huge so far, and not so disadvantageous to port traffic, as reported by

recent findings and analysis of the pandemic (in Notteboom & Pallis, 2021b), large impacts might surface again once the extremity of the of COVID-19 has taken effect.

4.2. Impacts on maritime supply chains and industry

The global health crisis was accompanied by an economic crisis. The severity of COVID-19 has driven world GDP into decline. On average, it is estimated to have gone down by 4.4 %, double the figure of 2008 financial crisis (Clarksons Research, 2020c). In the light of already weaker maritime trade momentum, the volumes of seaborne trade expanded slightly by 0.5 % in 2019, down from 2.8 % in 2018, and reached 11.08 billion tons (UNCTAD, 2020f). In addition, global container port traffic decelerated to 2 % growth, down from 5.1 % in 2018. Therefore, UNCTAD projects the volume of international maritime trade to fall further, by 4.1 % in 2020, amid supply-chain disruptions, demand contractions, and global economic uncertainty caused by the pandemic (UNCTAD, 2020f). A similar percentage decline was projected by Clarksons Research (Clarksons Research, 2020c). Consequently, the landscape of maritime transport and trade has been undermined, thus affecting trade growth prospects, which had already been undermined by lasting trade tensions and high policy uncertainty.

4.2.1. The shipping and maritime supply chains

Decline in demand and import and export protectionism during the pandemic led shipping to adjust its supply and deployed capacity (UNCTAD, 2020f), thus leading to fewer port calls for most vessel types (UNCTAD, 2020d). The container shipping market monitored and adjusted its capacity to balance the decline in demand (through capacity management i.e., service suspension, blank sailings, and rerouting (UNCTAD, 2020f)). Such reactions have impacted shippers and consignees, e.g., services were cut, transport capacity limited, and delivery dates delayed.

On the other hand, many world ports imposed restrictions on ships, e.g., requirements for crew medical inspection, requests for healthy checks or tests before entry, health declarations, social distancing, and sanitary controls (UNCTAD, 2020f, 2020d; Wilhelmsen, 2020; WPSP, 2020a). Changes in port procedures and restrictions resulted in delays for shipping (increases in turnaround time), heightened by disruption in port operations (IMO, 2020d; Michail & Melas, 2020). The highest delays were seen among passenger ships and ferries (Notteboom & Pallis, 2020c). In some cases, a ship with onboard infected crew is held in quarantine for 14 days, with testing afterward (Notteboom & Pallis, 2020a).

As can be seen in **Table 1**, according to the findings the IAPH-WPSP COVID-19 port economic impact barometer (Notteboom & Pallis, 2020a, 2020c), vessel calls, either container, other cargo, or passenger cruise ships, have seen a significant drop. World ports have reported that container and other cargo ship calls were down in the second and third quarters, with some improvement in the last quarter. Furthermore, even mega vessel calls decreased, showing an expected structural change in the shipping network. With respect to other cargo ship calls, including bulk and RoRo, although a reduction was witnessed (UNCTAD, 2020d, 2020f), the situation became rather stable, except for cruise shipping (Notteboom & Pallis, 2021a). It is worth noting that trends vary by ship types and regions; ports in Asia reported more stable ship calls compared to declines in the EU and the Americas. Remarkably, the decrease in calls was not only due to the economic downturn and to operational issues in ports, but also to trade restrictions imposed by some countries, such as permitting the delivery of only essential goods (Notteboom & Pallis, 2020a).

Compared to 2019, UNCTAD outlined the moving average of weekly ship port calls (up to week 31) (**Figure 2**), which were down by more than 10 % in the whole period. However, going back to weeks 21 and 22, i.e., the second half of May 2020, global port calls had fallen to less than 80 %, though a subsequent improvement could be seen from week 25 onward (UNCTAD, 2020d). Overall, the Clarkson's global deep sea cargo port activity index was down 5 % of the year-on-year

average in August, compared to 10 % in May (Clarksons Research, 2020c), signaling that the peak of pandemic impact on trade might have already passed. Now, efforts need to focus on post-COVID-19 recovery.

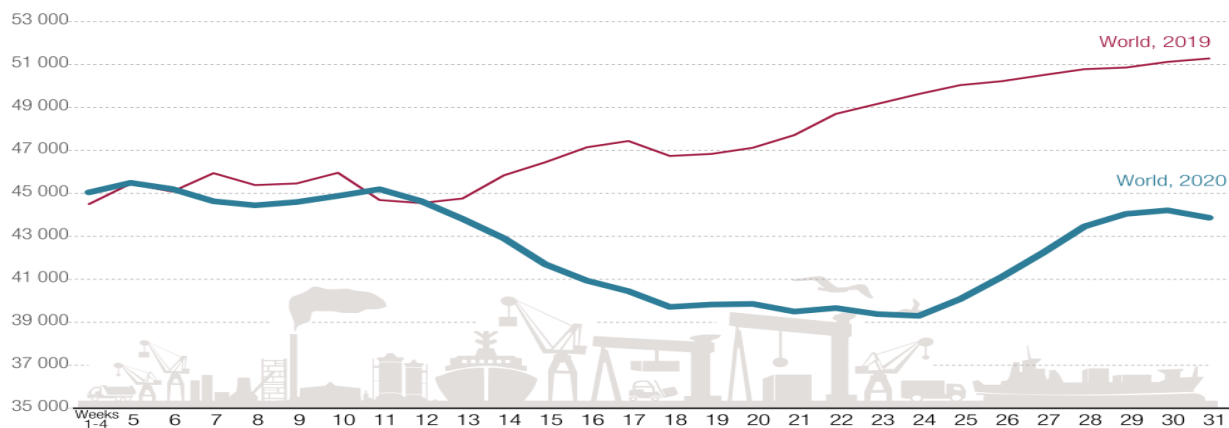


Figure 2 World total of “all ship” port calls- 4 weekly moving average.
Source (UNCTAD, 2020d)

Although improvements were seen from the 2020 third quarter on, the impact of the pandemic has varied by shipping sector. Cruise and container** shipping have been hit the most (UNCTAD, 2020d). Therefore, yearly box trade volume was projected to decline 4 % in terms of TEU across 2020. Similarly, a 3 % decline in bulk trade was predicted (Clarksons Research, 2020c). Furthermore, the port liner shipping connectivity index (container ports) recorded lower container shipping services worldwide in 939 ports, in the second quarter of 2020, showing a decline of 3.6 % compared to 2019, which is attributed to the capacity management in response to the pandemic (UNCTAD, 2020f).

Despite the severe impacts of the pandemic, the freight rates seem to have held good news for shipping sectors. The container freight rate was higher during the middle of 2020 than in 2019, with profits exceeding those of 2019 (UNCTAD, 2020f). This upwards trend increased even further in later months; the Shanghai Containerised Freight Index (SCFI) increased by 39 % between end-July and end-October to reach 1,530 points, before rising another 22 % and reaching a record (1,857 points) in the first 2 weeks of November, almost double that of the starting 2020 level (Clarksons Research, 2020a). Liners acting smart by adjusting their capacity (market control), in addition to the resumption of port operation, and the increase in demand due to relaxed restrictions (less lockdowns), could be attributed to the rise of freight rates. Other sectors, tankers, and bulkers witnessed volatility (ups and downs) and, thus, freight rates worsened by the demand imbalance (UNCTAD, 2020f).

