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Impact of the COVID-19 pandemic disruptions on container transport

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ABSTRACT
The COVID-19 pandemic caused unprecedented disruptions in the global economy, and container transport as a predominant means of the goods flow in global supply chains. Different measures employed worldwide to limit the virus spread, such as restrictions and quarantines on border crossings, port staff, container ships, transhipment terminals and the inland transport sector, created a colossal management challenge and caused a domino effect in delays. Consequently, it led to blank sailings and enormous rises in freight transport prices, the lack of supply reliability and shifts between different means of transport. These delays, enhanced by the Suez Canal blockage, exacerbated an already acute problem of the empty container shortage in the market. This paper aims to provide an in-depth overview of the COVID-19 pandemic's impact on container transport and underline ways to increase resiliency against future disruptions. The research included a literature overview and formulation of recommendations. The paper contributes to the broad research of container transport management and provides insights for practitioners responsible for transport planning and disruption management.

KEY WORDS
container transport, pandemic, COVID-19, Suez Canal, empty containers, blank sailing

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Introduction

Container transport has a leading position in the carriage of goods as it enables their seamless transfer to different transportation modes. The standardisation of containers and their compatibility with transhipment equipment ensures the fast and undisturbed flow of goods. The increase in consumption and globalisation turns container transport into a dynamically developing field. The tendency to build increasingly larger containerships (over 23000 TEU)

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pressurises ports and transhipment terminals to increase their efficiency (Pesch & Kuźmicz, 2020). Some predictions insist that by 2030, considering the current infrastructure of port terminals, ports in Asia, Western Europe and Oceania will possibly operate under conditions extremely close to their capacity limits and in many cases, they will be unable to manage the container flow (Digiesi et al., 2019).

However, 2020 and 2021 brought unforeseen disruptions, and logistics managers met unprecedented challenges. Although problems accumulated by the pandemic were often familiar, they rose in large numbers and scales, unearthing the issues in need of urgent attention.

The pandemic of the infectious disease, COVID-19, caused by the coronavirus SARS-CoV-2, started in November 2019 in Wuhan city in central China and was declared a pandemic by the World Health Organization (WHO) on 11 March 2020. The disease spread to all continents, affecting nearly 248 million people, with over 5 million deaths (Worldometers, 2021). The pandemic disrupted people's lives globally, affecting the world's economy, trade and transport. Internationally, measures have been taken to prevent the spread of the infection. Travel has been restricted, and quarantines and curfews were imposed. Some countries closed their borders or introduced restrictions on border traffic. The pandemic continues, but steps are being taken to restore the economy to its pre-pandemic state gradually. Container transport is closely linked to the developments in the global economy, production and consumption. As such, container port analysis can provide useful insights into underlying macroeconomic trends. During the first 31 weeks of 2020, container vessel port calls varied by region. Globally, container ship calls started to fall below 2019 levels around week 12 (mid-March 2020) and gradually recovered around week 25 (third week of June). These timelines correspond to the beginning of the pandemic. The gradual recovery since June reflects the easing out of lockdowns in some countries (UNCTAD, 2021a).

According to UNCTAD (2021a), the number of shipping services, weekly port calls, shipping operators, deployed container ships capacity and direct calls declined because of the different pandemic rates (Table 1).

The coronavirus spread in China, causing factory stoppages and, finally, downtimes at ports. In combination with the Chinese New Year celebrations, which influence delays in production and delivery on a regular basis, the full-scale delays became very disruptive. The expectation at the beginning of the pandemic was that container transport would experience a sharp fall; however, eventually, as people were staying at home due to restrictions, the demand was supposed to increase due to redecorations, the purchase of electronics, furniture, etc. Later, the lessening of the restrictions caused another rise in the third quarter of the year 2020. The increased demand and delays in transportation resulted in a sharp increase in container transport rates. The lowest relative increase of container freight rate was recorded on the Asia-East coast North America route (+63 %), from China to South America, 443 % higher than the median for this route (UNCTAD b). The justification is that ships

Tab. 1. Percentage change of shipping connectivity components between Q1 & Q2 2020 – Q1 & Q2 2019 in major container ports in developed countries

