

An aerial photograph of a busy port at dusk or dawn. The water is a deep blue, and the sky is a mix of purple, pink, and orange. Numerous large cargo ships are anchored in the harbor, some with their cranes raised. In the background, there are hills and a city skyline. The overall scene conveys a sense of a congested and active maritime hub.

PORT CONGESTION AND DELAYS: HOW ARE PORTS ADDRESSING AND MANAGING THEM?

ALG

January 2025



Port congestion has emerged as one of the most pressing challenges in global maritime logistics, with far-reaching implications for trade, the economy, the environment, and customer satisfaction. As international trade continues to grow, ports serve as critical nodes in the global supply chain, managing the movement of goods between production and consumption hubs. However, congestion at these key points disrupts the smooth flow of goods, creating ripple effects that extend beyond the port gates.

The impacts of port congestion are multifaceted. In economic terms, persistent congestion reduces the competitiveness of ports, forcing shipping lines to seek more efficient alternatives and leading to a decline in local trade and investment. This not only affects port revenues but also the broader economic ecosystem, as ports often function as vital economic hubs for surrounding regions. Strategically, congestion has led to the exploration of alternative shipping routes, such as the Northern Sea Route (NSR), which, despite its challenges, offers a potential shortcut to avoid bottlenecks such as the Red Sea and the Cape of Good Hope. These adaptations highlight the maritime industry's ongoing efforts to navigate the complexities of modern shipping.

From an environmental perspective, port inefficiencies contribute to increased carbon emissions and air pollution due to the prolonged idling of ships and trucks. These results underscore the urgency of addressing congestion to align with global sustainability goals.

Furthermore, customer experience and market dynamics are deeply affected, as delays erode trust and damage the reputation of companies that rely on on-time deliveries.

With over 30 years of experience in the maritime and logistics sectors, ALG has supported port operators, terminal managers, and port authorities worldwide in tackling congestion and improving operational efficiency. By combining deep industry expertise with cutting-edge analytical tools, ALG provides tailored solutions that help mitigate bottlenecks, enhance productivity, and future-proof port operations. Our commitment to innovation and sustainability ensures that we deliver value-added strategies to optimize performance, helping our clients meet the challenges of an evolving global supply chain landscape.

Efforts to address port congestion encompass several strategies, including infrastructure development, digitalization, policy reforms, and international collaboration. As ports tackle increasing cargo volumes, aging infrastructure, and emerging risks such as climate change, finding innovative and sustainable solutions is more critical than ever. This paper delves into the causes, impacts, and potential strategies to address port congestion, emphasizing the need for adaptive, collaborative, and technology-driven approaches to ensure the resilience of global trade networks.

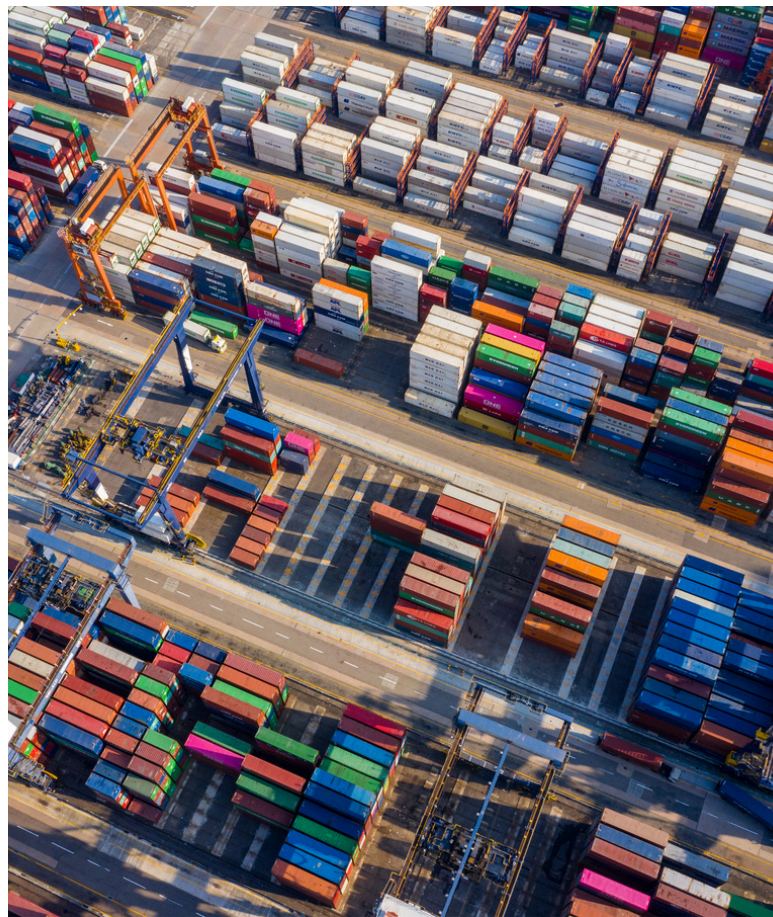
ROOT CAUSES OF PORT CONGESTION AND DELAYS

Surge in global demand for goods and container shortages

With economies rebounding post-pandemic, there's been a sharp increase in global consumer demand, especially for e-commerce and durable goods. This unprecedented surge has overwhelmed many ports, which are not equipped to handle such high volumes of cargo in a short span. That was the case of Los Angeles and Long Beach Ports (USA) which, handling around 40% of U.S. imports, faced historic congestion in 2021-2022 due to surging demand. At one point, over 100 ships were queued up waiting for berths. The combination of consumer demand and inefficiencies led to delays of up to three weeks for ships to unload cargo.

The demand growth has been linked with an imbalance between the availability of containers and cargo demand has contributed heavily to congestion. Containers are often stuck at ports or inland depots due to slow unloading, creating bottlenecks that cascade through the entire shipping system.

The global container shortage that started in late 2020 continues to affect port operations. As containers piled up in North America and Europe, Asian exporters, particularly in China and Southeast Asia, faced delays in securing containers to ship goods, further slowing down port turnaround times.



Increased vessel sizes

Modern shipping trends have shifted toward larger vessels to enhance efficiency and reduce costs. However, not all maritime infrastructure is adapted to the increasing vessel's dimensions as many of them were built some time ago. For the case of port terminals, many of them are not equipped to handle these mega-ships, resulting in longer unloading times and increased congestion. One recently affected port has been Jeddah Islamic Port (JIP), which experienced a surge in traffic as ships were diverted to unload or refuel. This influx overwhelmed JIP's handling capacity, causing delays and creating shortages of key goods throughout the Gulf and beyond.

Similarly, in 2024, Singapore's container port faced severe congestion, with berthing wait times extending up to a week. The delays were driven by a 22% surge in cargo volumes between January and May, compounded by the rerouting of vessels to avoid Red Sea attacks. These examples underscore the challenges ports face in accommodating the growing size and volume of modern shipping vessels.