Cruise and passenger ships, on the other hand, declined, as shown in **Table 1**. According to Notteboom and Pallis (2020b), cruise ports in Asia, North America, and the Caribbean have remained inoperative since the inception of the pandemic. Although a few cruise operators resumed activities on a small scale, another decline may occur to the current resurgence in COVID-19 cases and, hence, new restriction and lockdowns may be imposed. With regard to passenger ships, even with the progress in operation, the number of passengers was low, declining by 80 % in EU ports, for example. Passenger numbers were reduced by the limitations imposed on the number of onboard passengers in some regions. Many cruise ships ceased operations and chose to lay-up in ports, with a limited number of crew onboard (UNCTAD, 2020d, 2020f). It is worth mentioning the significant

** Account for 60 % of seaborne trade by value

facts that cruise shipping yields yearly USD 150 billion for the global economy, provides 1.2 million jobs, and pays USD 50 billion in wages, covering between 30 to 80 % of small islands and the least developed states' (SIDS) total exports (IMO, 2020f). However, halting cruise shipping operations until July 2020 caused USD 50.24 billion of economic loss, which represents the loss of 334,000 jobs and USD 14.75 billion in wages. (IMO, 2020f).

4.2.2. Hinterland transport

Hinterland transport (trucks, railways, and inland waterway barges) faced delays, or was even discontinued (UNCTAD, 2020f). Delays were due to lockdowns, lower availability of truck drivers, border checks, social distancing, hygiene inspections, and disruption in port operations. In addition, mandatory testing of truck drivers at borders and/or before entering ports, or a requirement for COVID-19 free certificates, was imposed by various authorities (Notteboom & Pallis, 2020a, 2020c). Ports reported delays in the hinterland transport (**Table 1**). The situation in general started with delays classified as minor, 6 to 24 h, then extended to more than 24 h. Delays were high in the second quarter of the year, then stabilized in the third, and significantly improved, reaching a low level in the last quarter. On the other hand, disruption in rail services and inland barges went slightly up in November, although the general trend was low. Reopening of markets, and a sudden surge in container throughput and cargo, may have led to difficulties in absorption, and put pressure on the downstream supply chain on one hand. On the other hand, with the recent rise of COVID-19 cases in the last quarter of the year, new restrictions (protective measures) were taken at borders or while accessing the ports, which contributed to these delays. In general, the delay trend is not uniform, and even differs in the same region. Rather, it depends on how relaxed restrictions are (Notteboom and Pallis, 2020a, 2020c).

4.2.3. Freight forwarding and shipping agencies

It should be noted that freight forwarding and shipping agency services were disrupted (UNCTAD, 2021), which also contributed to the port capacity utilization issues. Lockdowns, quarantines, safety measures, and other kinds of local restrictions disrupted freight forwarding mobility. For example, goods were held in containers, or empty containers were unavailable. The trucking capacity was also strained because of the high demand for trucking services, such as food and medical supply transport during the lockdowns. The considerable concern for freight forwarders is the risk related to delays in the delivery of cargo, which may lead to its deterioration and, hence, to legal and contractual consequences. According to a survey (Shipping and Freight Resource, 2020) cited in an UNCTAD report (UNCTAD, 2021), around 60 % of shipping agencies and freight forwarders were significantly affected by the pandemic, while 25 % were moderately affected. The main issues were the lack of capacity, transit delays (port to customers due to clearance issues), and decline in demand volume, in addition to the financial issues emerging from clients' late or non-payment, and cancelled credit lines from physical carriers.

4.2.4. Shipbuilding and yards

Against the backdrop of exceedingly reduced orders in 2020 thus far, the global orderbook has dropped by 16 %, in compensated gross tons (CGT) terms, from the end 2019. This represents a considerable decline in order volumes, i.e., by a 51 % year-over-year average in CGT terms (Clarksons Research, 2020c). The global orderbook shrunk for bulk carriers (34 % in dwt), tankers (12 % in dwt), and containers (24 % in TEU) compared to 2019. That said, this decline signifies the weakened investor' sentiments related to the Covid-19 pandemic and existing concerns (uncertainty) over technology and fueling choices. It seems that the delivery of ships was disrupted, even though yard output returned to normal levels. Overall, according to Clarksons Research (2020c), total delivery volumes are forecast to fall 13 % on year-on-year average in dwt terms, projecting the delivery of 86.4m dwt by the end of the year. Even the worlds' first electric and

autonomous container ship delivery, “Yara Birkeland”, was postponed until late 2021 instead of 2020 (Splash, 2020). Last but not least, these consequences have exerted a downward pressure on 2020 newbuilding prices; as of the end of September, the Clarksons Newbuild Price Index has fallen by 3 points from its end 2019 level, to stand at 127 points, its lowest level since February 2018 (Clarksons Research, 2020c).

4.2.5. Seafarer crisis

The world owes a great debt to seafarers for maintaining supply chains throughout the pandemic. Two million seafarers operate the shipping fleet (IMO, 2020f). However, seafarers have suffered due to restrictions on travel, embarkation, and disembarkation in ports, city calls, quarantine measures, reduction in available flights, and limits on the issuing of visas and passports, leading to a crew change crisis (IMO, 2020g). As of August 2020, around 300,000 seafarers were trapped working aboard ships and could not be repatriated. In addition, an equal number of unemployed seafarers were ashore because they are unable to board ships (IMO, 2020b). Seafarers were described as fatigued and subject to mental health issues that were leading to fears of self-harm and suicide (IMO, 2020b). The IMO described the seafarers’ crisis as a humanitarian crisis that affects the safety of shipping, the protection of the marine environment, and the continuation of efficient trade and the recovery of the world economy. As such, the IMO has established a Seafarer Crisis Action Team (SCAT) to help seafarers who are in critical situations and has circulated a framework of protocols for ensuring safe ship crew changes and travel (IMO, 2020b). Additionally, in recent circulars, the IMO has called on all governments to immediately recognize seafarers as “key workers”, to take swift and effective actions to eliminate the obstacles they face (IMO, 2020c), and to facilitate passenger flights, including repatriations, using public health corridors (IMO, 2020d). Similar efforts were exerted to sort out seafarers’ issues by UNCTAD (UNCTAD, 2020d, 2020a) and the UN Global Compact “COVID-19 Task Force on Geopolitical Risks and Responses” (UN Global Compact, 2020).

Unfortunately, limitations on crew changes continue, and were recently reported by several global ports (Notteboom and Pallis, 2020b, 2020a). The complication is not only from the port side, but other health official and immigration restrictions worsen the situation. Of immediate concern, the rights of seafarers, as enshrined in the maritime labor conventions (MLC-2006) and other instruments, have not been respected by all governments. Notably, seafarers’ rights to shore leave, annual leave, a maximum period of service on board (11 months), repatriation, and access to medical care on board and ashore have not been totally appreciated.

4.2.6. Sustainability implications

Nonetheless, COVID-19 has posed issues on port and shipping sustainability performance and management, additional to the introduction of marine and maritime environmental externalities. Such issues may undermine the progress of the implementation of the 17 UN SDGs (IMO, 2020f). Though there are no SDGs dedicated to ports and shipping, the IMO and the WPSP referred to such interlinkage in various reports. Researchers also mapped the interconnection of port sustainability with UN SDGs and shed light on how ports can advance the SDGs’ implementation (Alamoush et al., 2021, 2020a).

