

# Managing disruptions in the maritime industry – a systematic literature review

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Received 7 September 2021  
Revised 5 December 2021  
Accepted 21 December 2021

## Abstract

**Purpose** – This paper presents a systematic review of the literature in the domain of maritime disruption management, upon which future research framework and agenda are proposed. Two review questions, i.e. the measures that are employed to manage disruptions and how these contribute to resilience performance, were pursued.

**Design/methodology/approach** – The systematic literature review procedure was strictly followed, including identification and planning, execution, selection and synthesis and analysis. A review protocol was developed, including scope, databases and criteria guiding the review. Following this, 47 articles were eventually extracted for the systematic review to identify themes for not only addressing the review questions but also highlighting future research opportunities.

**Findings** – It was found that earlier studies mainly focused on measures, which are designed using mathematical models, management frameworks and other technical support systems, to analyse and evaluate risks, and their impacts on maritime players at the levels of organisation, transport system and region in which the organisation is embedded. There is, however, a lack of research that empirically examines how these measures would contribute to enhancing the resilience performance of maritime firms and their organisational performance as a whole. Subsequently, a Digitally Embedded and Technically Support Maritime Disruption Management (DEST-MDM) model is proposed.

**Research limitations/implications** – This review is constrained by studies recorded by the Web of Science only. Nevertheless, the proposed research model would expectedly contribute to enhancing knowledge building in the specific domain of maritime disruption management and supply chain management overall while providing meaningful managerial implications to policymakers and managers in the maritime industry.

**Originality/value** – This research is perhaps one of the first studies which presents a systematic review of literature in maritime disruption management and proposes a future research framework that establishes the link between disruption management and resilience and organisational performance for empirical validation.

**Keywords** Disruption management, Maritime industry, Maritime supply chain, Systematic literature review  
**Paper type** Research paper



## 1. Introduction

In the context of global trade and economic development, the maritime industry has always been playing a crucial role as the enabler and facilitator of prosperity. As widely acknowledged by various international organisations (e.g. [International Maritime Organisation, 2021](#); [OECD, 2021](#); [International Chamber of Shipping, 2021](#)), industry

periodicals such as the Washington Post (Green, 2018) and numerous academic publications (for example, see Fratila *et al.*, 2021), the maritime industry is pivotal as more than 80% of global trade in terms of volume are moved by sea, thus contributing significantly to economic growth in many countries and regions in the world. The maritime supply chain comprises a complex integrated system of nodes i.e. seaports, dry ports and intermodal depots, as well as links i.e., sea transport between key seaports and other shore-based modes of transport connecting seaports with the hinterland. There is also a plethora of players involved in the maritime supply chain such as shippers, shipping lines, port authorities and operators, hinterland transport operators, marine and cargo insurers, banks, among others, who have interrelated working relationships reflected in various processes. This is not yet mentioning an intensive system of documentation that is essential for the smooth transition of cargo from one to the other players. The effectiveness and efficiency of the maritime supply chain, therefore, rely on these complex and interrelated networks of infrastructure, players, documentation processes and relationships.

Given its important role, as well as its complex structure, any disruption in the maritime supply chain would lead to tremendous adverse impacts on freight supply chains, and eventually on global trade and economic development. There are numerous incidents that highlight the viability of the maritime supply chain over the years. For example, during the 11-day closure at the 29 major US West Coast ports in September/October 2002, port management projected losses of approximately USD 19.4 billion for a ten-day lockout with costs increasing exponentially as time went on. This estimate did not cover costs borne by non-American ports and manufacturers faced with container back-logs and increased warehousing costs (OECD, 2003; Pilla, 2003). Analysts also estimated a month-long disruption at US West Coast ports would lower Asian export receipts by up to 0.4% of nominal GDP, in which the negative impact in Hong Kong, Singapore and Malaysia was estimated to be as high as 1.1% of nominal GDP (Saywell, 2002). More recently, the stranding of the *M/V Ever Given* in March 2021 blocking the Suez Canal, which accommodates about 12% of global trade, resulted in the holding up of about \$9.6 billion of trade each day, equating to \$6.7 million a minute, and such a blockage could cost global trade between \$6 billion to \$10 billion a week and reduce annual trade growth by 0.2–0.4% points, according to the German insurer Allianz (Russon, 2021). Besides, the ongoing coronavirus disease 2019 (COVID-19) pandemic and corresponding anti-coronavirus measures at some key container ports in the world have resulted in major port congestion, as well as other delays in other ports, the backlog of vessels and increased shipping costs, which eventually will lead to higher price of commodities. This has been recently reported in various newspapers regarding the congestion at South China ports such as Yantian and Shekou (Crossley and Xu, 2021), and the closure of a container terminal in Meishan island of Ningbo-Zhoushan in China – the world’s third-busiest cargo port – due to a worker being infected with the Delta variant of COVID-19 (Leggett, 2021; Xu *et al.*, 2021).

It can be seen that the management of disruptions in supply chains is essential to ensure their resilience and thus performance. Numerous studies have been conducted on supply chain disruption risks and their mitigation strategies. These topics have become even more popular and have attracted lots of attention from researchers since the outbreak of the COVID-19 pandemic. The research on these topics has been well captured in some recent studies that reviewed earlier relevant work, such as on supply chains under COVID-19 disruptions (Pujawan and Bah, 2021), disruption risk (Xu *et al.*, 2020), methods for mitigating supply chain disruptions (Bier *et al.*, 2020), the role of collaboration in responding and recovering from supply chain disruptions (Duong and Chong, 2020) or the earlier review on supply chain disruption recovery (Ivanov *et al.*, 2017). Given the crucial role of the maritime supply chain in global trade and economic development, it is thus important to investigate the

strategies that have been used for disruption mitigation in the maritime industry and how these contribute to their resilience.

This paper, therefore, presents a systematic literature review on these topics. The remaining of the paper is presented as follows. The next section describes the review methodology, followed by an analysis of descriptive statistics and the literature reviewed. A summary of the main themes and elaboration on a suggested future research framework is presented in the next section, and the paper concludes with some recommendations on future research agenda.