Another notable instance of how larger vessels can strain maritime infrastructure was the grounding of the Ever Given, one of the world's largest container ships, in the Suez Canal in March 2021. The incident blocked the canal for six days, halting global trade and causing estimated losses of \$9 billion per day. This disruption threw global shipping schedules into chaos, leading to widespread port congestion and delays worldwide.





Infrastructure and labour shortages

Another significant contributor to port congestion is the infrastructure limitations and operational inefficiencies present in many ports around the world. Despite technological advancements, some ports still rely on outdated infrastructure, lack the ability to handle mega-vessels, or face bottlenecks in their inland logistics networks, such as trucking and rail systems. These issues are compounded by a shortage of skilled labor, particularly in key roles like crane operators, truck drivers, and warehouse workers.

In late 2021, the Port of Felixstowe, the largest container port in the UK, struggled with congestion primarily due to labor shortages, lack of truck drivers, and operational inefficiencies. Container dwell times increased significantly, with some reports indicating that containers sat at the port for up to 10 days, compared to the usual 2-3 days. Felixstowe's limited capacity to handle the growing number of mega-vessels also contributed to slow processing, leading to vessel diversions to other European ports like Rotterdam and Antwerp.

Geopolitical tensions and security threats

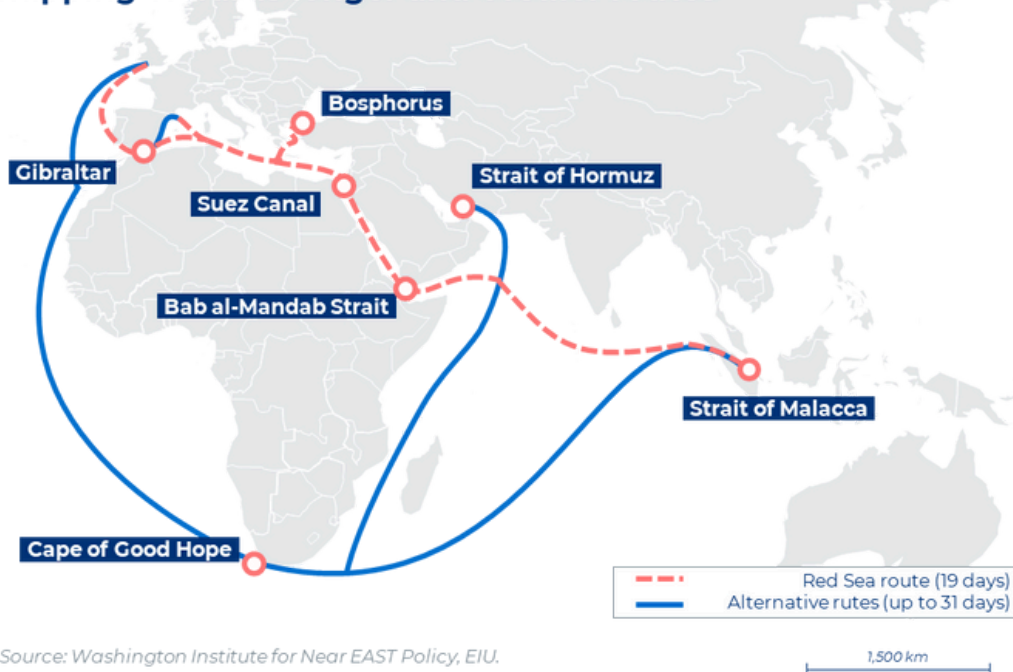
Ports in politically sensitive regions often face delays and disruptions due to geopolitical tensions, military conflicts, or security threats. These factors can affect the movement of goods and lead to operational slowdowns or complete shutdowns of critical port infrastructure.

The Red Sea and Suez Canal region, vital to global trade routes, has been facing significant disruptions due to geopolitical tensions and security concerns. The Yemeni Civil War has affected the operations of key Yemeni ports like Hodeidah, while the Bab-el-Mandeb Strait has seen security threats from piracy and military confrontations. Recent escalations, including piracy threats and civil unrest, have made certain routes and ports less safe, leading to delays as ships are rerouted or forced to anchor further offshore.

Due to the tensions in the Red Sea, commercial vessels were rerouted to the Cape of Good Hope, leading to a near doubling of vessel transits in the region and a 75% increase in trade volume. The increase in the distance traveled via the Cape of Good Hope resulted in extended transit times, disrupting sailing schedules and compromising service reliability, ultimately leading to delays.

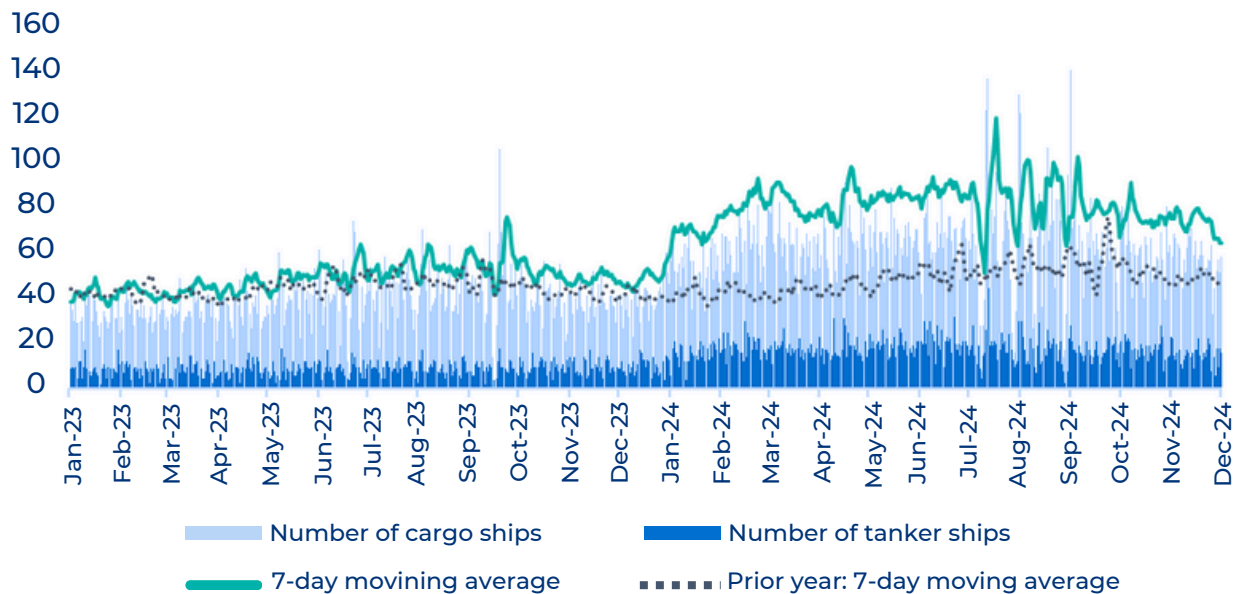
For instance, a journey from Singapore to Rotterdam would encompass 11,755 nautical miles if redirected via the Cape of Good Hope, in contrast to the usual route through the Suez Canal, covering 8,288 miles. That implies 10 additional days. Rerouting via the Cape of Good Hope incurs additional fuel costs of up to \$1 million for each round trip between the Far East and North Europe, and contributes to heightened carbon emissions (50% increase in CO2 emissions for a South Asia – Europe route).