As regards port investments in environmental sustainability, 54 % of surveyed ports (by WPSP) reported that investments continued as planned, 32 % were slightly delayed, 4 % were accelerated, and 2 % had seen supplementary funds. On the other hand, 15 % incurred major delays, and 2 % of ports had abandoned sustainability projects (Notteboom & Pallis, 2020c). Even in the most recent one year report of the WPSP, there was no change in these findings; thus, the report emphasized that the maritime industry remains devoted to advancing sustainability even in such a crisis (Notteboom & Pallis, 2021a).

Turning to the shipping side, from the perspective of SDG 7 (renewable energy), and SDG 13 (climate change), countless global meetings and assemblies called to discuss, adopt, and enact provisions to decrease emissions, particularly those related to climate change (greenhouse gas emission (GHG)), were held virtually (online), delayed, or postponed to later dates. For example, the IMO's Maritime Environmental Protection Committee (MEPC) 75 session for shipping GHG emission reduction was delayed for 7 months and, thus, the MEPC held a virtual meeting in November 2020 addressing short-term measures. Despite this, a recent analysis showed that container ships slowed by around 2 % (Clarksons Research, 2020a) and, generally, that shipping CO₂ emissions in 2020, according to Clarksons Research energy transition model, were estimated to amount to 807Mt, 2.3 % of global emissions, down by 4 % in terms of year-on-year average, due to decrease in total shipping activity. The same report suggests that decarbonization trends will soon accelerate (Clarksons Research, 2020d).

On another matter, to lower the health impact of using regular bunker fuel (SDG 3 health), implementation of IMO 2020's shipping global sulfur cap started almost a year ago, leading to the largest ever fuel grade switch^{††}. Hence, the industry has moved on by using either low sulfur fuel or scrubbers. It should be noted that there are two types of scrubbers: open-loop scrubbers, which discharge to the sea, have an adverse influence on water quality, and are banned by some ports, and close-loop scrubbers, with no discharge to the sea. Shipowners have to choose between investing in scrubbers and accepting the higher cost of low sulfur fuel. Nonetheless, although sustainability may not be the shipowners' main motivation to retrofit scrubbers, COVID-19 slowed scrubber retrofits. By the end of 2020, only 0.5 % of fleet capacity would undergo a scrubber retrofit, down from 2.0 % in early 2020, and thus, the accomplishment of some of the remaining program seems susceptible (Clarksons Research, 2020a). On the other hand, while compliance was reported with the cap, some authorities suspended checks on fuel due to COVID-19 disruption, raising questions about the commitment to the cap during such suspension. Marine pollution is another collateral issue in the wake of COVID-19. Masks, gloves, gowns, and other PPE are thrown recklessly on land, and end up in landfills, then seas and oceans. This is deemed to be a degradation of ocean sustainability (SDG 14 life below water). COVID-19 will send around 130 million people into extreme poverty, including those who lose their jobs in ports and shipping (SDG 1 poverty); the whole UN SDGs agenda implementation may derail, and repercussions may continue after the pandemic. Therefore, immediate policy actions must be taken to improve the situation (UNCTAD, 2020c).

4.2.7. Legal implications

COVID-19 has raised a plethora of legal issues that has influenced traders, shipping, and ports as a result of cargo stacking, delays in delivery and increase in dwell time, and a lack of workers for clearance and processing. Issues which have surfaced include insurance implications, liability breaches of contract, demurrage charges and delay clauses, and force majeure cases (UNCTAD, 2020d, 2020a). Therefore, UNCTAD has called on the industry and traders to waive some legal rights and agree to a moratorium for payments and performance when appropriate on one hand, and on the other hand has emphasized coordinated and collective government and industry actions.

^{††} 0.5 % Low sulfur fuel for international shipping compared to 0.01 % within emission control areas (ECAs)

5. Jordanian Port of Aqaba case study^{‡‡}

In an attempt to minimize the spread of COVID-19, the Jordanian government enacted the National Defence Law, which entailed implementation of lockdown measures from March 2020. Although the virus has recently spread considerably (486,470 confirmed cases and 5,428 deaths as of 16 March 2021), lockdowns were relaxed to weekends only, until recently imposed on Fridays, with a nationwide curfew running from 11 pm until 6 am. Restrictions on land and sea passengers continue, while air passengers must submit negative COVID-19 tests. Enforcing lockdown poses severe consequences for the country's maritime transport, as most of the trade is handled by the sole sea Port of Aqaba^{§§} (POA). Opportunely, however, POA and the logistics sector were exempted from the lockdown and the curfew and, thus, commercial traffic is exempted, but is regulated to allow trucks only in and out of POA. In addition, most of the vital trade sectors in Aqaba city were allowed to work from 10:00 - 18:00 h during the peak of the pandemic. **Table 2** summarizes findings in the case study in line with issues identified by the exploratory review, which is further elucidated below **Table 2**.

Table 2 Impacts of COVID-19 on the Port of Aqaba^a.

Impacts	Impact level	Remarks
Availability of port-related workers		
Dock worker shortages	No impact	
Technical-nautical service delivery worker shortages	No impact	
Harbor master service personnel shortages	No impact	
Port authority personnel shortages	No impact	
Truck driver shortages	No impact	
Port high capacity utilization of storage and warehousing	Partial	Due to rushing of cargo delivery, cargo prioritization (manufactured goods for example) and the country's lockdown that affected some factories
Issues in ports' investments projects	No impact	
Maritime supply chains		
Ship calls	Partial	Cruise ships were banned, other ship types remained around each year-over-year average
Hinterland transport	Partial	Particularly at the beginning of the pandemic
Freight forwarding and shipping agencies	No impact	
Seafarer crisis	Strong impact	Ban in crew change over
Sustainability implications	No impact	Particularly in the ACT
Legal implications	Not applicable	No data could be acquired

^a Data was acquired in reference to the whole 2020 impacts compared to 2019; thus, there is no quarters data available

^{‡‡} Data retrieved from Jordanian governmental reports, JMC guideline of measures and actions, personal communications through calls, emails, and brief Zoom interviews, and container terminal and Aqaba port statistics, in addition to global COVID-19 information portals (BIMCO, 2020; IG P&I, 2020; IMO, 2020h; ISS, 2020)

^{§§} A landlord model, owned by Aqaba Development Corporation, environmentally governed by the Aqaba Special Economic Zone Authority (ASEZA), and regulated by JMC. APM is the operator of the container terminal, and Aqaba Port Management Company is the operator for the rest of the ports (general cargo, RoRo etc.)

As a *response to the pandemic*, the Jordanian Maritime Commission (JMC) issued guidelines and imposed measures to maintain the safety and efficiency of operations in POA, which were circulated to the IMO (IMO, 2020h). Actions taken by JMC regulated their staff work and imposed safety measures for calling vessels, including flagged ships and nautical services. JMC agreed with stakeholders on fumigation and sanitation ceiling prices, and always allowed working from home and staggering shifts, with social distancing and PPEs worn. In addition, a COVID-19 guidance manual was issued to flag ships and requested them to develop risk plans to manage the outbreak. The port operators also regulated their staff work and imposed safety measures. For example, offices and facilities were sterilized and disinfected; with regards to employees, there were daily temperature checks, social distancing, prohibition of any physical contact, and the wearing of protective clothes and tools, in addition to conducting periodic random tests.