## 2. Review methodology

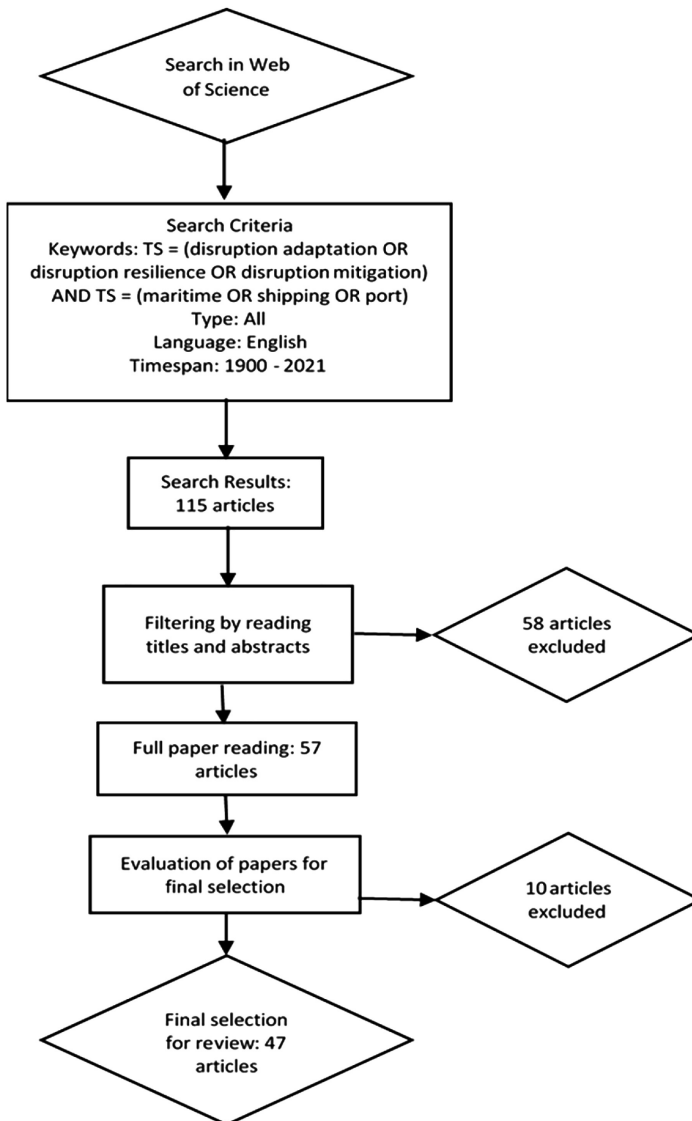
The importance and significance of systematic literature review have been highlighted in various studies, recently well captured in a short article by [Perićić and Tanveer \(2019\)](#), which also indicated that the first systematic review was conducted in 1753 by James Lind, who published a paper that aimed to provide a concise and unbiased summary of evidence on scurvy. There have since been numerous systematic literature review papers published on various topics across research domains. In a nutshell, a comprehensive review of literature on a given topic provides a more systematic, evidence-based approach to research that has been conducted on a given topic, both in terms of contents and methodologies, and maps out a clear framework for future research or prospective research propositions leveraged on what has been done. As this study also aims at developing a future research framework on a maritime disruption management model and examining its relationship with the firm's resilience and organisational performance, a systematic literature review is preferred given its well-recognised advantages.

To further elaborate on the objective of this literature review, the following two review questions were employed as the guide:

- RQ1.* What are disruption management strategies that have been employed by players in the maritime industry?
- RQ2.* How do these disruption management strategies contribute to the resilience performance of players in the maritime industry?

These two review questions are significant, as findings from the review will shed light on the current status of maritime resilience management research, upon which future research agenda can be devised accordingly. The systematic procedure of reviewing the literature was strictly followed, including identification and planning, execution, selection, and synthesis and analysis. First, the review protocol ([Figure 1](#)), including scope, databases and criteria are established in the identification and planning stage. In this research, only studies related to the two review questions in the maritime industry were included. The database used is the Web of Science and the search was conducted in June 2021. The second stage involves the download of relevant articles using search keywords defined by the Boolean expression of "TS = (disruption adaptation OR disruption resilience OR disruption mitigation) AND TS = (maritime OR shipping OR port)." All diverse types of articles including journal and conference papers, book chapters, etc. published since the year 1900 in English are considered in this research. As a result, 115 articles were obtained.

In the selection stage, the screening process was conducted to exclude articles with duplication of titles, and those that do not focus on disruption, while including articles that discussed disruption management or mitigation strategies in enhancing resilience performance in the maritime industry. Following these exclusion and inclusion criteria, a total of 57 articles were identified for analysis. Following the full paper reading process, 10 additional articles were excluded, leading to the final 47 articles, including 45 journal articles and 2 book chapters, being identified for a full review. In the last stage, these 47 articles were



**Figure 1.**  
Protocol for the  
systematic literature  
review

systematically reviewed to identify themes for not only addressing the review questions but also highlighting future research opportunities. In this stage, tools such as Microsoft Excel and VOSviewer version 1.6.17, developed by [Van Eck and Waltman \(2021\)](#), were used to extract and present meaningful results for the analysis.

### 3. Descriptive statistics

[Figure 2](#) demonstrates the number of publications in the domain of disruption management in the maritime industry from 2006 to 2021. In this review, this domain has attracted research intention especially since 2006 albeit quite low in terms of outputs. However, more academic research publications have been generated in recent years especially since 2016.

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**Figure 2.**  
Total number of  
publications by year

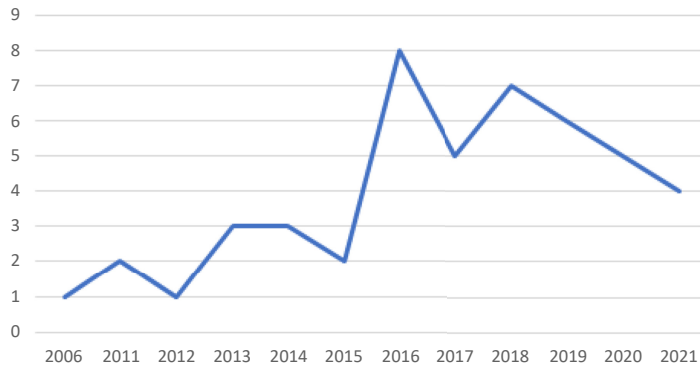
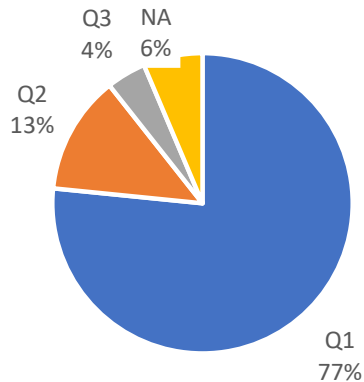