Houthi attacks in Red Sea are driving commercial shipping towards longer and costlier routes



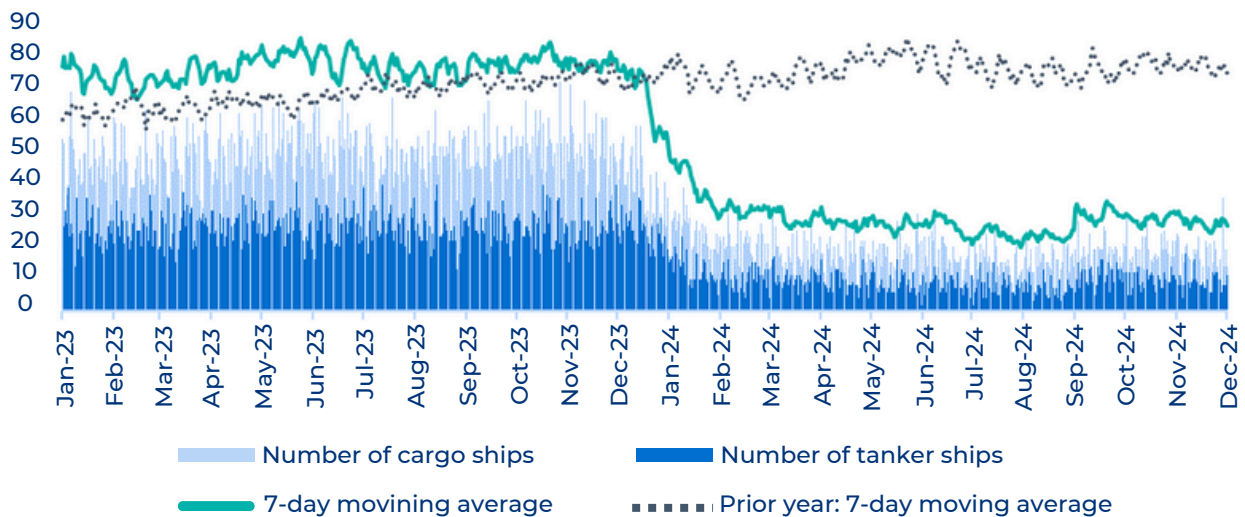
The number of ships navigating the Suez Canal in 2024 has decreased significantly compared to previous months. At the same time, the Cape of Good Hope has seen a marked increase in daily transits, particularly during 2024, as shown in the figures below.

Cape of Good Hope daily transits



Source: PortWatch, 2024

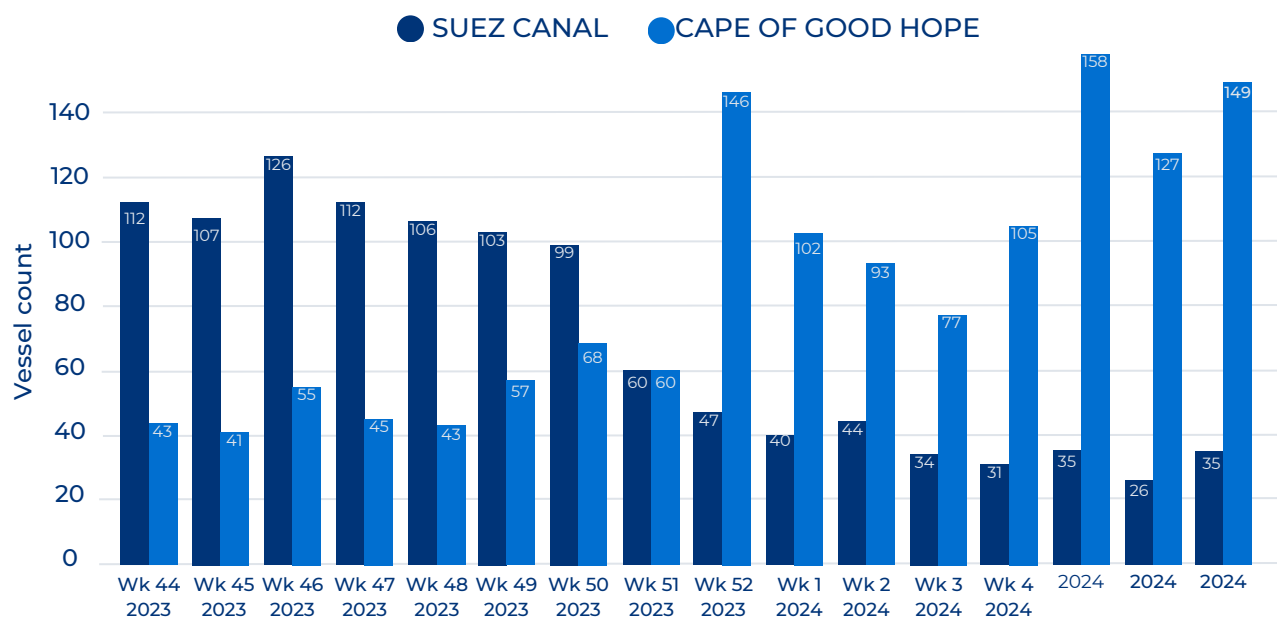
Suez Canal daily transits



Source: PortWatch, 2024

Container ships saw the heaviest drop in traffic through the Suez Canal, with the second week of February seeing only 26 vessels crossing in either direction. On the other side, container Ship traffic via the Cape totaled nearly 160 vessels in the first week of February – a 222.4% increase over the weekly average preceding the R Sea crisis.

WEEKLY CONTAINER SHIPS TRAFFIC



Source: Global Maritime Hub, 2024

The changing in major sea trade routes also lead to changes in some ports of call: the rerouting by the Cape of Good Hope has opened an opportunity for other ports, however, African ports on this route have greater limitations in terms of infrastructure and size of vessels they can serve compared to ports situated along the Europe-to-Asia route through the Red Sea, adding to the delays.