	Shipping Services		Weekly Port Calls		Shipping Operators		Max TEU capacity		Deployed Capacity		Direct Calls	
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
Los Angeles	↓	↓	↓	↓	↓	↓	-	↑	↓	↓	↑	↓
Long Beach	↑	↓	↑	↓	↑	↓	↑	↑	↑	-	↑	↑
NY&NJ	↑	-	↑	-	-	↑	-	↑	↑	↑	↓	↓
Rotterdam	↓	↓	-	↓	↓	↓	↑	↑	↑	↓	↓	↓
Antwerp	↓	↓	↓	↓	↓	↓	↑	-	-	↓	↓	-
Hamburg	-	↓	-	↓	↓	↓	-	↑	-	↓	↓	↓
Bremerhaven	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓
Piraeus	-	-	-	↓	-	↑	-	-	-	↓	-	↓
Felixstowe	↑	↑	↑	↑	-	↑	↑	↑	-	↑	↑	↑
Marsaxlokk	↓	↓	↓	↓	-	↓	↑	↑	↓	↓	↓	↓
Melbourne	↓	↓	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓
Sydney	↓	↓	↓	↓	↓	↓	↑	↑	-	↑	↓	↓

Memo ↓ $R < -2\%$ -- $-2\% \leq R \leq +2\%$ ↑ $R > +2\%$

Source: (UNCTAD, 2021a).

and containers were engaged longer on lengthier routes. The rise of containerised freight rates is presented in Fig. 1.

This paper presents the broad spectrum of the pandemic's impact on container transport (Fig. 2). The most important discussed aspects include the shortage of empty containers, blank sailings, disruptions in ports and inland transport, increase in prices in many domains, the lack of reliability of supplies, shifts between transport modes and production delays. These problems have been exacerbated by the Suez Canal blockage. The paper is concluded with the

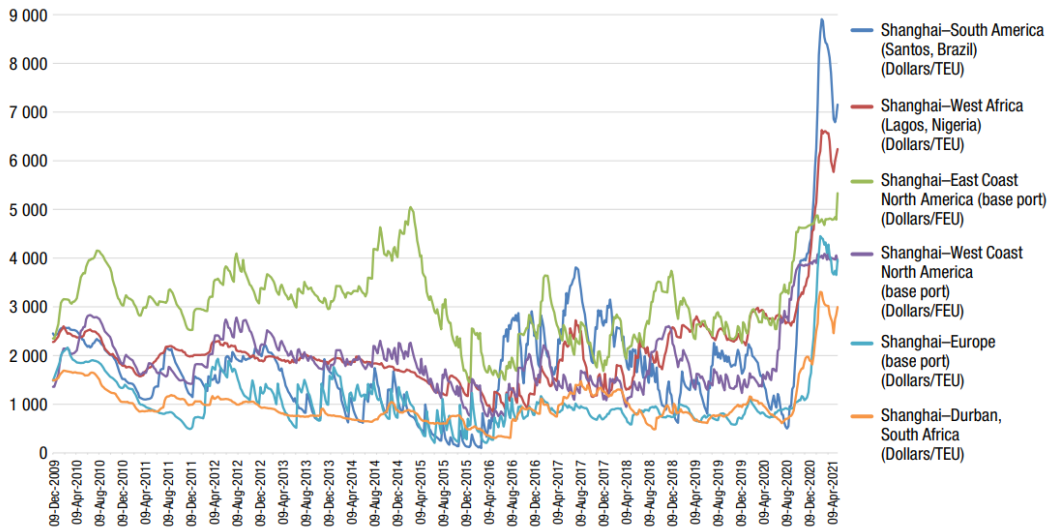

Fig. 1. Rise of containerised freight rates (UNCTAD calculations based on data from Clarkson Research Shipping intelligence Network Time Series)
Source: (UNCTAD, 2021b).