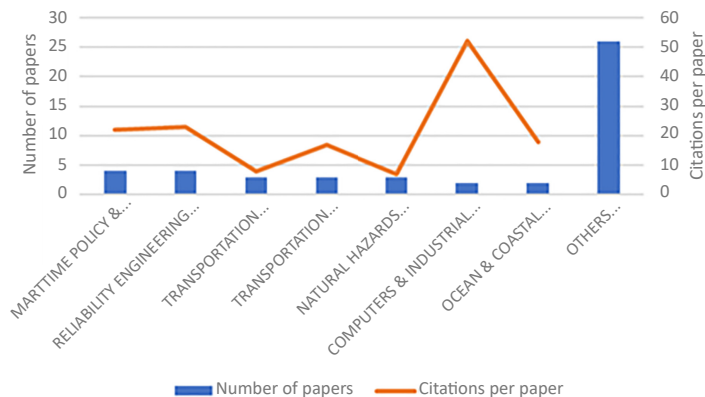
Figure 3 demonstrates that most of the selected articles were published in high quality journals on the Scientific Journal Ranking (Scimago) website in 2020, with 77 and 13% of them are ranked Q1 and Q2 journals, respectively.

Figure 4 shows the list of journals in which most of the reviewed articles were published, as well as the average citations of each article on the journals. It can be seen that the articles

**Figure 3.**  
Distribution of  
reviewed articles in  
Scimago ranked  
journals



**Figure 4.**  
Most influential  
journals by the number  
of publications and  
citations per  
publication



were mainly published in several top-quality journals such as *Maritime Policy and Management*, *Reliability Engineering and System Safety*, *Transportation Research Record*, *Transportation Research Part A – Policy and Practice*, *Natural Hazards*, *Computer and Industrial Engineering*, and *Ocean & Coastal Management*. With the exclusion of *Transportation Research Record* that is a Q2 ranked journal, the rest of the other journals are Q1 ranked. While *Maritime Policy and Management* and *Reliability Engineering and System Safety* have the highest number of publications in this research domain, interestingly, *Computer and Industrial Engineering* is the most influential journal in terms of the highest number of citations per paper, followed by *Maritime Policy and Management* and others.

According to the collected data, 125 authors have published in this research domain. As illustrated in Figure 4, Jasmine Siu Lee Lam has the highest number of publications while Adam Rose and Dan Wei are the most influential authors with the highest number of citations per publication, followed by Vinh V. Thai and Hui Shan Loh.

Tables 1 and 2 show the lists of authors' countries and institutions that were compiled using the information extracted from VOSViewer, sorted by the number of publications, in which the five countries having the most articles in this domain are USA, Singapore, England, Australia, and Norway, while the top two universities are Nanyang Technology University and RMIT University.

#### 4. Analysis of reviewed literature

The final selection of 47 papers is gathered and analysed following the disruption management strategies employed by players in the maritime industry to find out the levels that the players can implement in this domain. Therefore, the literature is divided into two categories, which are the disruption management strategies employed by players in the maritime industry and the link between disruption management strategies employed by players in the maritime industry and their resilience performance. At the same time, the researchers examine the tools used to manage the disruption in each level. The summary of this classification is presented in Appendix.

##### 4.1 Disruption management strategies employed by players in the maritime industry

The strategies employed by players in the maritime industry to manage disruptions are very diversified, while the unit of analysis is also varied. Specifically, there are five levels of strategy implemented in the discussion of the 47 papers mentioned. Among those, 19 studies on the management of disruption in this domain were conducted at the port level, nine at the

Country	Publications
USA	19
Singapore	14
England	10
Australia	7
Norway	4

**Table 1.**  
Top countries based on  
number of publications

Organisation	Publications
Nanyang Technological University	11
RMIT University	3

**Table 2.**  
Top institutions based  
on number of  
publications

levels of transport network while seven at the level of supply chains, four studies from the perspective of the region in which the port is an integrated component, apart from eight other articles.

There is also a plethora of strategies for disruption management ranging from management models and frameworks to the deployment of mathematical modelling and technical support systems.

*4.1.1.1 Managing disruptions from the port level.* 4.1.1.1 Using mathematical models. Among 19 studies discussing about management of disruption at the port level, there are seven papers using mathematical modelling as a tool to analyse and manage the risks of disruption is quite popular at the port level. The advantage of this tool is that it allows the quantification of all resources following the objective function to mitigate the risks and losses in a specific context. For example, both [Hsieh \(2014\)](#) and [Hsieh et al. \(2014\)](#) examined the risk of port failures from the perspective of vulnerability, using internal factors such as ground access travel time, gantry crane efficiency, wharf productivity, electronic data interchange (EDI) connectivity, labour productivity, free trade zone (FTZ) business volume and electric power supply. These authors proposed an assessment framework to assist decision-makers in understanding the vulnerabilities and adopting appropriate strategies to minimise risks and losses. Meanwhile, [Pant et al. \(2014\)](#) recommended stochastic measures of resilience for port operators to use in order to achieve resilience, including Total System Restoration, Time to Full System Service Resilience and Time to  $\alpha$ %-Resilience, as a starting point in the development of a resilience decision-making framework. On another note, [John et al. \(2016\)](#) analysed the causes of seaport disruption using Bayesian Networks, which categorised risk factors into operational risk, security risk, technical risk, organisational risk and natural risk. It was concluded that port operators must pay more attention to terrorism attacks because it is more sensitive than hydrologic, surveillance system failure and lack of navigational maintenance. This was recommended to be included in the port's disruption management strategy without further details.

Meanwhile, [Rose et al. \(2018\)](#) estimated the total economic consequences of a disruption of crude oil and refined petroleum product trade at a major seaport using a modified demand- and supply-driven I-O model. The study proposed multiple tactics to mitigate the risk such as ship re-routing, drawing inventories from storage, accessing the strategic petroleum reserve, geographic shifting of petroleum refining and production rescheduling. Along this line, [Cao and Lam \(2018\)](#) and [Cao and Lam \(2019\)](#) developed frameworks for port risk assessment. Specifically, [Cao and Lam \(2018\)](#) introduced a catastrophe-induced port loss estimation framework for port stakeholders, with input parameters being port information, ship arrival information and quay crane utilisation information, while the outputs are ship arrival number and container throughput. The input parameters in [Cao and Lam \(2019\)](#) include efficiency, resilience and robustness, while the outputs are the bottlenecked systems at the port. Both studies suggested using tactic solutions to disruptions, corresponding to the bottlenecked systems identified at the port.