With respect to the commercial status of POA, operations continued normally for containers and other cargo. In terms of the *availability of port-related workers*, it was not affected by the pandemic restrictions due to the fact that the port was open, and workers were not highly constrained. The port reported no tariff or rebate changes. The Marine Service Company (tugs, pilotage etc.) continued work as usual. By looking at the port statistics, it seems that *cargo tonnage* remained constant, but containers (TEUs) increased compared to the year 2019. The Aqaba Container Terminal (ACT), despite COVID-19's impact, saw throughput increase in 2020 by 7 % compared to 2019 (857,283 TEUs). Furthermore, the total number of trucks served increased in 2020 by 6 % compared to 2019 (327,351) and, thus, the total truck transactions reached 545,537, which represented a 3 % increase in comparison to 2019. Additionally, ACT perceived an 11 % increase in the export of full TEU's in 2020 compared to 2019, and the number of transshipment containers increased by 41 % compared to 2019. Such increases can be partially attributed to the relaxed measures against COVID-19 and the increase in demand due to the lockdowns in the country. Notably, as a measure to increase resilience against the pandemic, ACT extended the full container storage free-time period from 6 to 14 days, giving consignees sufficient time for clearance. As COVID-19 called for digitalization to minimize physical contact, ACT launched a direct electronic payment service platform "e-Fawateercom" (website and application), which allows clients and customers to pay their bills online. Implementing automated processes reduces paper use and physical contact between customers and employees.

On the other hand, main port cargo handling (tonnage) increased in the beginning of the pandemic but remained relatively constant on a year-over-year average. This was due to the fact that most of the cargo ended up landing only in Jordan, though there were some transshipment and cross-border containers. The increase in tonnage handled can be attributed to rushing cargo delivery before its due date, and fear of, and uncertainty about, the outbreak's consequences. Such trends have affected the *capacity utilization* of warehouses, storage and distribution centers, as the focus has been on moving essential goods, while other, nonessential, goods have to wait.

Notably, port *investment plans* continued as usual. For example, the ACT plans to retrofit some cranes and equipment with advanced machinery in the upcoming 5 years, in addition to investment in terminal tractors, reach stackers, and shore-to-ship gantry cranes. The main port, the landlord, also promises to continue investing in different aspects to improve its services, despite the challenges of the pandemic.

However, requirements were imposed on *calling ships* and crews by JMC, which may have heightened the barriers to shipping operations. Forty-eight hours prior to arrival at POA, vessels should provide: a list of the ports called at by the vessel for the last 30 days prior to calling at POA, and details of the previous 10 ports of call, including the names and nationalities of the crew onboard the ship, any crew changes over the past 30 days, with places, dates, and times of the changes, and any crew members suffering from temperatures above 37.5 °C. With regard to vessels entering Jordanian waters, pratique, and the operations of other competent authorities, check the temperature of every crew member at the pilot station. Thus, shore and ship personnel, including

ship crew on the water and at the berth (i.e., crew members and any officials, agents, visitors, or terminal employees and stevedores) must wear PPE (face masks, eye protection, gloves) and use hand sanitizers before and after boarding. Additionally, JMC requires vessels to submit medical declarations for crew and fill a maritime declaration of health and send it back to the agent (who passes it to concerned authorities' prior to vessel arrival). All vessels are required to be fumigated before being allowed to berth at POA. Such requirements incur around a 2 h *delay* for each vessel before berthing, thereby increasing the turnaround time for the same vessel and other waiting vessels. This delay is minor compared to delays in other ports, which could go up to days. In addition, these responses, either safety or market measures - by keeping the port open - by JMC and port operators, responded to the national defense law and alleviated the public and employees concerns on the spread of the virus. On another note, ship waste discharge is also not allowed, which is a global issue that creates inconvenience for many ships.

Similar to the global response, *cruise lines* were forced to halt due to the foreign policy ban. This had huge financial impact on the cruise industry in Jordan, though the port intends to lift the ban soon. Contributing to the aggravation of the *seafarers' crisis*, and similar to the global trend, JMC banned crew changes and offshore calls or leave (even to come down onto a jetty). However, it is worth mentioning that JMC launched an online repatriation platform to facilitate the traveling of Jordanian seafarers.

Hinterland transportation, particularly cross-border trucks, which most of the time do not call at the ports, witnessed disruption in the second and third quarter of the year. Mandatory COVID-19 tests, and strict safety measures, congestion, and long waiting times (up to 3 - 5 days) were prevalent and, thus, drivers held strikes, protesting against such requirements (supply chain implications). Later on, the situation improved due to some leniency, i.e., express testing and back to back truck transfer, etc. It seems unlikely that POA operations will be highly affected by the resurgence of COVID-19 cases. Rather, the lockdown has been totally relaxed and, even during the lockdown, operations have continued. With respect to *freight forwarding* and shipping agencies, they continued to work normally, and there was no considerable impact on operation, except for the financial and contractual issues that emerged.

Finally, *sustainability issues*, particularly environmental, are not reported by the main port operator (Aqaba Port Management Company). ACT, on the other hand, reports its environmental footprinting. During the Pandemic (2020), ACT claims that they reduced energy intensity and, thus, GHG emission intensity by 3 %. In addition, ACT increased waste recycling to 34 %.

6. The way forward

Considering the various impacts of the COVID-19 pandemic on ports and shipping, the way forward requires adoption of digital technologies to enable mitigation of the current pandemic, or similar future shocks, while at the same time encompassing climate change adaptation and mitigation measures.

6.1. Technological advances

Undeniably, COVID-19 provided an impetus to invest in port technologies. Therefore, ports need to integrate *digital technologies* in operations for seamless connectivity and efficiency and to facilitate trade while reducing human contact and physical interaction. Electronic solutions for ship-shore administrative and commercial interactions, between all entities operating in ports, are highly sought after (IMO, 2020a). Examples are the incorporation of Automated System for Customs Data (ASYCUDA), the port community system^{***}, investment in information and communication technology (ICT) infrastructure, and single window, to expedite cargo clearance, and support for electronic payments and paperless trade. International standards for data exchange, such as those

^{***} Only 49 of the 174 IMO Member States have functioning port community systems (WPSP, 2020b).

developed by UN/CEFACT, also assist in reducing physical interactions and enhancing streamlined processes (IMO, 2020f). Digitalizing port call processes can be augmented by the PortCDM (see (UNCTAD, 2020f)), the use of Digital Ledger Technology (UNCTAD, 2020b), and similar block chain innovations e.g., electronic bills of lading (Bolero), and the Internet of Things (IoT), and big data platforms and clouds (Pu & Lam, 2020; UNCTAD, 2019b). Definitely, these enhance smart port operation and efficiency and can be integrated effectively in transport chains. Advances in data analytical technologies (artificial intelligence, big data, edge computing) hold immense innovative and transformative solutions for maritime transport sectors (Yap & Lam, 2020). Big data gathering and edge computing can be used to enhance policy actions and, thus, guide decision making.