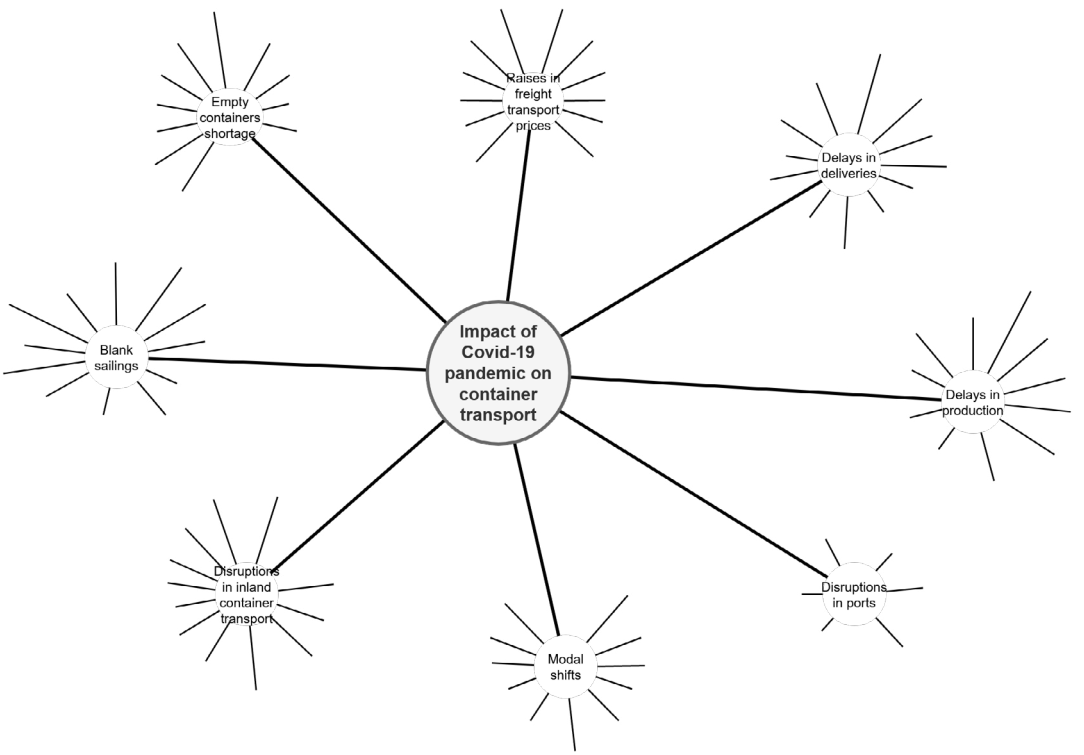

Fig. 2. Spectrum of the pandemic influence on container transport

analysis of the crucial areas needing development to ensure higher resiliency of the container supply chain in the future from two perspectives: customers and transport providers.

1. The areas of the influence of the pandemic on container transport

The pandemic exacerbated the persistent problem of intermodal transportation, namely, empty container management. The relocation of empty containers is a topical issue in scientific research. Kuźmicz and Pesch presented an in-depth study of the problem and approaches to its modelling (Kuźmicz & Pesch 2017; Kuźmicz & Pesch, 2019). The global trade imbalance and the predominance of export or import oriented regions result in the imbalance in container availability. Export-oriented regions, such as China, lack empty containers to be filled with exported goods, whereas import-oriented regions, such as many of the EU countries, receive many full containers but do not have the potential to fill them with products to be exported. This results in the problem of empty repositioning of containers or keeping them and waiting for future demand. The empty container problem is essentially their transportation cost which is close to the cost of full containers.

Empty containers do not generate revenues and are rarely filled with low priority goods, such as paper for recycling, metal or electronics rubbish or other waste that was frequently shipped from Europe to Asia in the past (Kuźmicz & Pesch, 2019). The imbalance of containers shipped in both directions, Europe–Asia, is clearly visible in Table 2.

The difference between supply and demand and ship utilisation in both directions is significant. The demand is nearly double westbound, which clearly explains the problem of empty container imbalance.

The storage of empty containers in a port also involves labour and equipment (cranes, straddle carriers, AGVs, reach stackers, front stackers, etc.). Minimising container movements is not only an issue of cost reduction as it also contributes to the reduction in congestion at and around seaports and inland container terminals and limits detrimental effects to the environment.

The domino effect of delays in maritime transport, ships stacked in waiting at ports under quarantines, reduced staff and safety precautions, and isolated ship crews resulted in a dramatic shortage of empty containers since they were trapped in the prolonged maritime and inland transportation. There was also a shortage of containerships.

All vessels in appropriate technical condition were used. The rise in demand also resulting from the pandemic caused massive disturbances at ports and in inland-bound transport. Ships had to wait for about 10–14 days before being allowed to enter the port.

Hapag Lloyd reported that in January 2021 alone, their ships were 170 hours late on average on the most frequented Far East routes, while on trans-Pacific routes, delays reached 250 hours on average (DW, 2021).

As a result of all delays, carriers introduced blank sailing, i.e., skipping port calls (UNCTAD, 2021a) and not picking up containers at ports. The transportation preference of full to empty containers is a common practice, but under these critical circumstances, blank sailings exacerbated the empty container shortage.