*4.1.1.2 Using management frameworks.* Other eight studies analysed the disruptions at the port and proposed management frameworks to lessen the risks, losses and prevent future disruptions for port operators and related stakeholders. [Lam \(2012\)](#) examined the disruptions in a port affecting ships calling at the port. Using interview data, it was recommended that terminal operators, shipping lines and insurance companies should collaborate on risk mitigation strategies such as emergency preparation planning, re-routing of shipping service, flexibility in productivity level and capacity by adjusting operation processes and adjusting ship's speed. Other authors divided the causes of disruption by groups and proposed solution frameworks according to the nature of each group. Specifically, [Loh and Thai \(2015\)](#) and [Loh et al. \(2017a\)](#) analysed and categorised the disruptions in ports by infrastructure threats, planning threats, manpower threats and security threats. Using slightly distinct groups of



disruption's causes, [Lam and Su \(2015\)](#) categorised and analysed the disruptions in Asian ports by natural disasters, labour strikes and man-made accidents.

Meanwhile, [Gharehgozli et al. \(2017\)](#) proposed a conceptual framework for port operators to evaluate how ports currently strategize against the risks associated with weather disruption events and how they plan to ensure port resiliency. This includes (1) collecting and analysing historical records on past events, (2) recognising and managing stakeholders' expectations, (3) developing ever-changing resilience strategies and (4) implementing these strategies with flexibility. Along this line, [Almutairi et al. \(2019\)](#) built an integrated framework for port stakeholders including participants mapping and disruption scenario-based preferences in risk analysis to analyse the resilience of a container port in the events of traffic congestion, economic slowdown, high operation cost and environmental mitigation. [Gonzalez-Aregall and Bergqvist \(2019\)](#) analysed the effects on hinterland logistics resulting from the port conflict in which dry ports are considered as a potential solution for port disruption. The authors suggested increasing the combination of intermodal transport and a dry port setup. On another note, [Amodeo and Francis \(2021\)](#) defined the trade-off space for vessel-move sequencing decisions to shift from decentralised to centralised decision-making temporarily during the disruption. Their study demonstrated that prioritisation rules can alter the recovery dynamic without compromising existing safety protocols.

4.1.1.3 Using technical support systems. The technical support systems have been recommended by four studies to be used for mitigating disruption risks in ports. Specifically, [John et al. \(2018\)](#) developed a decision support system (DSS) to analyse security risks for port operators and seafarers. The system uses Analytical Hierarchy Process and Evidential Reasoning to measure three risk parameters: threat likelihood, vulnerability and consequence. This tool helps the players understand the role of developing robust resilience strategies; however, no actual strategies were proposed. Meanwhile, even though vessel tracking data are recommended to be used for many purposes, specifically security, [Verschuura et al. \(2020\)](#) were first to recommend the use of these data, in which the data of port disruptions due to natural disasters in the past were analysed. The results showed multiple ports being affected simultaneously, challenging some earlier studies that only focused on single port disruptions. These authors also recommended using the vessel tracking data in future modelling studies to better approximate the extent of the disruption and the potential resilience of the port and maritime network.

Another study conducted by [Zhou et al. \(2021\)](#) recommended using the port's DSS together with the digital twinning-based resilience analysis for port resilience computation and updating. The authors confirmed that this approach enables the inclusion of ordinary operational uncertainties within the resilience evaluation while hedging against impacts from probabilistically known disruption events. Along this line, [Dhanak et al. \(2021\)](#) also developed a microscopic traffic simulation model (VISSIM) based hybrid multimodal to analyse port operations and provide a quantifiable assessment of resilience. This hybrid modelling approach is used to visualise vessels and allow them to interact in both time and space with each other and landside infrastructure. Local and regional resilience was quantified through the analysis of time-dependent resilience plots and used as a performance measure in this study.

4.1.2 *Managing disruptions from the transport system level.* 4.1.2.1 Using mathematical models. Among nine studies which consider the management of disruption from the transport system level, five publications in this approach divided transportation networks into nodes and links as components, in which some of the studies also considered ports as the nodes of the networks. They used optimisation models as a tool to identify the weakest nodes in the system. For instance, [Chen et al. \(2016\)](#) developed three optimisation models to manage operations in intermodal logistics networks, from routine scheduling delays to recovery from major disruptions. The authors suggested a list of solutions for stakeholders in the networks,



including switching shipping nodes and routes, renting other carriers' capacities, reallocating local trucks and prioritising the order of shipments because of limited capacities. [Thekdi and Santos \(2016\)](#) proposed an I-O model to measure disruptive scenarios following transport sectors impacted. Four proposed scenarios are dockworker strike at the port facility, Hurricane, terrorist attack on the port facility and baseline. The I-O model identified the most vulnerable sectors based on inoperability and economic loss for the decision-making process of relating players including policymakers, port operators and supply chain operators. [Uddin and Huynh \(2016\)](#) presented a mathematical cost model (stochastic mixed-integer program to calculate the cost of modes, transfer and penalty) for the routing of multicommodity freight in an intermodal network under disruptions. By using this model, the recommendation for the case study examined is to ship commodities by road–rail intermodal network.

Meanwhile, [Chen et al. \(2018\)](#) used network game theory to investigate the strategic investment of players in a port–hinterland container transportation network to prevent risks and losses during the disruption. They recommended considering either a complementary network under the influence of market concentration, or complete network for competition degree, or combined influence of market concentration and competition degree. In their conclusion, this method will enhance the network's resilience to man-made unconventional emergency events. [Alderson et al. \(2020\)](#) presented a broader view when constructing the global maritime transportation system as a multilayer network of sea routes and land routes including nodes (seaports and maritime chokepoints) and arcs (route segments at sea or on land). They identified important nodes from a connectivity standpoint and directed the aggregate movement of goods between ports on the shortest and/or cheapest available route, then used re-routing strategies if a route segment becomes impassable for container ships. At the same time, they assessed the impact of the loss of one or more container ports or maritime chokepoints. The solution provides computational tractable results regarding the security and resilience of the global maritime transportation network.