On the other hand, utilization of automation technologies in terminals and berths (Gekara & Nguyen, 2018), aside from holding promising environmental (energy efficiency and emission reduction) and economic benefits, improves operational efficiency and minimizes human interaction and physical contacts. Ports can utilize the Terminal Operating System (TOS) for automated yard management, automated quay and yard cranes (Devaraju et al., 2018), and gates, and can employ robots, such as Automatic Guided Vehicles (AGV)^{†††} and drones (for monitoring, security surveillance, and inventory inspections) (PEMA, 2016). On the other hand, automation technologies in ports can enhance shipping operations; for example, in the use of an automatic mooring system (Alamoush et al., 2020b), which substitutes shore line handlers, provides flexibility in mooring regardless of ship length, and reduces mooring time to minutes (Piris et al., 2018). Also, there is the laser docking system, which provides information for pilots and shore personnel for safe and fast docking, and automatic plug-in systems to expedite connection to shore power supply (Devaraju et al., 2018). Although not yet mature, there are remote controlled tugboats that advance port automation, such as the tugboat RAMora (Hertog et al., 2016). These intertwine with the race for maritime autonomous surface ships (MASS) (see (AAWA, 2016) for MASS details and its interaction with ports). Importantly, ports need to enhance communication and internet capability within the port areas (UNCTAD, 2020b) while accommodating the InMarsat technology (with ships) (Devaraju et al., 2018), so as to boost port internal and external connectivity. Strengthening ships' connectivity to the internet through WiFi and other terrestrial communications (LTE, 4G, 5G, mesh, and ad hoc networks) (Höyhty & Martio, 2020) would improve the ships' infotainment and, thus, help seafarers who are locked on board, and also streamline whole ship-shore communications.

Finally, it should be noted that application of technologies has various implications. Therefore, to increase technology uptake, and enable its efficient operation, ports require governmental funding, grants, investment in research, and incentives from policy makers (Schröder-Hinrichs et al., 2020). Also, ports need to focus on the re-skilling and up-skilling of human resources through training, including IT and software engineering skills. It is equally important to note that, with use of digital technologies, cyber threats increase. Even during the pandemic, port and shipping cyber security was compromised (attacks on shipping increased by 400 %) (UNCTAD, 2020a). Raising awareness of, and the use of countermeasures to minimize, cyber risk are becoming essential priorities (see cyber measure for ships and ports in Kavallieratos et al. (2019); UNCTAD (2020a)).

6.2. Climate change adaptation and mitigation

While it could be argued that COVID-19 has relaxed the the environment in some ways, post-COVID-19 sustainable socio-economic recovery needs to be the focus and should be aligned with environmental sustainability. Port authorities, irrespective of their sizes, and business and governance models, can play vital roles in sustainable development (Acciaro et al., 2014; Alamoush

^{†††} An automatic vehicle is capable of working without manual intervention, but operators send remote commands, while an autonomous vehicle is more advanced, to the extent the vehicle works independently and is self-governed based on artificial intelligence programs.

et al., 2020b; Puig et al., 2014). In addition, ports hold a significant capacity for advancing and enabling environmental upgrading in maritime transport value chains (Poulsen et al., 2018), and maritime supply chains (Notteboom et al., 2020).

The crisis has been associated initially with a drop in CO₂ emissions but, looking at its impact on ports and shipping, COVID-19 has brought to the forefront the climate change mitigation and adaptation issue. Climate change remains the central theme, highly endorsed, while post-COVID-19 recovery is sought (UNCTAD, 2020c, 2020b, 2020a; WSPSP, 2020b). The climate change threat might be worse than COVID-19, so much that, while the whole industry opens back up, synchronization with the climate issue should be the new paradigm.

As ports emit 3 % of global GHG emissions (Misra et al., 2017), port decarbonization by implementing technical and operational measures, including energy efficiency for port landside operations and ship-port and port-hinterland interfaces contributes immensely to climate change mitigation. Examples are the utilization of alternative fuels, electrification, hybridization, renewable energy resources (wind, geothermal, ocean, and solar), and smart grids and microgrids, and energy management on one hand and, on the other hand, measures that facilitate the reduction of ships and hinterland transport GHG emissions, such as onshore power supply, alternative fuel bunkering, vessel speed reduction program, modal shifts, and gate improvement (Alamoush et al., 2020b). See the same study for in-depth measures that can be implemented to decarbonize ports. Importantly, building walls, dredging and beach restoration, enhancing natural defenses, protecting against coastal erosion, and using monitoring applications are among the port measures available to prepare for climate change adaptation (Ng et al., 2013; Wilmsmeier, 2020).

While seen as a global issue, the reduction of shipping GHG emissions remains the focus of the IMO regulatory agenda. Notably, the IMO's targets aim to decrease GHG emissions from the shipping industry by 50 % by 2050, in addition to a 40 % cut in carbon intensity by 2030, as proposed in the Initial GHG strategy (IMO, 2018). The recent IMO fourth GHG study showed that total shipping GHG emissions (expressed in CO₂e⁺⁺⁺) increased 9.6 % in 2018 (1,076Mt^{\$\$\$}) compared to 2012 (977 Mt), and that CO₂ itself increased 9.3 % over the same period (IMO, 2020i). Thus, the share of shipping emissions in global anthropogenic emissions has increased, from 2.76 % in 2012 to 2.89 % in 2018. For international shipping, and based on the new voyage-based allocation, CO₂ emissions increased over the same period by 5.6 %, from 701Mt in 2012 to 740Mt in 2018, a lower growth rate than total shipping emissions, and accounting for a steady 2 % of the global share. In the business-as-usual scenarios, the emissions of shipping are projected to increase from 1,000 Mt CO₂ in 2018 to 1,000 to 1,500 Mt CO₂ in 2050, representing an increase of 0 to 50 % over 2018 levels, and are equal to 90 - 130 % of 2008 levels. During the COVID-19 pandemic, various measures to reduce shipping GHG emissions were proposed, i.e., IMO short term measures^{****} (regulator), EU Emission Trading System (political), and the Sea Cargo Charters Poseidon Principle to track emissions voyage by voyage (stakeholders) (Clarksons Research, 2020d). Despite frequent efforts to meet emissions targets, progress is still ambiguous owing to two uncertainties; the specifics of policies and regulation, and the timing and technology choice (Clarksons Research, 2020d). To this end, it seems that longer-term GHG emission reduction measures, to meet 2050 targets, require considerable changes, in particular, the use of alternative fuels for 'zero carbon', such as ammonia or hydrogen (Clarksons Research, 2020a). Also, under MARPOL responsibility, ports would need to cooperate with the IMO and play a key role in the

⁺⁺⁺ CO₂ equivalents (CO₂e) is a common unit that converts all greenhouse gas (GHG) emissions- based on global warming potential- thus signifying the amount of CO₂ which alone would have an equivalent global warming impact.

^{\$\$\$} Mt: million tons.

^{****} Technical measures, from 2023 onward, include the existing energy efficiency design index (EEXI) to enforce existing ships for technology retrofits, engine power limitations or scrapping. In addition, the operational measures introduce carbon intensity targets for ships of 5,000 gross tons and above and carbon intensity indicators (CCI), which will be calculated based on guidelines the IMO develops in the future and will become mandatory beyond 2026.

implementation of new targets, in addition to the facilitation of shipping decarbonization through the provision of alternative fuels, onshore power supplies, and automatic mooring systems, and the facilitation of virtual and just in time arrival, among others.