The Port of Djibouti, a critical regional hub, has seen increased congestion as vessels avoid unsafe ports in Yemen. Ships rerouted from Yemen have strained Djibouti's limited capacity, creating backlogs as the port struggles to process the additional volume.

The Red Sea Crisis highlights the intricate web of factors that contribute to port congestion and delays in one of the world's most vital maritime regions. From geopolitical risks and infrastructure deficiencies to surging global demand and pandemic-related challenges, the pressures on Red Sea ports are multifaceted. The ripple effects of these disruptions are felt globally, underscoring the need for coordinated efforts to modernize ports, improve security, and streamline logistics across the region.

Disruptions in inland logistics networks

Port efficiency is heavily reliant on the smooth flow of goods through inland logistics networks such as trucking, rail, and warehousing. When these networks face disruptions, ports experience congestion as cargo accumulates without the means for prompt inland distribution. Factors like labor shortages, trucking capacity constraints, and regulatory bottlenecks exacerbate delays and congestion.

The U.S. inland logistics system, especially the trucking sector, faced severe disruptions in 2021-2022, contributing significantly to port delays. A shortage of truck drivers, estimated to be over 80,000 drivers, hindered the movement of goods from ports to inland destinations. This shortage, coupled with increased cargo volumes, resulted in longer dwell times for containers at ports and bottlenecks at intermodal terminals. Rail congestion further compounded these issues, especially in Chicago, where gridlock at rail yards exacerbated delays for goods moving across the country.

Regulatory and custom delays

Customs clearance procedures and additional regulatory checks can sometimes cause bottlenecks, especially when shipping routes cross multiple jurisdictions. Ports dealing with complex or inefficient customs processes are more prone to congestion.

In Lagos, customs delays and regulatory bottlenecks have consistently been cited as a major reason for the port's congestion. Inefficiencies in clearance processes and lack of digitization have often resulted in lengthy delays for importers and exporters.

Another example is the Port of Felixstowe, the UK's largest container port, where the implementation of post-Brexit customs procedures led to significant traffic delays. Complex documentation requirements and the need for additional checks caused processing bottlenecks. Containers experienced dwell times of up to 10 days, far exceeding the usual 2-3 days and many shipments were diverted to European ports like Rotterdam and Antwerp.



Extreme weather events and climate change

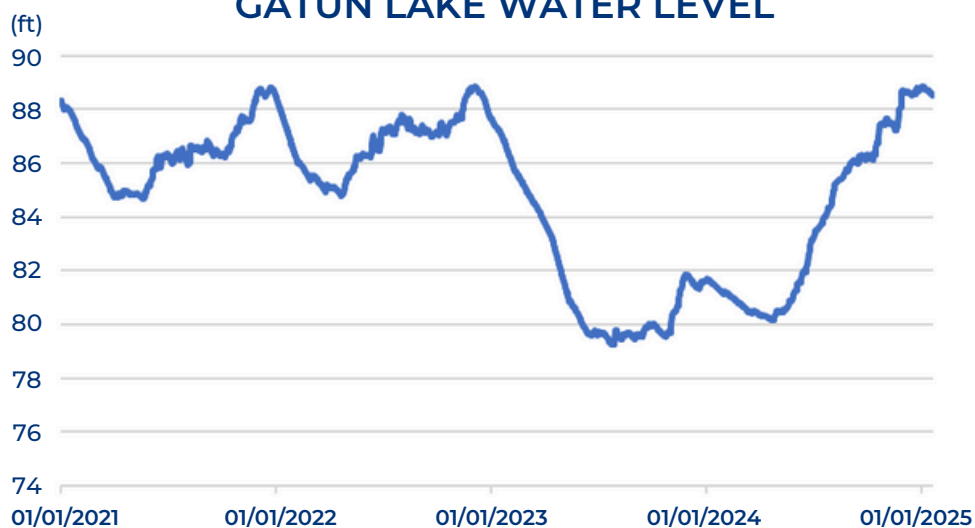
Increasingly frequent extreme weather events, such as hurricanes, floods, and typhoons, driven by climate change, have been another source of disruption. Ports are particularly vulnerable to these events, which can result in the closure of facilities, damage to infrastructure, and delays in cargo handling.

This is the case of the decrease in the water level of Lake Gatun that occurred in the Panama Canal in 2023, severely affecting maritime traffic, and the case of the east coast of the United States, where there are predictions of an above-normal 2024 Atlantic hurricane season, where warmer-than-average ocean temperatures are major drivers of tropical activity, increase the risk of longer downtimes and the resulting port congestion.

In July 2021, Typhoon In-Fa hit the eastern coast of China, forcing the Ningbo-Zhoushan Port, the world's third-largest container port, to shut down for several days. The storm caused extensive flooding, disrupted port operations, and led to significant cargo backlogs. This incident, combined with ongoing COVID-19-related disruptions, resulted in widespread delays and ripple effects across global supply chains.



GATUN LAKE WATER LEVEL



Source: Autoridad del Canal de Panama

IMPACT AND CONSEQUENCES OF PORT CONGESTIONS

Port congestion can have significant repercussions across various sectors. The effects are felt not only by the ports themselves but also throughout the supply chain and the broader economy. Here are some key impacts:

1. OPERATIONAL IMPACTS

Port congestion directly disrupts port operations and the efficiency of logistics networks, creating significant challenges for shipping lines, port authorities, and land transport systems.

Increased waiting times

The most obvious sign of port congestion is the increase in waiting times for vessels and trucks. Ports globally have seen higher waiting times, which cause disruptions in scheduling and overall efficiency.

One of the most relevant examples can be seen in African ports, with Durban port being one of the most affected in the region. As of December 2024, Durban port has reached a dwell time of 11.3 days on average for combined anchor and berth time, driven by the redirection of vessels around the Cape of Good Hope in South Africa amid the ongoing Red Sea crisis. This issue has been further exacerbated by operational challenges and persistent equipment shortages.

Delays and rerouted shipping caused by the Red Sea crisis have had widespread repercussions, particularly at Singapore port, which has emerged as the global epicenter of the resulting backlogs. Similar bottlenecks are also surfacing in other major Asian and European ports.

With vessels taking longer routes around Africa, shipping timetables are being disrupted due to missed sailing schedules and reduced port calls, especially for container cargo. Consequently, larger volumes of containers are being unloaded into primary transshipment hubs such as Singapore, where cargo is redistributed onto smaller feeder vessels for final delivery. This practice has led to a buildup of containers in Singapore and other hubs, significantly increasing the number of vessels waiting at anchorages. As of November 2024, the average waiting time for a container ship to berth in Singapore stands at three to four days, with peak waiting times in October and November reaching up to nine days, a sharp rise compared to the typical half-day wait seen in earlier periods.