4.1.2.2 Using management frameworks. There are three studies using management frameworks as the tool to analyse and manage disruptions from the transport system level. Specifically, [Berle et al. \(2011\)](#) summarised the failure modes and built a framework to address disruption vulnerability in the maritime transportation system. The framework describes the components of each transport system, identifies hazards and then processes to assesses, mitigate risks, estimate cost/efficiency, and finally recommend decisions for business continuity plans (BCPs) for all identified failure modes. [Rousset and Ducruet \(2020\)](#), meanwhile, analysed the effect of local exogenous shocks on seaports and maritime networks throughout three case studies: Kobe, New York and New Orleans. Their findings highlighted the network lost efficiency due to the disruption of one of the region's major hubs or gateways including ports. In addition, the ports lost efficiency as they get (topologically) further away from each other. Finally, the main gateway or hub was under threat since the network became sparser after the shock. No strategy to mitigate the threats was mentioned, but the findings may support the decision process of the port operators, shippers and carriers.

Another noteworthy study was conducted by [Notteboom et al. \(2021\)](#), which investigated the temporal and spatial sequences of the supply and demand shocks of COVID-19 on container ports and the container shipping industry. The study analysed short-term impacts and their differences, the reasons for these variations, and the evolution in the adaptive capacity and resilience of ports, terminal operators and carriers. The discussion focused on the impacts on global supply chains, operational aspects, market structure, and strategic behaviour of shipping lines and terminal operators, etc., in comparison to the prior crisis in 2008–2009.

4.1.2.3 Using technical support systems. Only one research, conducted by [Farhadi et al. \(2016\)](#), suggested using Nationwide Automatic Identification System Data (AIS) to create new methods and metrics for the assessment or measurement of resiliency in maritime

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transportation systems. These can be used to assess the resilience of port operations following major disasters and other disruptive events and can benefit all the stakeholders of the maritime transportation system.

*4.1.3 Managing disruptions from the supply chain level.* There are only seven studies illustrating the managing disruptions from the supply chain level using mathematical models as a tool.

*4.1.3.1 Using mathematical models.* Some of the earliest studies on this track are [Gurning and Cahoon \(2011\)](#), and [Gurning et al. \(2013\)](#). Both papers used Markovian-based methodology to address the issues concerning multi-mitigation analysis. They proposed the optimised mitigation strategies for the wheat supply chain following processes to measure and predict the wheat supply chain costs and time functions. The processes under the examination include inventory and sourcing, contingency rerouting, business continuity planning and recovery planning. However, no specific response plan to enhance resilience was discussed. Meanwhile, [Lewis et al. \(2013\)](#) measured potential cost impacts of temporary port-of-entry closures, optimising the global inventory lead-time to reduce the order lead-time, so as to reduce losses when facing Port-of-Entry disruption by controlling the inventory of the supply chain. The solution creates an impact on port operators and users, supply chain operators and users and government agencies. The authors also suggested several responses to enhance resilience, such as implementing a suboptimal inventory policy by the domestic customer and prioritising the investments that increase the processing capabilities of highly utilised seaports to reducing the impacts on supply chain productivity by seaport closures and congestion.

On another note, [Zavitsas et al. \(2018\)](#) proposed a comprehensive analytic approach to optimise maritime supply chain performance beyond minimisation of operational costs, to also minimise exposure to costly supply chain disruptions, which can be considered by policymakers and supply chain operators. The framework analyses various abatement options, disruption intensities, fuel pricing instances and regulatory strategies. [Avci \(2019\)](#) investigated the effects of lateral transshipment and expedited shipping on supply chain performance in presence of disruptions by using a simulation-based optimisation approach. Two alternative system configurations, which are characterised by lateral transshipment and lateral transshipment and expediting, were compared with the base case configuration with no sourcing flexibility. The findings are sourcing flexibility strategies relating to lateral transshipment and expedited shipping, in which lateral transshipment is suitable for a cost-efficient stock-out risk mitigation strategy, while expedited shipping may be preferred since it is an effective stock-out risk mitigation strategy despite the high average supply chain cost. [Loh et al. \(2017b\)](#), meanwhile, identified key factors causing port-centric supply chain disruptions by using fuzzy comprehensive evaluation for the port operators. They identified congestion within terminals, congestion at hinterland transfer, shortage of facilities or equipment, port equipment breakdown and inadequate port cargo-handling equipment as key factors.

Going beyond the above, [Hossain et al. \(2020\)](#) developed a framework for assessing the interdependency between the port's disruption and its supply chain performance. The authors identified three interdependency types, including geographic, service provision and access for repair, visualised by the Bayesian Network. The study found that the environmental factors and supplier responsiveness are imperative to port disruption and supply chain performance respectively.

*4.1.4 Managing disruptions from the regional level.* Among four studies examining managing disruption from the regional level in which the port is an integrated component, there are three papers using mathematical models as a tool, while one paper used technical support systems to manage disruptions.

4.1.4.1 Using mathematical models. In their study, [Rose and Wei \(2013\)](#) proposed an I-O model to measure the loss of ports and the economy in monetary terms when disruption happened and caused the port's shutdown. A list of resilience measures was proposed to reduce the risk in future disruptions, for instance, calculating the cost lost, re-routing ships carrying imports, releasing of strategic petroleum reserve, using inventories, applying diversion of export commodities, conserving on scarce materials and recapturing production. These resilience measures are suggested for port operators and stakeholders, importers and exporters. Following this, [Wei et al. \(2020\)](#) presented an analytical framework for analysing various aspects of the economic consequences of and resilience to seaport disruptions, including adapting the enormous regional model (TERM) multi-regional computable general equilibrium (CGE) model for a seaport disruption, distinguishing inherent resilience working through the price system from adaptive resilience and other inherent tactics to cope with input shortages. Meanwhile, [Zhang and Lam \(2016\)](#) developed a systematic framework for performing economic loss estimation of the industry clusters due to port disruptions. The whole risk assessment is split into three stages focusing on the establishment of a network flow model, economic estimations and evaluating risk mitigation strategies. The framework is recommended for port operators, importers, exporters, manufacturers and local transporters likely trucking companies.

4.1.4.2 Using technical support systems. [Kalogeraki et al. \(2018\)](#) suggested implementing technical support systems to manage disruptions from the regional level. Their research addressed the security particularities and specificities of the complex nature of SCADA infrastructures and Cyber-Physical Systems of the maritime logistics industry. The suggested system includes several security assessments services, such as Supply Chain Service Modelling, Vulnerabilities Management and Open Intelligence, Threats/Controls Management and Open Intelligence, Supply Chain Risk Analysis, Attack Paths Simulation, Supply Chain Risk Management, and Social Engineering and Open Intelligence.