Tab. 2. Asia–North Europe: estimated monthly supply/demand of containers

Period	Supply (thousands of TEU)		Demand (thousands of TEU)		Ship utilisation (%)	
	Westbound	Eastbound	Westbound	Eastbound	Westbound	Eastbound
Sept.2017	917	674	818	407	89%	60%
Oct. 2017	922	679	742	419	80%	62%
Nov. 2017	919	670	731	436	80%	65%

Source: (Drewery Maritime Research, 2021).

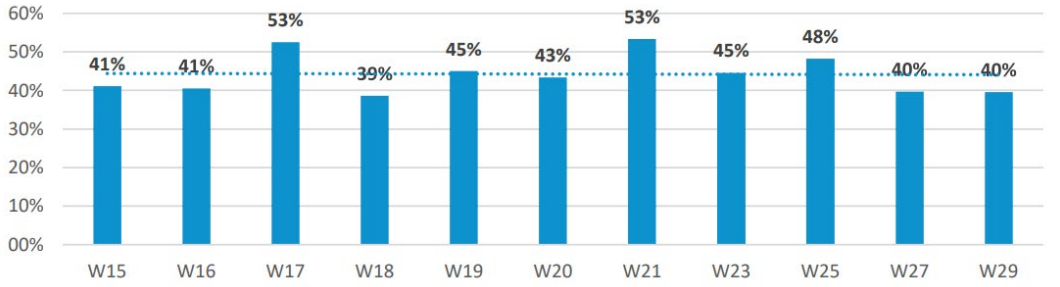

Fig. 3. Percentage of ports touched by blank sailing in 2020
Source: (UNCTAD, 2021a).

In the first half of 2020, there was a fall of 3.5 % of container ship calls in comparison with the corresponding period from the previous year. Since the declaration of the pandemic by WHO, container ship calls worldwide were 5.8 % below the level during the same period in 2019 (UNCTAD, 2021a). According to the IAPH-WPSP COVID-19 Economics Impact Barometer, at least 40 % of container ports worldwide have experienced blank sailings each week since March 2020 (Fig. 3). For example, on the Asia-United States trade route, blank sailings reached 19 % in May 2020 (which means that 47 out of 249 calls were blanked).

Blank sailings cause significant consequences in especially big container ports, such as peaks in ship-to-ship and yard-to-ship operations as well as labour disturbances due to being overworked on some days followed by several days off-duty (UNCTAD, 2021a).

The repositioning of empty containers was experiencing significant disturbances globally. As a consequence of the empty container shortage for export, prices per container underwent a sharp increase.

Another reason for the empty container crisis was their prolonged keeping hinterland. The problem was exacerbated by COVID-19 restrictions in inland transport, measures taken at the border crossing, shortages of drivers, and staff issues at intermodal terminals. Pandemic problems among importers also contributed to prolonging the return of empty containers to the system.

The blockage of the Suez Canal from 23 until 29 March 2021 by the big container ship Evergiven carrying over 18300 containers, was another pivotal factor affecting empty container management. The containers trapped on this ship but also those blocked on all the ships queuing at the entrance to the Canal and later waiting in lines in the ports to be transhipped, reduced the global fleet of available containers significantly. Ships from China or India had to sail around Africa to reach Europe. Considering that about 50 large ships pass through the Canal every day and that as much as 13 % of all global trade, including 30 % of global container traffic, passes through the Canal, the blockage had critical consequences. At that time, the cost of transporting a container has risen from USD 1 500 before the pandemic to USD 8 000–10 000 (Russon, 2021). This resulted in the price rise not only for containers on the route passing through the Suez Canal but on nearly all routes. Large rises on long routes were explained by higher employment on a weekly basis, so more containers were stocked there. Therefore, in the light of a dramatic shortage of containers, importers in this area had to pay not only for the transportation of a full container but also for the inventory cost of an empty container.

Due to the blockage, container ships and tankers were not delivering food, fuel and production components to Europe, and European goods could not have been exported to the Far East. Additional charges were introduced, such as equipment imbalances and/or congestion charges and temporary storage payments. The other consequences followed: longer handling times, increased demurrage charges and port congestions caused by hundreds of delayed ships to be served. Those delays had a severe impact on production companies. They faced a difficult dilemma: wait for their order, organise alternative transport by land or make a new order with an alternative transport route. The natural decision was to shift to rail, and this again resulted in the lack of empty containers and space available on the trains. In the case of certain types of loads or transportation corridors, this phenomenon of the modal shift (from maritime to rail transport) continues.