Operational inefficiencies

Port congestion often leads to increased labor costs, as extended operational hours and overtime for dockworkers and other personnel become necessary to manage the backlog of shipments. These additional expenses can strain port budgets and raise the overall cost of operations.

At the same time, congestion creates challenges in resource allocation, as port authorities may struggle to distribute manpower, equipment, and space efficiently during peak periods. This can lead to further inefficiencies, reducing the port's overall productivity and slowing down the handling of goods.

Together, these issues underscore the financial and operational strain that congestion places on port authorities and stakeholders, highlighting the need for better planning and improved resource management to mitigate such challenges.

Logistical challenges

Congestion at ports can create significant bottlenecks that disrupt the entire supply chain, leading to widespread inefficiencies in inventory management and logistics planning. When goods are delayed at ports, businesses face challenges in maintaining adequate stock levels, fulfilling orders, and optimizing their operations. These disruptions complicate logistics strategies, forcing companies to adapt quickly to unexpected delays.

Additionally, port congestion often results in a backlog of cargo trucks waiting to pick up or deliver containers, placing increased pressure on land transport systems. This can cause severe traffic congestion on surrounding roadways, further straining local infrastructure and compounding delays.

The combined effects of these issues highlight the critical need for improved port efficiency and better coordination across the supply chain to minimize disruptions and maintain smooth operations.



2. ECONOMIC IMPACTS

Port congestion has a direct effect on shipping companies' finances, local economies, and global trade.

Economic losses

Port congestion can substantially increase costs for shipping companies. Delays often lead to extra charges for extended berthing times, higher fuel consumption from idling or rerouting, and potential penalties for late deliveries. These expenses ripple through the supply chain, complicating logistics and raising prices for businesses and consumers.

In the first half of 2024, global shipping costs surged, driven by unprecedented disruptions in major maritime routes and rising operational expenses. Key chokepoints, such as the Red Sea, Suez Canal, and Panama Canal, experienced significant delays, causing heightened freight rate volatility. Increased shipping distances, higher fuel consumption, and rising insurance premiums have created a "perfect storm" of financial pressures.

The impact is evident in the Shanghai Containerized Freight Index (SCFI), a benchmark for global shipping rates. By mid-2024, the SCFI had more than doubled compared to late 2023. On the Shanghai–South America route, the average rate soared to \$9,026 per twenty-foot equivalent unit (TEU) between January and July 2024, the highest level since September 2022.



Freight rate hike: Shipping prices resurge amid Suez and Panama Canal disruption

Comprehensive Index of the Shanghai Containerized Freight Index, October 2009–October 2024



Source: UN Trade and Development (UNCTAD), based on data provided by Clarkson Shipping Intelligence Network, 20 October 2024

Reduced competitiveness

Ports that consistently face congestion risk losing their appeal to shipping lines and businesses, which may choose more efficient competitors to avoid delays and disruptions. This shift can lead to a decline in the volume of trade and investment at the congested port, impacting its overall economic viability.

Furthermore, reduced port activity can have a significant ripple effect on the local economy. Ports often serve as major economic hubs, supporting a range of jobs and industries that depend on smooth port operations. When activity slows, the resulting decrease in trade can lead to job losses, reduced income for local businesses, and a general downturn in economic growth for the surrounding community.

Exploration of new and more efficient routes: The Northern Sea Route case

Port congestion has forced many shipping companies to reconsider their traditional routes, leading to the exploration of new, more efficient alternatives. As global shipping faces unprecedented disruptions—ranging from delays caused by port congestion to unpredictable geopolitical issues—rerouting vessels has become an essential strategy to ensure timely deliveries. However, rerouting, particularly around bottlenecks like the Red Sea or the Cape of Good Hope, often results in longer shipping times, increased fuel consumption, and higher operational costs.

In response to these challenges, companies are looking toward new maritime routes that promise time savings and reduced congestion. One such route is the Northern Sea Route (NSR), which offers a potential shortcut between Northern Europe and the Far East. While it holds the promise of reducing transit times by up to 35% compared to the Suez Canal, its commercial use still faces significant challenges. Limited accessibility due to ice conditions, extreme weather, and its seasonal availability pose significant risks to its widespread adoption. Despite these hurdles, the increasing interest in the NSR reflects the broader push toward finding more efficient ways to navigate the complexities of global shipping in an era of heightened uncertainty and disruption.



Source: Bekkers, Francois and Rojas-Romagosa (2016).

Several commercial trial voyages have been conducted over the years to explore the potential of the Northern Sea Route (NSR). In 2013, the "Yong Sheng," a vessel from COSCO Shipping Group, became the first Chinese cargo ship to navigate the NSR. In the summer of 2015, the same ship completed a full NSR voyage, arriving at Tianjin Port without the assistance of an icebreaker. This journey not only saved valuable shipping time but also significantly reduced fuel and icebreaking pilot fees.

Another notable example is Maersk's "Venta Maersk." In September 2018, this container feeder, with a capacity of 3,600 TEUs and 600 reefer plugs, completed a full transit of the NSR. Despite this achievement, Maersk's Chief Technical Officer stated that the company does not currently see the NSR as a viable alternative to other east-west routes due to its limited availability—being passable for only about three months each year. However, this could change as conditions evolve.

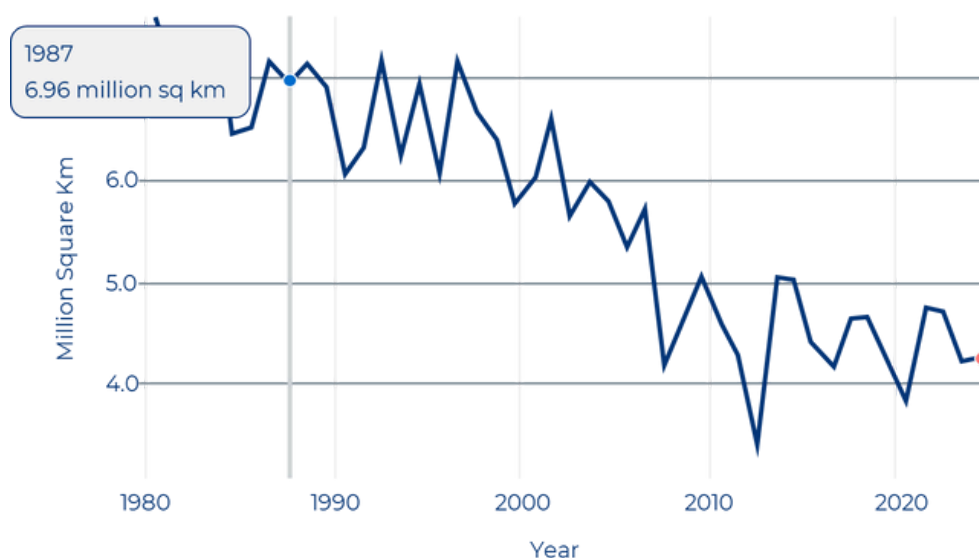
In the context of global warming, the receding Arctic Sea ice is steadily increasing the potential for year-round navigation along the NSR.