4.1.5 *Managing disruptions using other approaches.* There are seven papers employing other approaches. Specifically, three papers developed a maritime disruptions database and forecast systems, two papers examined disruptions from the safety and security approaches, while two other papers investigated disruption management from the regulation approach.

4.1.5.1 Developing a maritime disruptions database and forecast systems. [Adam et al. \(2016\)](#) developed a database of maritime disruptions that have affected the UK from 1950 to 2014, defined different types of maritime disruption observed, analysed the occurrence of each type, and assessed temporal and spatial trends. This database could be used to potentially forecast maritime disruptions and can support the decision-making process of port operators and governmental bodies. Meanwhile, [Repetto et al. \(2017\)](#) presented a set of integrated tools including a monitoring network (webGIS portal) and an innovative forecasting system for the safe management and risk assessment of seaports under extreme wind events. [Lam et al. \(2017\)](#) developed a cyclone risk map for seaports. The risk maps are created by the integration of cyclone hazard maps showing historical cyclone tracks, wind intensity distributions and frequency distributions, with port's container throughput data map.

4.1.5.2 Managing disruptions from the safety and security approaches. [Yang and Hsu \(2018\)](#) examined the enablers and performance outcomes of resilience capability in maritime firms from a relational perspective. The findings indicate that relationship orientation is positively related to maritime firms' security management practices and resilience capability, whereas security management practices are positively associated with maritime firms' resilience capability and cargo operational performance. Moreover, results reveal that resilience capability is positively associated with cargo operational performance, and security management practices are found to play a mediating role. Meanwhile, [Wang et al. \(2019\)](#) discussed the essential causes and draw relevant insights for the safety in the water

transport system, by examining human factors as the main cause. Other causes include defects in maritime administration, defects in ship inspection administration and the safety culture of the industry. The outcomes suggest to articulate the relationship between resilience and risk assessment following three levels of technical (clear objectives and coordinated plans to mitigate the risks), human and management (well maintains of the capability maturity of individuals and organisations) and socio-economic (a good balance between economical effectiveness and safety soundness).

4.1.5.3 Managing disruptions from the regulation approach. [Eskijian \(2006\)](#) analysed the potential risks leading to port closure in practice and pointed out that the proposed regulations contain many issues that raise economic and political questions. Therefore, an important step to be done is to amend the relevant regulations. Meanwhile, [Kwesi-Buor et al. \(2019\)](#) investigated the impacts of policy interventions on industry actors' preparedness to mitigate risks and to recover from disruptions along with the maritime logistics and supply chain network. The level of disaster preparedness response to forecast accuracy, technology change, attitude to risk prevention, port activities and port environment was also simulated. The authors found that there is a bi-directional relationship between regulation and industry actors' behaviour.

#### *4.2 The link between disruption management strategies employed by players in the maritime industry and their resilience performance*

The study of [Loh and Thai \(2016\)](#) is perhaps one of the few which formulated and empirically tested the hypotheses on the link between a management model, incorporating various risk, business continuity and quality management (QM) principles, and port performance using financial health, market reputation, the resilience of internal operations, and internal and external opportunities. It was found that employing this model contributes positively to the identification of internal and external opportunities and through that to the port's resilience of internal operations. This in turn positively influences the port's financial health and market reputation.

## **5. Discussion and proposed research framework**

As can be seen from the review so far, most studies in the literature researched various measures, from using mathematical models, management frameworks and technical support systems, and from various levels of analysis, to analyse risks of disruption and their impacts on maritime systems. There has been so far no study that delved further to empirically examine how the proposed measures contribute to enhance the resilience performance of players in these systems, as well as their organisational performance as a whole. This poses a need for further research in the future, especially in the aftermath of the COVID-19 pandemic.

In addition, with 83% of the studies reviewed (i.e. 39 out of the total of 47 papers) using mathematical models as tools to manage disruptions in the maritime industry, it is confirmed that mathematical optimisation has been considered in ongoing technology adoption in supply chain management strategies in general, and maritime industry in particular. Mathematical models are implemented in addition to technologies on bespoke planning applications, not only for greater efficiency and profitability but also for managing and mitigating disruptions and fostering resilience.

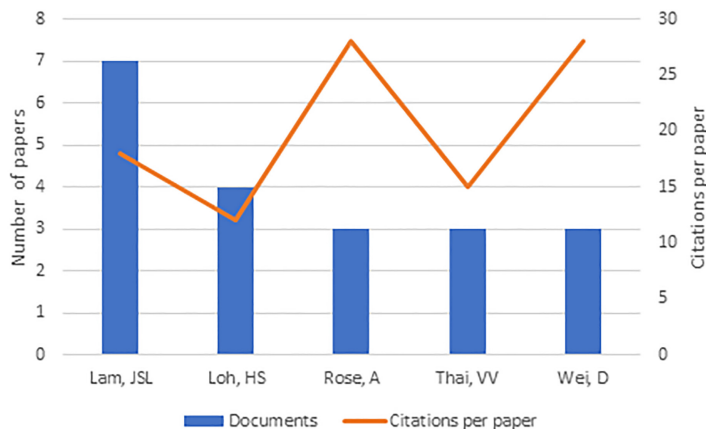
From the systematic review of the literature in the domain, several themes can be drawn relating to the management of disruptions in the maritime industry. First, given the complex nature of the maritime supply chain in which multiple players and systems are mutually interrelated, a disruption to the operations of one player would lead to domino effects on the others. Hence, managing disruptions occurring to any player in the maritime supply chain

would need to take into account collaborative inputs from other relevant primary and secondary stakeholders. In addition, the measures designed to manage disruptions would need to be oriented not only internally within the organisation but also externally toward other agents i.e. suppliers, direct customers, relevant regulatory bodies, etc. who have mutual relationships within the same supply chain.