7. Discussion and conclusions

This study conducted an exploratory review of the COVID-19 pandemic's immediate impact on maritime ports, shipping, and supply chains, and on other aspects of the industry. In addition, we have investigated the identified global impacts in a case study of the port of Aqaba, Jordan. At the same time, the way forward for global ports, beyond the pandemic, was illustrated, based on recommendations of reviewed studies and identified global needs. This study takes a holistic approach to analyze the impact of COVID-19 from the perspective of ports, including shipping and the maritime industry and is, thereby, seen as one of the first studies that takes this approach and covers a variety of dimensions.

The impacts of the COVID-19 pandemic were classified into various spheres, then analyzed and discussed to draw out significant insights and raise awareness. The study of the vulnerabilities and immediate impacts caused by the pandemic generated insights (the study contribution) that work as lessons for future resilience against shocks such as pandemics, climate change impacts, cyber attacks or terrorism, and other crises. It is, thus, necessary that ports widen their preparedness for any future hit, and plan for required interventions.

While countries, to contain the contagion, imposed restrictions on mobility, required safety measures, closed borders, and forced entire and partial lockdowns, global efforts called for keeping goods flowing all over the world, and for minimizing the repercussions on the industry (e.g., the seafarers' crisis and cruise shipping issues, among others). The lockdowns, safety measures, and physical distancing disrupted maritime trade and affected port calls. Although shipping adjusted its capacity, and ports took measures to maintain their business, the response to the aforementioned calls, including efforts to restrain COVID-19, showed limited coordinated action, while conflicting procedures were implemented in countries and regions, which exacerbated the already growing disruption, and influenced world connectivity. On the other hand, negligence and/or not paying due diligence to maritime global conventions to facilitate trade (e.g., the Facilitation of Maritime Traffic (FAL) Convention^{††††}) risked supply chain resilience, coordination and cooperation, and national assets. Therefore, the harmonization and standardization of efforts, nationally, regionally, globally, and by sector, turn out to be key to improving maritime transport connectivity and mitigating the consequences of COVID-19. This brings about compatible safety and security requirements to cope with wide ranging operational challenges and allows the establishment of a collective agreement toward better response management.

Based on the results of the review, it appears that the dynamics of COVID-19 generated severe and unprecedented magnitudes of economic knock-on, delay, and legal and sustainability implications, and challenged the integrity and reliability of ports and of shipping and supply chains. Meanwhile, the pandemic brought to the fore the importance of ports and shipping and maritime supply chains as pillars for coping with the pandemic by the delivery of basic needs and medical tools.

Aside from the measures taken against ships, e.g., safety procedures, issues arose as barriers to shipping (delays) in the Jordanian case study; however, there was not a large impact on maritime transport and supply chains. Similar to the global trend, the port quickly adapted to the COVID-19 environment by providing various facilitation measures (digital clearance at ACT, for example). The impact was not severe, and this is attributed to the fact that restrictions were not imposed on ports - ports and logistics operations were not shut down. On the other hand, the port of Aqaba is mostly the final destination for imported cargo, with no high volume of export. We could conclude,

^{††††}[https://www.imo.org/en/About/Conventions/Pages/Convention-on-Facilitation-of-International-Maritime-Traffic-\(FAL\).aspx](https://www.imo.org/en/About/Conventions/Pages/Convention-on-Facilitation-of-International-Maritime-Traffic-(FAL).aspx)

here, that such ports, final destination ports, could be resilient contrary to large hub ports, and that countries that did not extend generalized lockdowns to ports had less impacts for maritime trade.

Importantly, this study generated manifold implications for maritime policy and decision makers. The repercussions of the pandemic sent warnings to prepare and plan for future risks and disruptions, so as to ensure that shipping, ports, and terminals function well. Therefore, recovery, along with post COVID-19 priorities, requires port policymakers and practitioners to concentrate on building risk-based plans for future similar events, such as further pandemics, climate change impacts, political issues (wars), natural disasters, cyber risks, and economic crises. By doing so, ports improve emergency responses, build capacity, minimize the risks, and consolidate the interlinkage with health departments, customs, immigration, and maritime authorities and administrations. In this way, ports maintain their resilience and boost adaptability to sudden shocks. Overall, as recommended by Notteboom and Pallis (2020a), global tracking mechanisms to monitor trends, mitigate risks, alleviate impacts, and build resilience need to be adopted. This includes the tracking of port land side operations (including logistics) and nautical services, ship-port interfaces, hinterland connections, and supply and logistics chains. By the same token, shipping companies can include risk-based plans that outline appropriate measures to be taken to safeguard a crew's rights to repatriation and changeover, among others, and maintain operations. Risk management procedures can be documented in Safety Management Systems (SMS).

Equally important, ports need to enhance multi-sector, regional, and global cooperation, collaboration, and coordination, while at same time accelerate the integration of digital technologies, in order to streamline the whole supply chain and facilitate trade and efficient operations. Data sharing with various stakeholders and ship-shore relations are deemed necessary for mitigation efforts and, thus, COVID-19 is the spark to rethink such actions. Of immediate consideration, post-COVID-19, economic recovery needs to be in harmony with inclusive, sustainable, socioenvironmental dialogues, such as the climate change mitigation - GHG emission reduction agenda. On the other hand, it is important for ports to assess what has worked and what has not and, thus, lock in and improve promising measures.

As COVID-19 unfolds, new trends may reshape and refigure setups of ports and shipping, e.g., shortened supply chains (nearshoring, reshoring) and redundancy (high inventories) (UNCTAD, 2020c), and may entail implications (challenges and opportunities) for ports and shipping. Such trends may decrease the reliance on overseas production and increase supply chain resilience (Notteboom & Pallis, 2020a). While the pandemic led to new social, institutional, economic, and management changes, some argue that it may create ruptures in port management and governance (Notteboom & Haralambides, 2020) and, thus, the need arises to address emerging gaps and challenges, whilst building on originating opportunities.

Given the fact that maritime transport is still recovering, as the world navigates out of the pandemic, this study identified impacted areas and parameters for *academicians* to consider in future research. It is highly likely that more research is needed, particularly to monitor additional consequences and focus on potential long-term impacts. Other fertile research areas are *research* on new business models to survive such crises, connection and relationships with ship-port interface, data sharing, risk-based planning, and, importantly, sustainable recovery post-COVID-19 pandemic. Notably, research needs to focus on developing countries and small island states, in addition to being conducted in cooperation with the industry (shipping and ports). Results of research should be customized in order to answer and provide evidence for policy makers, managers, owners, and operators and, thus, to ultimately increase maritime research uptake and transfer. While this exploratory review is *limited* by having an open-ended approach concerning data collection, outcomes cannot be generalized with certainty. Future research may, thus, consider other approaches for further investigation, such as a replicable systematic review and empirical research.

Acknowledgment

The authors of this article acknowledge and appreciate the constructive comments provided by the anonymous reviewers which helped in improving the whole paper.