NASA's Vital Signs offers a graph depicting the annual minimum extent of Arctic Sea ice each September since 1979. This data highlights the shrinking ice cover, which influences the navigability of the NSR.

Amid uncertainties in the Red Sea zone, Russia has also sought alternatives for its shipping routes from Western and Asian ports. On July 30, 2024, the Russian shipping company Sovcomflot initiated Northern Sea Route transport for crude oil. This route, open for oil shipments from July to October each year, will transport Russian Urals crude oil to Asia.

In addition, two Chinese container ships have used the NSR as a new Arctic route to bypass the Red Sea zone and the lengthy detour around the Cape of Good Hope. These vessels, which sailed from Taicang Port and Rizhao Port near Shanghai, aim to establish a more efficient international shipping route. Their final destination is Arkhangelsk Port in northwestern Russia, from where they will continue on to other ports in the Baltic Sea.

While navigation along the NSR currently faces many limitations, it is emerging as a promising alternative. Its growing traffic, potential to shorten navigation times, and ability to bypass congested regions like the Red Sea and the Cape of Good Hope demonstrate its increasing viability in the future.



Arctic Sea Ice Minimum Extent
Source: NASA Vital Signs
<https://climate.nasa.gov/vital-signs/arctic-sea-ice>

3. ENVIRONMENTAL IMPACTS

Port congestion has significant environmental consequences, primarily in terms of increased carbon emissions and air pollution.

Increased carbon emissions

Delays at ports can have a considerable environmental impact, primarily due to the increased idling of ships and trucks that occurs during congestion. When vessels are forced to wait for extended periods to berth, and trucks linger for longer times to load or unload cargo, fuel consumption rises significantly, leading to higher carbon emissions and air pollution.

These emissions not only harm air quality in the surrounding areas but also contribute to the broader issue of climate change. Such outcomes run counter to the shipping industry's ongoing efforts to enhance sustainability through cleaner technologies and more efficient operations. The environmental toll of these delays underscores the importance of addressing port inefficiencies to minimize their ecological footprint and support global sustainability goals.

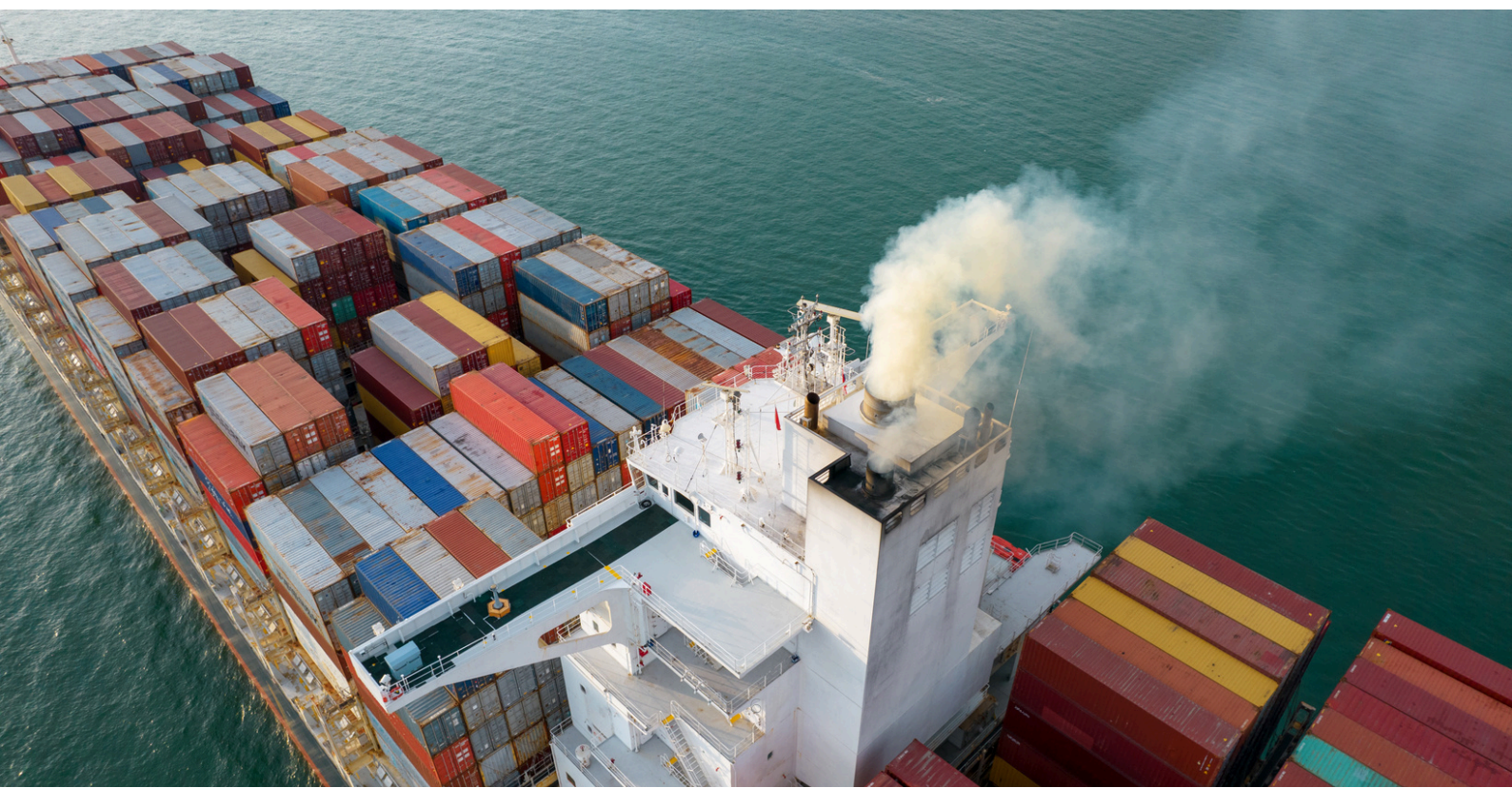
4. CUSTOMER AND MARKET IMPACTS

Port congestion also has profound consequences for customer satisfaction, brand reputation, and market dynamics.

Customer dissatisfaction

Delays in shipments can have a profound impact on end-users, often leading to frustration and dissatisfaction among customers. When products fail to arrive on time, businesses risk losing customer trust and loyalty, which can ultimately result in a loss of future sales.