2. Effect on Eurasian transport

The development of container transport is also stimulated by various bilateral agreements and initiatives to expand intermodal corridors, such as China's One Belt One Road (OBOR) project. Many countries along the route connecting Asia to Europe were very interested in active participation in this initiative, expecting benefits in terms of investment, infrastructure expansion and future benefits from the development of trade and transport in the area. The OBOR idea embraces the development of land and maritime transportation corridors linking Asia and Europe.

Many of the projects under OBOR are performed in developing countries where the control of the pandemic is weak because of the slow vaccination process. Therefore, there is a significant delay in the implementation of the projects. The long-term impact of the pandemic on OBOR can be complex. There are major problems with financial viability as banks decide not to proceed with funding.

The main source of OBOR funding is the Chinese development banks, the Silk Road Fund, the New Development Bank and the Asian Infrastructure Investment Bank. Since the long-term profitability of the projects is threatened, the continuation of the financing is questionable. In China, the priority is set on the restoration from the pandemic crisis and investments in the domestic market (Wu et al. 2020).

China, as the "world's factory", is the global leader in container and bulk transport, with almost half of the global growth in maritime trade in the last decade. In 2018, China's maritime imports were estimated to be a quarter of the world's maritime trade. In this context, the outlook for this trade is highly dependent on the Chinese economy. It is difficult to foresee the extent to which the COVID-19 pandemic and the ambiguities surrounding the pandemic outbreak in China, and the circumstances of its global spread would cause reluctance to cooperate with China or to purchase Chinese products. The consequences for trade and transport in this respect can only be assessed over time.

The pandemic exposed the weakness of long supply chains and dependence on Asia. Some companies looked for more secure alternatives for their future. The OBOR partner countries focused on fighting the pandemic, limiting the spread of the virus and supporting health care, which resulted in less attention to infrastructural investments. Therefore, the development of intermodal infrastructure on the OBOR route has been hampered.

3. Measures to build-up resilience

The global impact of the COVID-19 pandemic proved beyond any doubt that measures have to be taken to improve the resilience of supply chains and, consequently, container transport. The two relevant terms referring to the situation are resilience and vulnerability. Resilience describes the capability of dynamic systems to positively react to disruptions, whereas vulnerability pertains to the capability to react negatively (Chen et al., 2018). Berle et al. (2011) and Chen et al. (2018) indicated that resilience deals with the consequences of hazards after their occurrence. Increasing a system's resilience should reduce its vulnerability. One aspect of the problem is the resilience and vulnerability of supply chains with the perspective of safe distribution and diversification of suppliers, which is the responsibility of enterprises. The other side is the resilience and vulnerability of ports and container terminals to provide smooth operation despite unexpected events.

The scale of the COVID-19 pandemic disruptions was difficult to foresee, and it brought attention to the solutions making the supply chains more reliable and resilient. Since container transport is a result of global trade, these two perspectives of entrepreneurs providing trade exchange should also be considered (Table 3).

The topic of shortening the supply chains and reducing the dependence on Chinese production returned. The UNCTAD experts indicate three areas important for the future preparation for further disruptions (UNCTAD, 2021a):

- facilitation and digitalisation of trade;
- tracking and tracing;
- competition in maritime transport.

The need to reduce the physical contact and paper documentation triggered the acceleration of digitisation solutions. In a broader sense, the value of digitalisation and even further digital transformation became clearly visible. Although tracking maritime traffic has been a vibrant field for development, much needs to be done in this respect. Providing a robust solution for empty container repositioning remains