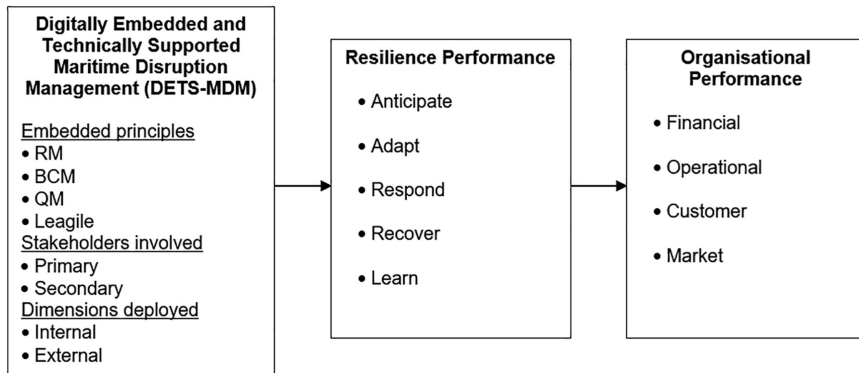
Across the literature, measures designed to manage disruptions are derived from well-known and widely acknowledged principles of risk management (RM), business continuity management (BCM) and QM, as postulated in the study of [Loh and Thai \(2016\)](#) which synthesised various earlier studies. Indeed, as disruptions are often caused by realised threats, an organisation would need to possess the capability to identify, analyse, evaluate risks and prepare well for business continuity, employing recovery measures such as contingency and buffer capacity planning. Meanwhile, QM principles i.e. employee involvement and empowerment, continuous improvement, performance measurement, etc. are essential to assuring the buy-in and smooth implementation of RM and BCM measures both internally and externally. Besides, while extra capacity is often mentioned as a popular measure for managing disruptions, the organisation is also required to be flexible in adopting lean principles to be efficient in the normal operating environment. It is therefore critical that disruption management measures are designed taking into account the leagile principles employed in modern supply chains.

In the context of Industrial Revolution 4.0 and the widespread application of digital technologies in various sectors nowadays, the embeddedness of digital technologies and technical support systems in managing disruptions in the maritime industry is also essential. This would provide a digitally embedded and technically supported ecosystem of the maritime supply chain that supports the identification, measurement and evaluation of risks, as well as information sharing and collaborative planning between various players. These are essential for the effective management of disruptions in the maritime industry (see [Figure 5](#)).

Given the above, a future research framework ([Figure 6](#)) is proposed accordingly. It is hypothesised that a Digitally Embedded and Technically Support Maritime Disruption Management (DETS-MDM) model, incorporating RM, BCM, QM and leagile principles, involving both primary and secondary stakeholders, and being deployed internally and externally, would positively affect the resilience performance of the maritime organisation, measured by their capability to anticipate, adapt, respond, recover and learn from a disruption ([Ali et al., 2016](#)). This would, in turn, lead to enhanced organisational performance



**Figure 5.**  
Top influential authors  
by the number of  
publications and  
citations per  
publication



**Figure 6.**  
Proposed future  
research framework

which is often reflected through their financial-, operational-, customer- and market-related performance after a disruption.

From the holistic level, a maritime organisation should first clearly establish and understand the context – the business and social environments in which it is operating and where the risks of disruption may originate from. In addition, all primary and secondary stakeholders of the maritime organisation and their interdependent relationships in the supply chain setting are also to be identified accordingly. This is essential for all prospective risks of disruption, both under the organisation’s direct control (within the organisation’s systems) and beyond theirs (i.e. at the other supply chain players) are properly identified, analysed and assessed. Based on the outcomes of this assessment, risk treatment strategies will be devised accordingly, which can be to absorb the risks, to transfer or avoid them or to minimise these risks using a plethora of other strategies such as risk hedging or building an agile supply chain. At the same time, the maritime organisation also needs to have in place the BCP, which clearly devises the steps that are to be taken so that the organisation can continue its usual business operations as quickly as possible.

The aforesaid key components of the DETS-MDM framework incorporate the traditional RM and BCM principles in managing disruptions both within the organisation’s processes and between those with other supply chain partners, encompassing the working relationships between the organisation and its primary and secondary stakeholders. These can only be sensibly designed and effectively and efficiently implemented with senior management support, employee participation, internal and external communication within the organisation and between the organisation and its supply chain partners and stakeholders, measurement of disruption management performance and continuous improvement of all necessary processes and steps. In other words, these key principles of QM must be in place as the catalysts for the implementation of other RM and BCM practices. At the same time, it is critical that the maritime organisation would need to analyse its supply chain and identify the decoupling point upon which the leagile strategy can be applied, for example, a particular route for a shipping line or a specific cargo handling equipment or service in the case of a port where extra capacity such as further slots from those vessels of other shipping lines in the same alliance or additional cranes from contingency port equipment vendors can be added. Last but not least, web-based platforms and connected systems, such as those for sharing the identification of threats across the supply chain and scientifically assist the process of risk analysis and assessment, would greatly facilitate and enhance the quality of disruption management in the modern environment where business entities are interdependent in a complex web of relationships.

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The proposed DETS-MDM framework, leveraged on well-rounded disruption management approaches, therefore well addresses the gaps in the extant literature where the links between disruption management models and resilience performance and organisational performance in the maritime supply chain context are not well examined. Given the importance of un-disrupted maritime supply chains in assuring the lifeblood of global trade and economy, it is expected that this proposed framework will facilitate further research on maritime disruption management which contributes to both theory building and management practice.

## 6. Conclusion

The maritime industry plays an indispensable role in global trade and economic development, and the maritime supply chain is complex with multiple players, systems and networks mutually interrelated with each other. In this context, managing disruptions in the maritime supply chain is critical, as any disruption to a player in the chain would have tremendous impacts on others, and the overall performance of the chain would be negatively affected eventually. This paper presents a systematic review of the literature in this important domain. It was found that earlier studies mainly focused on measures, which are designed using mathematical models, management frameworks and other technical support systems, to analyse and evaluate risks, and their impacts on maritime players at the levels of organisation, transport system and region in which the organisation is embedded. There is, however, a lack of research that empirically examines how these measures would contribute to enhancing the resilience performance of maritime firms and their organisational performance as a whole.

A future research framework is therefore put forward, in which a DETS-MDM, built upon the principles of RM, BCM, QM and leagile, involving both primary and secondary stakeholders internally and externally, and digitally embedded and technically supported, is hypothesised to positively contribute to a maritime firm's resilience performance and eventually their organisational performance. This proposed research framework is of significant contribution to both theory building and management practice. Firstly, the DETS-MDM framework presents an all-rounded approach to managing disruption risks in the maritime industry, as it is perhaps one of the first which incorporates various management principles and levels of analysis together in tackling maritime disruption threats. This establishes the foundation for further in-depth research on the mechanism of how these should be blended together in addressing specific maritime disruption threats in each of the sub-sectors of the maritime supply chain. Secondly, this framework also paves the foundation for theory building on how a disruption management model incorporating these principles would contribute to a maritime organisation's resilience and organisational performance, which is currently under-researched in the literature. These will lead to flow-on effects on management practice as findings from these studies would shed light on how effective maritime disruption management can be achieved and which management aspects the practitioners and policymakers should focus on in the quest of enhancing their organisations' resilience and organisational performance overall.