This is especially critical for companies that rely on prompt deliveries, such as e-commerce retailers, where timely fulfillment is a key component of their business model. Prolonged delays not only damage customer relationships but can also harm a company's reputation, making it harder to retain existing clients or attract new ones. For businesses operating in highly competitive markets, such disruptions can have long-lasting negative effects on their brand image and overall success.



ADDRESSING THE ISSUE

Tackling port congestion has become a priority for numerous ports worldwide which are continuously working to increase flexibility, improve efficiency, and develop different solutions to deal with future scenarios that could arise. Addressing the issue is critical for the efficiency of global trade, economic impact, and supply chain stability. Different port authorities and port operators around the world are continuously working on implementing solutions through a variety of innovative strategies to tackle port congestion with different levels of success. Many of these solutions are focused on technology, infrastructure, and improved coordination across the supply chain, as shown below.

Improvement of infrastructure and port equipment

Increasing port capacity through infrastructure investments, including new terminals, improved berths, and upgraded equipment, is crucial in reducing congestion, particularly for ports handling increasing cargo volumes due to larger container ships and global trade surges.

As vessels continue to increase in size, ports frequently need to enhance their infrastructure to accommodate this growth in capacity. This typically involves investing in dredging and modifications to berth structures to accommodate larger vessel's drafts and heavier quay handling equipment. Hence, rehabilitation of aging infrastructure can be an effective solution for accommodating larger ships and increasing the capacity of the port. For more information, check out the following article: [Rehabilitation of Aging Maritime Infrastructure](#).

Deepening and widening of shipping channels and berths is another crucial infrastructure improvement. With the aim to improve operational efficiency and reduce congestion, especially during peak trade periods, Jeddah Islamic Port (Saudi Arabia) built two 16 meter deep and 1,100 meter long berths at the multi-cargo terminals to accommodate large bulk grain carriers.

Optimizing the port layout by creating specialized areas for specific types of cargo (e.g., containers, bulk, breakbulk) can help speed up the handling process and avoid congestion.

Investing in modern cargo handling equipment is crucial as well. Automated stacking cranes, rail-mounted gantry cranes, and automated guided vehicles significantly boost container handling speeds and efficiency. For example, the Port of Hamburg's Container Terminal Altenwerder employs advanced automation to achieve some of the fastest container handling times globally.

Finally, establishing inland and dry ports can alleviate congestion at seaports by relocating certain operations inland. The Virginia Inland Port in Front Royal, USA, functions as an intermodal container transfer facility, helping to reduce pressure on the Port of Virginia while offering more efficient access to inland markets.

Port of Los Angeles & Long Beach (USA):

In response to the 2021-2022 congestion due to the surge in global demand, both ports have invested heavily in expanding their infrastructure. Long Beach's Middle Harbor Terminal is a state-of-the-art, semi-automated facility designed to handle ultra-large vessels with higher efficiency. Additionally, the Port of Los Angeles has focused on deepening its berths, allowing larger vessels to dock and reducing the backlog of ships waiting to offload.

Port of Felixstowe (UK): Felixstowe Port has addressed congestion by expanding its rail network and increasing the capacity for rail freight, reducing truck traffic and easing bottlenecks in the port. The port has also upgraded its cranes to handle larger vessels and improve loading/unloading speeds, ensuring smoother cargo flows even during peak periods.

Port of Hamburg (Germany): To tackle congestion, the Port of Hamburg has implemented several infrastructure upgrades, including the Expansion of the Deepwater Port and enhancements to its rail and road connections.

Singapore Port has been implementing an ambitious development plan called the Next Generation Tuas Port Project since 2015 when reclamation works of phase 1 started. Port operations at Tuas Port Phase 1 will have 21 deep-water berths that can handle 20 million TEUs annually when fully operationalized in 2027. The project, when fully developed in four phases, will be the world's single-largest container port capable of handling up to 65 million TEUs annually, planned and developed as a resilient port. This project will consolidate container port activities and will increase efficiency in port operations due to the elimination of inter-terminal haulage.



Tuas Port Project. Source: Maritime & Port Authority of Singapore (MPA), 2024.

When planning a port expansion to increase capacity, adopting a flexible and adaptive approach is essential for the success of the project. This flexibility allows the port to respond to shifting trade patterns, economic fluctuations, evolving environmental requirements, and regulatory changes. It also helps in managing uncertainties and risks, ensuring the port stays relevant, competitive, and resilient in the face of future challenges.



Adaptation and development of resilient infrastructure in the face of climate change events

With climate change-related phenomena on the rise, adaptation and resilient infrastructure development have become critical to safeguarding communities and ecosystems. This involves designing and implementing structures that can withstand extreme weather conditions, such as stronger storms, flooding, and rising temperatures.

Resilient infrastructure incorporates advanced materials and engineering techniques that enhance durability while integrating flexible systems that can be quickly adjusted in response to changing conditions. By prioritizing these adaptation strategies, ports can mitigate damage, reduce recovery costs, and ensure long-term sustainability, ultimately improving their ability to thrive despite the uncertainties of a changing climate, preventing extended downtimes, and contributing to reducing associated congestion.

Extended gate hours and appointment systems

The increase in sea transport and the arrival of megaships has led ports to get large-volume operations concentrated in peaks of work that put loads of pressure on terminals and land transport. It is now common to find ships on the scale of more than 18,000 TEUs at main European ports and these can generate more than 6,000 moves concentrated in peaks of just a few hours.

Faced with volumes of this magnitude, ports are increasingly extending gate hours and implementing gate appointment systems to manage the flow of trucks and avoid bottlenecks at terminals. By spreading truck movements across off-peak hours, ports can alleviate congestion and improve overall efficiency. Some examples of these solutions can be found in these ports:

- **Port of Los Angeles:** During the congestion crisis in 2021, the Port of Los Angeles introduced 24/7 gate operations to accommodate surging imports and reduce the buildup of trucks. This shift to round-the-clock operations helped alleviate peak-time congestion and optimized resource allocation.
- **Port of Antwerp (Belgium):** Antwerp has implemented a Truck Appointment System (TAS) that requires trucks to schedule their arrival times at container terminals. By regulating the flow of trucks into the port, Antwerp has been able to balance terminal workloads and reduce queuing times, leading to smoother terminal operations.

Digitalization and automation of port operations

One of the most effective ways to combat congestion is through the digitalization of port operations. Automation, real-time tracking systems, and predictive analytics can optimize cargo handling, reduce wait times, and streamline communication between stakeholders. Some examples of this technologies applied to ports are:

Automated systems: Automated guided vehicles (AGVs), automated stacking cranes, and robotic systems can significantly enhance container handling speeds and reduce human error. These systems allow for faster loading and unloading processes, decreasing congestion at terminals.