References

- AAWA. (2016). *Remote and autonomous ships: The next step*. The Advanced Autonomous Waterborne Applications (AAWA) Initiative.
- Acciaro, M., Vanellander, T., Sys, C., Ferrari, C., Roumboutsos, A., Giuliano, G., Lam, J. S. L., & Kapros, S. (2014). Environmental sustainability in seaports: a framework for successful innovation. *Maritime Policy & Management*, 41(5), 480-500.
<https://doi.org/10.1080/03088839.2014.932926>
- Alamoush, A. S., Balini, F., & Dalaklis, D. (2020a). *Framework for port sustainable supply chain management and its contribution to the united nations' sustainable development goals* (pp. 1-23). In Proceedings of the Conference of the International Association of Maritime Economists. Hong Kong.
- Alamoush, A. S., Ballini, F., & Dalaklis, D. (2021). Port supply chain management framework: Contributing to the United Nations' sustainable development goals. *Maritime Technology and Research*, 3(2), 137-161. <https://doi.org/10.33175/mtr.2021.247076>
- Alamoush, A. S., Ballini, F., & Ölçer, A. I. (2020b). Ports' technical and operational measures to reduce greenhouse gas emission and improve energy efficiency: A review. *Marine Pollution Bulletin*, 160, 111508. <https://doi.org/10.1016/j.marpolbul.2020.111508>
- Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology*, 8(1), 19-32.
<https://doi.org/10.1080/1364557032000119616>
- BIMCO. (2020). *COVID19 portal*. Retrieved from <https://www.bimco.org/covid19>
- Clarksons Research. (2020a). *Shipping market overview*. Clarkson Research.
- Clarksons Research. (2020b). *Container freight rates surge to record highs*. Shipp. Intelligence Netw. Retrieved from <https://sin.clarksons.net/News/Article/157170#!%23sincustomhome>
- Clarksons Research. (2020c). *World shipyard monitor*. Clarkson Research.
- Clarksons Research. (2020d). *Fuelling transition: Tracking the economic impact of emission reductions & fuel changes*. Clarkson Research.
- CPHA. (2020). *Guidance on the prevention and control of COVID-19 for ports and its front line staf*. China Ports and Harbours Association.
- Devaraju, A., Chen, L., & Negenborn, R. R. (2018). Autonomous surface vessels in ports: Applications, technologies and port infrastructures. *Lecture Notes in Computer Science*, 11184, 86-105. https://doi.org/10.1007/978-3-030-00898-7_6
- Dinwoodie, J., Truck, S., Knowles, H., Benhin, J., & Sansom, M. (2012). Sustainable development of maritime operations in ports. *Business Strategy and the Environment*, 21(2), 111-126. <https://doi.org/https://doi.org/10.1002/bse.718>
- Exportvirginia. (2014). *Seaports of the world by country*. Retrieved from <http://exportvirginia.org/wp-content/uploads/2014/04/Seaports-of-the-World.pdf>
- Gekara, V. O., & Nguyen, V. X. T. (2018). New technologies and the transformation of work and skills: A study of computerisation and automation of Australian container terminals. *New Technology, Work and Employment*, 33(3), 219-233. <https://doi.org/10.1111/ntwe.12118>
- Hertog, V. D., Oscar, L., Stapleton, R., & Chris, K. (2016). *Revolutionary RAMora brings tele-operated capability to ship-handling tugs*. Retrieved from <http://seaways.net.au/wp-content/uploads/2018/07/Revolutionary-RAMora-Tug.pdf>
- Höyhty, M., & Martio, J. (2020). Integrated satellite-terrestrial connectivity for autonomous ships: Survey and future research directions. *Remote Sensing*, 12(15), 2507. <https://doi.org/10.3390/RS12152507>

- ICS. (2020). *COVID-19 related guidelines for ensuring a safe shipboard interface between ship and shore-based personnel*. International Chamber of Shipping.
- IG P&I. (2020). *COVID-19 restrictions-Online tracker*. Retrieved from <https://www.igpandi.org/covid-19>
- IMO. (2018). *MEPC/72/17/ADD.1. Resolution MEPC.304(72): Initial IMO strategy on reduction of GHG emissions from ships*. International Maritime Organization.
- IMO. (2020a). *Circular Letter No.4204/Add.6 - 27 March 2020: Preliminary list of recommendations for Governments and relevant national authorities on the facilitation of maritime trade during the COVID-19 pandemic*. International Maritime Organization.
- IMO. (2020b). *Circular letter No.4204/Add.14 - 5 May 2020: Recommended framework of protocols for ensuring safe ship crew changes and travel during the coronavirus (COVID-19) pandemic*. International Maritime Organization.
- IMO. (2020c). *Circular letter No.4204/Add.30 - 11 September 2020: Joint statement calling on all government to recognise seafarers as key workers - COVID-19 pandemic*. International Maritime Organization.
- IMO. (2020d). *Circular letter No.4204/Add.32 - 25 September 2020: ICAO Harmonized guidance on facilitating passenger flights, including repatriation flights, using public health corridors during the COVID-19 pandemic*. International Maritime Organization.
- IMO. (2020e). *Circular letter No.4204/Add.33 - 5 November 2020: Joint Statement IMO-UNWTO to support the safe resumption of cruise ship operations following the COVID-19 pandemic*. International Maritime Organization.
- IMO. (2020f). *Circular letter No.4204/Add.31 - 17 September 2020: Joint Statement on the contribution of international trade and supply chains to a sustainable socio-economic recovery in COVID-19 times*. International Maritime Organization.
- IMO. (2020g). Allow crew changes to resolve humanitarian crisis, insists IMO Secretary-General. Retrieved from <https://www.imo.org/en/MediaCentre/PressBriefings/Pages/26-Allow-crew-changes.aspx>
- IMO. (2020h). *Circular letter No.4235/Add.1 - 21 April 2020: Communication from the Government of the Hashemite Kingdom of Jordan*. International Maritime Organization.
- IMO. (2020i). *Fourth IMO GHG Study: Reduction of GHG Emissions from Ships. MEPC 75/7/15*. International Maritime Organization.
- ISS. (2020). *COVID-19 Port/ Country implications*. Inchcape Shipping Services. Retrieved from <https://www.iss-shipping.com/pages/coronavirus-port-country-implications>
- Jaakkola, E. (2020). Designing conceptual articles: Four approaches. *AMS Review*, 10, 18-26. <https://doi.org/10.1007/s13162-020-00161-0>
- Kavallieratos, G., Katsikas, S., & Gkioulos, V. (2019). Cyber-attacks against the autonomous ship. *Lecture Notes in Computer Science*, 11387, 20-36. https://doi.org/10.1007/978-3-030-12786-2_2
- Michail, N. A., & Melas, K. D. (2020). Shipping markets in turmoil: An analysis of the Covid-19 outbreak and its implications. *Transportation Research Interdisciplinary Perspectives*, 7, 100178. <https://doi.org/10.1016/j.trip.2020.100178>
- Misra, A., Panchabikesan, K., Gowrishankar, S. K., Ayyasamy, E., & Ramalingam, V. (2017). GHG emission accounting and mitigation strategies to reduce the carbon footprint in conventional port activities: A case of the Port of Chennai. *Carbon Management*, 8(1), 45-56. <https://doi.org/10.1080/17583004.2016.1275815>
- MPA. (2020). *COVID-19 protocol on crew change and repatriation of seafarers: Singapore crew change guidebook*. Maritime Port Authority (MPA) of Singapore.
- Ng, A. K. Y., Chen, S. L., Cahoon, S., Brooks, B., & Yang, Z. (2013). Climate change and the adaptation strategies of ports: The Australian experiences. *Research in Transportation Business & Management*, 8, 186-194. <https://doi.org/10.1016/j.rtbm.2013.05.005>