Acknowledging that this review was conducted based only on the most prestigious database i.e. Web of Science, future research may need to expand the review to other databases so as to further refine and operationalise the DETS-MDM model. Another future research would be the empirical validation of the proposed research framework in different organisational contexts i.e. shipping lines, ports, etc., or even between various port types. Such studies in the future would contribute to enhancing knowledge building in the specific domain of maritime disruption management and supply chain management overall while providing meaningful managerial implications to policymakers and managers in the maritime industry.



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Appendix

No	Categories	Publications
1	Disruption management strategies employed by players in the maritime industry	
1.1	Managing disruptions from the port level	
a	<i>Using mathematical models</i>	
	1. Risk of port failures using assessment framework for internal factors	Hsieh (2014), Hsieh <i>et al.</i> (2014)
	2. Stochastic measures of resilience for port operators	Pant <i>et al.</i> (2014)
	3. Causes of seaport disruption using Bayesian networks	John <i>et al.</i> (2016)
	4. Estimated the total economic consequences of a disruption by a modified demand- and supply-driven I-O model	Rose <i>et al.</i> (2018)
	5. Loss estimating framework for risk management of port stakeholders	Cao and Lam (2018, 2019)
b	<i>Using management frameworks</i>	
	1. Management frameworks to lessen the risks, losses for port operators and related stakeholders	Lam (2012)
	2. Proposed solution frameworks according to the nature of each group of disruption's causes	Loh and Thai (2015), Loh <i>et al.</i> (2017a), Lam and Su (2015)
	3. Conceptual framework for port operators to evaluate ports strategize against the risks associated with weather disruption events	Gharehgozli <i>et al.</i> (2017)
	4. Integrated framework for port stakeholders mapping scenario-based preferences in risk analysis	Almutairi <i>et al.</i> (2019)
	5. Framework analysing the effects on hinterland logistics resulting from the port conflict	Gonzalez-Aregall and Bergqvist (2019)
	6. Trade-off space for vessel-move sequencing decisions to shift from decentralised to centralised decision-making temporarily during the disruption	Amodeo and Francis (2021)
c	<i>Using technical support systems</i>	
	1. A DSS to analyse security risks for port operators and seafarers	John <i>et al.</i> (2018)
	2. Vessel tracking data	Verschuura <i>et al.</i> (2020)
	3. Port's DSS together with the digital twinning-based resilience analysis	Zhou <i>et al.</i> (2021)
	4. A microscopic traffic simulation model (VISSIM) based hybrid multimodal	Dhanak <i>et al.</i> (2021)
1.2	Managing disruptions from the transport system level	
a	<i>Using mathematical models</i>	
	1. A three optimisation model to manage operations in intermodal logistics networks	Chen <i>et al.</i> (2016)
	2. An I-O model to measure disruptive scenarios following transport sectors impacted	Thekdi and Santos (2016)
	3. A mathematical cost model (stochastic mixed-integer program) to calculate the costs and penalties	Uddin and Huynh (2016)
	4. A network game theory to investigate the strategic investment of players	Chen <i>et al.</i> (2018)
	5. A multilayer network of sea routes and land routes	Alderson <i>et al.</i> (2020)
b	<i>Using management frameworks</i>	
	1. A framework to address disruption vulnerability in the maritime transportation system	Berle <i>et al.</i> (2011)
	2. A decision process of the port operators, shippers, and carriers	Rousset and Ducruet (2020)

(continued)

**Table A1.**  
Summary of literature  
classification

No	Categories	Publications
	3. Temporal and spatial sequences of the supply and demand shocks of COVID-19 on container ports and the container shipping industry	Notteboom <i>et al.</i> (2021)
<i>c</i>	<i>Using technical support systems</i>	Farhadi <i>et al.</i> (2016)
1.3	1. Use nationwide automatic identification system data (AIS) Managing disruptions from the supply chain level	
<i>a</i>	<i>Using mathematical models</i>	
	1. Optimising mitigation strategies using Markovian-based methodology	Gurning and Cahoon (2011), Gurning <i>et al.</i> (2013)
	2. Potential cost impacts of temporary port-of-entry closures	Lewis <i>et al.</i> (2013)
	3. Optimising maritime supply chain performance using a comprehensive analytic approach	Zavitsas <i>et al.</i> (2018)
	4. The effects of lateral transshipment and expedited shipping on supply chain performance using a simulation-based optimisation approach	Avci (2019)
	5. Factors causing port-centric supply chain disruptions using fuzzy comprehensive evaluation	Loh <i>et al.</i> (2017b)
	6. The interdependency between the port's disruption and its supply chain performance using Bayesian network	Hossain <i>et al.</i> (2020)
1.4	Managing disruptions from the regional level	
<i>a</i>	<i>Using mathematical models</i>	
	1. The loss of ports and the economy using I-O model	Rose and Wei (2013)
	2. The economic consequences of and resilience to seaport disruptions adapting TERM multi-regional CGE model	Wei <i>et al.</i> (2020)
	3. Economic loss estimation of the industry clusters	Zhang and Lam (2016), Lewis <i>et al.</i> (2013)
<i>b</i>	<i>Using technical support systems</i>	
	1. SCADA infrastructures and cyber-physical systems	Kalogeraki <i>et al.</i> (2018)
1.5	Managing disruptions using other approaches	
<i>a</i>	<i>Developing a maritime disruptions database and forecast systems</i>	
	1. Database of maritime disruptions that have affected the UK from 1950 to 2014	Adam <i>et al.</i> (2016)
	2. Integrated tools for the safe management and risk assessment of seaports	Repetto <i>et al.</i> (2017)
	3. Cyclone risk map for seaports	Lam <i>et al.</i> (2017)
<i>b</i>	<i>Managing disruptions from the safety and security approaches</i>	
	1. The enablers and performance outcomes of resilience capability	Yang and Hsu (2018)
	2. The essential causes and relevant insights for the safety in the water transport system	Wang <i>et al.</i> (2019)
<i>c</i>	<i>Managing disruptions from the regulation approach</i>	
	1. Risks leading to port closure	Eskijian (2006)
	2. The impacts of policy interventions on industry actors' preparedness	Kwesi-Buor <i>et al.</i> (2019)
2	The link between disruption management strategies employed by players in the maritime industry and their resilience performance	Loh and Thai (2016)

Table A1.

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