Real-time data sharing: Implementing platforms that facilitate real-time data exchange among shipping lines, terminal operators, and logistics providers allows for better visibility into port activities. This transparency helps all parties plan more effectively, reducing wait times for vessels and trucks.

As one of the most advanced ports globally, Port of Rotterdam has fully embraced digitalization. The port's PortXchange platform provides real-time data on vessel arrival times, berth availability, and weather conditions. Through the use of Artificial Intelligence (AI) and predictive analytics, the port can anticipate traffic and allocate resources more efficiently. Rotterdam's fully automated container terminals, such as the APM Maasvlakte II, reduce human error, increase cargo throughput, and drastically minimize vessel idle time.

Port of Singapore has taken a lead in adopting automation and digital port solutions. The port's Next-Generation Port initiative focuses on increasing automation, such as using Automated Guided Vehicles (AGVs) for container movement, enabling seamless cargo transfer.

Integrated port community systems (PCS) allow for seamless communication between all stakeholders involved in port operations, from customs to freight forwarders. This integration minimizes bottlenecks and ensures that all parties are aligned, reducing delays.

Predictive analytics: Utilizing predictive analytics helps ports anticipate demand fluctuations and optimize resource allocation. By analyzing historical data and current trends, ports can make informed decisions about staffing, equipment usage, and infrastructure needs.

Extended gate operations: Digital solutions can facilitate 24/7 gate operations, allowing for the continuous flow of trucks and containers. Appointment systems help regulate the flow of vehicles, minimizing congestion during peak hours.

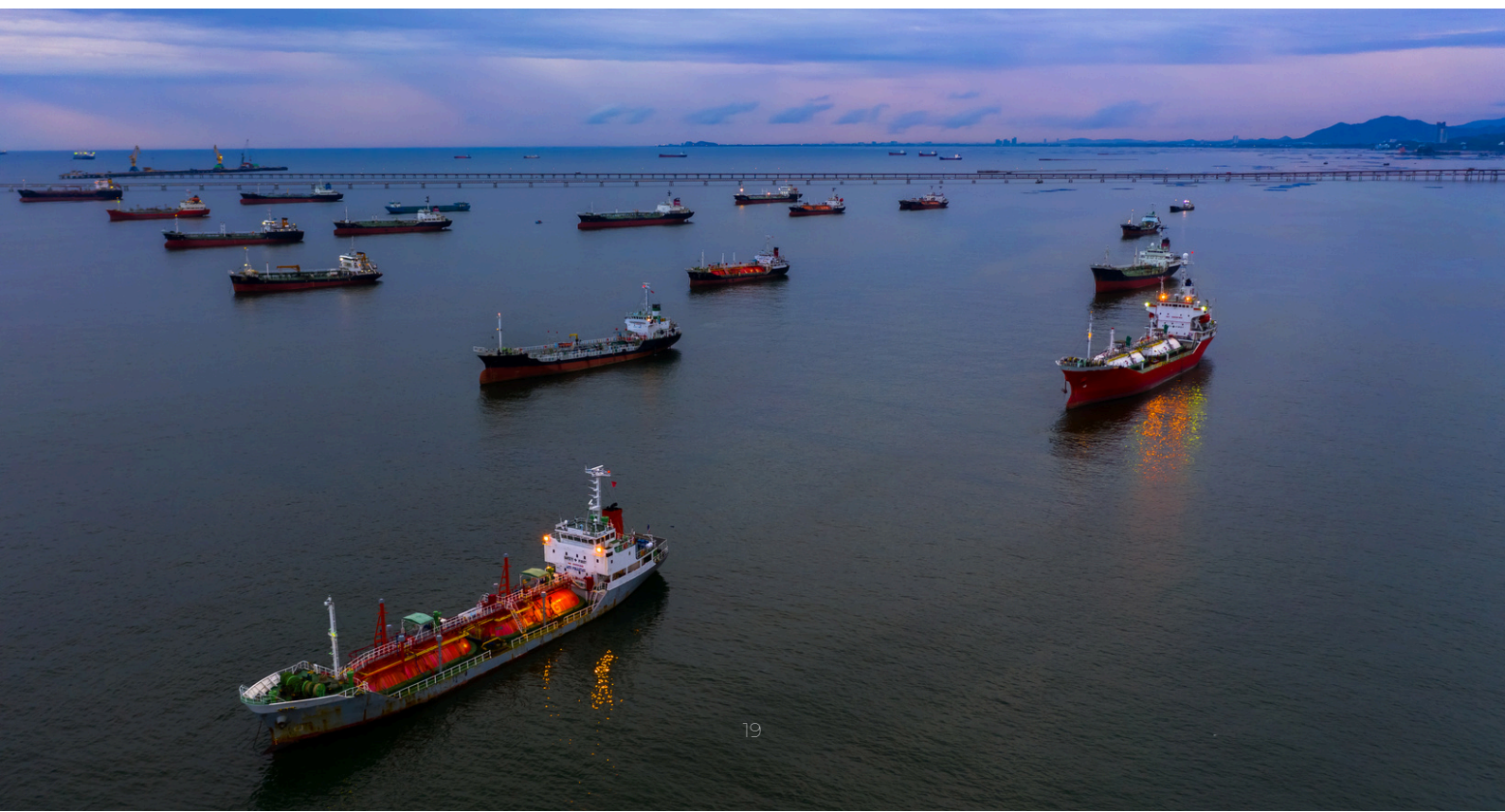
In addition, the Singapore Maritime Data Hub (SG-MDH) leverages big data and IoT to connect all port actors and enhance visibility across the supply chain. These advancements have helped the port handle significant cargo volumes efficiently while minimizing delays.

Digitalization and automation are transformative forces in the maritime sector, offering effective solutions to reduce congestion and delays at ports. By embracing these technologies, ports can enhance operational efficiency, improve cargo handling, and maintain competitiveness in an increasingly complex global trade environment. For more information regarding the revolutionary [impacts of AI in maritime operations](#) check the following article.

CHALLENGES AND FUTURE OUTLOOK

The increase in congestion is a reality affecting ports all around the world to a greater or lesser extent. There are several factors that produce and accentuate current port congestions, including increased transported volumes, global events, and climate change effects, among others. The Red Sea crisis caused by Houthi attacks has been the most relevant event with global repercussions, severely affecting ports located on the route that links Asia and Europe through the Suez Canal. To avoid Red Sea, ships are looking for alternative routes, such as the longer detour through the Cape of Good Hope, impacting dwell times and port rates.

Different efforts are being made to tackle the congestion issue, however, there are ports where congestion and delays still persist despite efforts to address them. Among the main challenges facing ports, managing growth while maintaining environmental and operational sustainability has become particularly relevant in recent years. In this sense, the need for constant innovation, collaboration, and investment to effectively address these challenges has become a priority for different port authorities and port operators.



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