- Notteboom, T. E., & Haralambides, H. E. (2020). Port management and governance in a post-COVID-19 era: Quo vadis? *Maritime Economics & Logistics*, 22, 329-352.
<https://doi.org/10.1057/s41278-020-00162-7>
- Notteboom, T., & Pallis, T. (2020a). *IAPH-WPSP Port Economic Impact Barometer: Half Year Report*. World Ports Sustainability Program and International Association of Ports & Harbours.
- Notteboom, T., & Pallis, T. (2020b). *IAPH-WPSP Port Economic Impact Barometer: November Report*. World Ports Sustainability Program and International Association of Ports & Harbours.
- Notteboom, T., & Pallis, T. (2020c). *IAPH-WPSP Port Economic Impact Barometer: October Report*. World Ports Sustainability Program and International Association of Ports & Harbours.
- Notteboom, T., & Pallis, T. (2021a). *IAPH-WPSP Port Economic Impact Barometer One Year Report: A survey-based analysis of the impact of COVID-19 on world ports in the period April 2020 to April 2021, IAPH-WPSP Port Economic Impact Barometer*. World Ports Sustainability Program and International Association of Ports & Harbours.
- Notteboom, T., & Pallis, T. (2021b). *IAPH-WPSP Port Economic Impact Barometer: February Report*. World Ports Sustainability Program and International Association of Ports & Harbours.
- Notteboom, T., Lugt, L. Van Der, Saase, N. Van, Sel, S., & Neyens, K. (2020). The role of seaports in green supply chain management: initiatives, attitudes, and perspectives in Rotterdam, Antwerp, North Sea Port, and Zeebrugge. *Sustainability*, 12(4), 1688.
<https://doi.org/doi:10.3390/su12041688>
- Palmatier, R. W., Houston, M. B., & Hulland, J. (2018). Review articles: Purpose, process, and structure. *Journal of the Academy of Marketing Science*, 46, 1-5.
<https://doi.org/10.1007/s11747-017-0563-4>
- PEMA. (2016). *Container terminal automation*. Port Equipment Manufacturers Association.
- Piris, A. O., Díaz-Ruiz-Navamuel, E., Pérez-Labajos, C. A., & Oria, C. J. (2018). Reduction of CO2 emissions with automatic mooring systems. The case of the port of Santander. *Atmospheric Pollution Research*, 9(1), 76-83. <https://doi.org/10.1016/j.apr.2017.07.002>
- Poulsen, R. T., Ponte, S., & Sornn-Friese, H. (2018). Environmental upgrading in global value chains: the potential and limitations of ports in the greening of maritime transport. *Geoforum*, 89, 83-95. <https://doi.org/10.1016/j.geoforum.2018.01.011>
- Pu, S., & Lam, J. S. L. (2021). Blockchain adoptions in the maritime industry: A conceptual framework. *Maritime Policy & Management*.
<https://doi.org/10.1080/03088839.2020.1825855>
- Puig, M., Wooldridge, C., & Darbra, J. P. (2014). Identification and selection of environmental performance indicators for sustainable port development. *Marine Pollution Bulletin*, 81(1), 124-130. <https://doi.org/10.1016/j.marpolbul.2014.02.006>
- Roh, S., Thai, V. V., & Wong, Y. D. (2016). Towards sustainable ASEAN port development: Challenges and opportunities for Vietnamese Ports. *The Asian Journal of Shipping and Logistics*, 32(2), 107-118. <https://doi.org/10.1016/j.ajsl.2016.05.004>
- Schröder-Hinrichs, J. U., Hebbar, A., & Alamoush, A. S. (2020). Maritime risk research and its uptake in policymaking: A case study of the Baltic Sea Region. *Journal of Marine Science and Engineering*, 8(10), 742. <https://doi.org/10.3390/jmse8100742>
- Shipping and Freight Resource. (2020). *Survey on impact COVID-19 on supply chains*. Retrieved from <https://shippingandfreightresource.com/supply-chain-strategies-post-COVID-19-impact-survey>
- Splash. (2020). *Yara Birkeland tipped to launch late next year*. Retrieved from <https://splash247.com/yara-birkeland-tipped-to-launch-late-next-year>

- Stebbins, R. A. (2001). *Exploratory research in the social sciences, qualitative research methods*. SAGE Publications, Thousand Oaks, CA.
<https://doi.org/https://dx.doi.org/10.4135/9781412984249>
- Swedberg, R. (2020). *Exploratory research* (pp. 17-41). In Elman, J. G., & Mahoney, J. (Eds.). *The Production of Knowledge*. Cambridge University Press.
<https://doi.org/10.1017/9781108762519.002>
- Thomas, A. (2003). *Research skills for management studies, research skills for management studies*. Routledge, New York. <https://doi.org/10.4324/9780203006146>
- Torres, P. L., & Marriott, R. de C. V. (2009). *Handbook of research on collaborative learning using concept mapping*. Information Science Reference, Hershey. <https://doi.org/10.4018/978-1-59904-992-2>
- UN Global Compact. (2020). *COVID-19 task force on geopolitical risks and responses*. UN Global Compact.
- UNCTAD. (2019a). *Review of maritime transport 2019*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2019b). *Digitalization in maritime transport: Ensuring opportunities for development*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2020a). *Review of maritime transport*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2020b). *Ports in the fight against COVID-19*. Retrieved from <https://tft.unctad.org/ports-covid-19/> (accessed 11.17.20).
- UNCTAD. (2020c). *Impact of the COVID-19 pandemic on trade and development: Transitioning to a new normal*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2020d). *Covid-19: A 10-Point action plan to strengthen international trade and transport facilitation in times of pandemic*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2020e). *How countries can leverage trade facilitation to defeat the Covid-19 pandemic*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2020f). *Digitalizing the port call process - Transport and trade facilitation series no 13*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- UNCTAD. (2021). *COVID-19 and maritime transport impact and responses: Transport and trade facilitation series No. 15*. In Proceedings of the United Nation Conference on Trade and Development, Geneva, Switzerland.
- United Nations. (2015). *Resolution A/RES/70/1, Adopted by the General Assembly on 25 September 2015, Transforming our World: The 2030 Agenda for Sustainable Development*. United Nations.
- Wilhelmsen. (2020). *COVID-19 global port restrictions map*. Retrieved from <https://www.wilhelmsen.com/ships-agency/campaigns/coronavirus/coronavirus-map>
- Wilmsmeier, G. (2020). *Climate change adaptation and mitigation in ports: Advances in Colombia* (pp. 133-150). In Ng, A. K. Y., Monios, J., & Jiang, C. (Eds.). *Maritime transport and regional sustainability*. Elsevier. <https://doi.org/10.1016/b978-0-12-819134-7.00008-3>
- WPSP. (2020a). *World ports COVID19 information portal*. Retrieved from <https://sustainableworldports.org/world-ports-covid19-information-portal>
- WPSP. (2020b). *WPSP COVID-19 guidance document for ports*. World Ports Sustainability Program.
- Yap, W. Y., & Lam, J. (2020). *Data analytics for international transportation management*.

Research in Transportation Business & Management, 34, 100470.

<https://doi.org/10.1016/j.rtbm.2020.100470>

Yin, R. K. (2014). *Case study research design and methods*. 5th ed. Sage. Thousand Oaks, CA.

[https://doi.org/ISBN 978-1-4522-4256-9](https://doi.org/ISBN%20978-1-4522-4256-9)