Tab. 3. Implications affecting container transport resilience

Importers, exporters	Ports, container terminals and depots
analysis and redesign of supply chains, deglobalisation, awareness of all triers of suppliers	digitisation, digitalisation, digital transformation, limitations of personal contact and paper documentation
more attention brought to risk management	intensified efforts to provide robust solutions for tracking and tracing
advancement of technology use, digitisation and digitalisation	automatisation, application of drones, advanced analytics, internet of things, digital twins, blockchain, virtual reality and augmented reality
higher responsibility of supply departments organising transport, high competences and market knowledge as well as flexible reaction to disruptions needed	investment in advanced tools optimising terminal operations with consideration of mega container vessels on one side and limited resources (human, equipment, yard) on the other side; resilience to big differences in peak and non-peak periods caused by disruptions such as the pandemic

a challenge due to the low transparency of the process, not including all containers in computer systems and insufficient tracking. The pandemic has shown how varied is the level of information technology used in ports. New realities forced terminals to exchange data with new stakeholders in a faster and more transparent way. Communication had to take place between the company and emergency services, local communities, the media or, to a greater extent, with employees. The information about infections, changes in terminal operations, delays, congestion, etc., has to be distributed on time. An important aspect of this process is also to educate employees about changed working rules, restrictions, sanitary rigour or procedures related to the detection of infection. This challenge is particularly demanding for operators with a low level of digitalisation. In this light, even greater importance is placed on the recommendation of Szymczak et al. (2018) on data integration implementation within the information structure of the whole supply chain.

Many local hubs, especially in developing countries, have often failed to keep up with the achievements of modern technology. Only 49 of the 174 Member States of the International Maritime Organization have fully functioning Port Community Systems, which are considered the cornerstone of any port in the current digitalised business (World Ports Sustainability Programme, 2020). They rely on the physical exchange of documents between ships, land carriers and the port. This exposes employees to infections. It also raises an additional problem. The low level of digitisation means that a company has less potential to reorganise work to an online mode in critical periods. Realising the urgent need for digitisation, the International Association of Ports and Harbors (IAPH), BIMCO, the International Cargo Handling Coordination Association (ICHCA), the International Chamber of Shipping (ICS), the International Harbour Masters' Association (IHMA), the International Maritime Pilots Association (IMPA), the International Port Community Systems Association (IPCSA), the International Ship Suppliers' Association (ISSA), the Federation of National Associations of Ship Brokers and Agents (FONASBA) and the PROTECT Group provide a joint effort to accelerate digitisation in the port sector, especially support development in emerging technologies, such as artificial intelligence, advanced analytics, internet of things, digital twins, robotics process automation, autonomous systems, blockchain, virtual reality and augmented reality.

Automatisation of operations in big container terminals with few staff members proved to increase resilience and maintain the terminal's undisturbed functioning during the pandemic due to little required personal contact. Automatisation provides the physical flow of containers in the terminal by means of automatic cranes and automatic guided vehicles (AGV), as well as assures real-time data transmission. Technologies allow real-time decision-making based on both current and historical data. This helps synchronise all elements of the terminal operation and reduces the reaction time needed to make decisions. Another interesting aspect of automatisation is the use of aerial vehicles (UAVs) or

aerial drones, limiting human interaction and reducing the exposure of people to risks (Otto et al., 2018). In container terminals, drones are already used for inspections of cranes, yards, work safety and container security.

An inspiring example of using drones for transportation is presented by Wang et al. (2022). In this paper, the problem is modelled as the Piggyback Transportation Problem, where an autonomous driving vehicle carries drones or delivery robots. This study refers to Amazon's last-mile concept and the flying warehouse, which launches drones, and upon their return to an earthbound depot, they are resupplied to the flying warehouse by an air shuttle. This solution could also be applied for autonomous or non-autonomous ships or vehicles from where drones carrying containers are distributed to difficult-to-reach or pandemic-affected places. It allows for the distribution without berthing to the port. Drones carrying containers have already been tested by the port of Hamburg (HHLA, 2021). Hamburger Hafen und Logistik AG (HHLA) can be perceived as a leader in drone application in the field, providing advanced software and a drone control centre.

The shortage in containers and ship supply capacity is attributed mainly to the disruptions caused by the pandemic, but it should be observed that national competition authorities should monitor freight rates and market behaviour (UNCTAD, 2021a). Policymakers should strengthen national competition control authorities in the area of maritime transport and ensure that they provide the necessary regulatory oversight.

The pandemic proved that diversification of supply chains to a broader array of locations and not limited to one source or one region provides safety and resilience. Moreover, transparency of a supply chain should be ensured to make companies aware of where their supplies of all tiers are located. While

corporations know who they directly purchase from (their tier 1 suppliers), they often can lack transparency about their second- and third-tier suppliers and beyond (Cybersecurity and Infrastructure Security Agency, 2020). Long and complex supply chains, e.g., the dependency on Chinese suppliers, have proved to be risky. The delays caused by the pandemic as well as the Suez Canal blockage brought attention to a higher responsibility of supply departments organising transport. It was their task to maintain production at their enterprises unstopped, which caused a big pressure on staff members. It proved how high competences, market knowledge and flexible reaction to disruptions are needed to provide supplies on time in such critical situations.

Conclusions

The pandemic brought changes in transport mobility patterns, reversing some trends (Kuźmicz et al., 2022; Kiryluk et al., 2021). The indirect effects of the pandemic, including the reduced availability of transport, showed how quickly nature restored when humans stopped for a moment, proving that sustainability is not just a buzzword but a necessity. In this sense, paradoxically, the pandemic also had some positive impacts. One such example is the influence on the environment. According to Rothengatter et al. (2021), the CO2 emissions were reduced worldwide by 6.3% in 2020 compared with 2019. They indicated that the transport sector was responsible for about 25 % of emissions and that the strict lockdown measures contributed to the reduction of CO2 emissions, particularly, in the first quarter of 2020, due to a reduction in the overall traffic activity.

Čurović et al. (2021) performed a time comparative analysis of shipping traffic, meteorological conditions, and noise emissions from the port. The number of ships decreased in the analysed period by 35 %, and the noise levels during the night decreased by 2.2 dB to 5.7 dB. The results showed that moored ships and industrial activities were the most dominant source of noise and should, therefore, be regulated internationally.

However, the study results by Liu et al. (2021) showed that the ship emissions in ports increased by an average of 79 % because of the prolonged turnaround time in port. It is important that most ship emissions occurred during the extended staying time at berth and anchorage areas due to longer operational times caused by the pandemic. According to the investigation, the increases ranged from 27 to 123 % in the total emissions across ports, with container ships and dry bulk carriers reaching the highest pollutants, increasing by an average of 94–142 % compared with 2019.

Such observations made during the pandemic should lead to constructive changes for the future, and efforts should be made to enhance solutions to protect the environment and provide resilience to the business. The research of Ketudat and Jeenanunta (2021) pointed to key factors that resulted in the

resilience of logistics during the pandemic: flexibility, a business continuity plan, diversified market, IT systems, and leadership.

The developing megatrend of deglobalisation in response to the pandemic and shortening supply chains may influence container transport. The throughput of container terminals of ports, huge container vessels carrying over 23000 TEU and condensed traffic accumulating all kinds of delays due to the pandemic unearthed issues in urgent need of efficiency increase. Since port space is scarce in most parts of the world, the field is open for smart management using scientific achievements to optimise processes, improve forecasting and optimally schedule resources (Kuźmicz & Pesch, 2019; Tekil et al., 2022).

The pandemic appeared to be a strong signal (Ejdys, 2017) that such events would repeat. The COVID-19 pandemic comes in waves, and currently, high infection rates in China applying the zero-tolerance policy for COVID-19 result in big delays in factories and ports. This shows that measures have to be taken to provide a fast response to repeatable disruptions. Experts predict future pandemics and natural disasters resulting from climate change, which should motivate managers to be prepared for a new reality of transport and supply chain management. The war in Ukraine since February 2022 also proved that measures preventing disruptions in transport are pivotal. This paper thoroughly investigated the pandemic impact on container transport and offered recommendations for strengthening the resilience from two perspectives: (1) importers and exporters and (2) container terminals and depots. The key outcomes for entrepreneurs point to the analysis and redesign of supply chains towards deglobalisation, increasing awareness of all triers of suppliers, focusing on risk and disruption management supported by high advancement of technology solutions, digitisation, digitalisation (for increased effectiveness and the reduction of physical contact between employees) and higher responsibility and flexibility for departments responsible for the supply chain management. The port and terminals should increase efforts for digitisation and digitalisation, automatisation, and use of drones, and intensify efforts in providing robust solutions for tracking and tracing. Unavoidable is an investment in advanced tools optimising terminal operations considering mega container vessels on one side and limited resources on the other. A managerial insight points to the resilience in work organisation and big differences in peak and non-peak periods caused by disruptions, such as the pandemic.

Future research should embrace the development of models and algorithms providing robust solutions concerning processes in ports, container terminals and depots, resilient to big differences in numbers of containers processed in periods of accumulated work and those times with limited flows caused by delays, congestions and disruptions in transportation. Redesign of supply chains towards deglobalisation is another important direction of research, which is likely to become an intensive field of scientific investigation and practical development.

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