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RESILIENCE FROM ADVERSITY

16 - 20 May 2022
Hong Kong

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Department of Logistics & Maritime Studies 物流及航運學系
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Edited By:

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The **International Forum on Shipping, Ports and Airports** (**IFSPA**) is an annual international conference jointly organized by the C.Y. Tung International Centre for Maritime Studies, the Department of Logistics and Maritime Studies and Faculty of Business of The Hong Kong Polytechnic University. It aims to invite international academics and practitioners to discuss and exchange views on issues related to global maritime and aviation economics, policy and management. The conference also serves as a good platform for networking and promoting academic-industry collaboration.

The roots of IFSPA can be dated back to 2006 when it was started as a workshop with the objective to promote high-quality research papers. Since then it has experienced significant successes and has attracted more than 900 participants from different countries and regions of the world.

Preface

The 11th International Forum on Shipping, Ports, and Airports (IFSPA) 2022 was successfully held from 16 to 20 May 2022 online. It is one of the highlighted celebration events of The Hong Kong Polytechnic University's 85th anniversary. The proceedings contained a collection of 27 full papers out of 102 presentations presented during the Conference. The topics covered include liner shipping, maritime economics and finance, logistics environmental issues, port efficiency and development, maritime safety and risk, logistics innovation and technology, transportation and trading, maritime regulation and policy, sustainability and development, human resources and training, and aviation operation and management.

The theme of IFSPA 2022 was "Resilience from Adversity". It aimed at providing an interactive platform for international academics to discuss important issues related to shipping, ports and airports. It also advocated the adoption of innovation management and technology for maximization of competitive advantage, economic benefits and sustainable developments of transport, logistics, shipping and trading industries worldwide.

This year the Forum comprised of 3 Keynote Sessions, 3 Industrial Sessions, 4 School Sessions, 6 Special Sessions, and 21 Parallel Sessions. During the event, world-famous scholars and industry leaders shared with participants their insights on issues relevant to maritime and trade economics, policy and management. More than 350 participants came from different parts of the world including Austria, Belgium, Brazil, Brunei, Canada, China, Colombia, England, Germany, Greece, Ireland, Israel, Italy, Korea, Singapore, Spain, Taiwan, Thailand, Turkey, and United States.

Led by the C. Y. Tung International Centre for Maritime Studies of The Hong Kong Polytechnic University, IFSPA is an annual international event devoted to maritime, aviation and logistics studies to discuss and exchange views on contemporary issues facing the sectors, and further advance academia-industry cooperation. Through participation from relevant international and regional organizations, the increased pool of participants has enabled IFSPA to become an important event in the transport logistics sector. We are pleased that the event has secured significant support from local government agencies and institutions to assist with its coordination and implementation. Conference participants now include the world's leading maritime and aviation experts and professionals.

The IFSPA 2022 Organizing Committee greatly appreciates the invaluable contribution from the invited speakers, paper authors, paper reviewers, conference co-organizers and partners.

Finally, we thank members of the Organizing Committee and Conference Secretariat who had offered both moral and technical support to the conference and this proceeding. In particular, we would like to thank Charlene Zhou, Cherry Law, Rachel Cheong, and Tsz-him Chan.

The Editors

Chin-Shan Lu
Tsz Leung Yip
Dong Yang
Stephen Li
Hong Kong, August 2022

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The Organizing Committee would like to express heartfelt thanks to the following scholars for their invaluable inputs to the peer-review process of the academic papers submitted to IFSPA 2022.

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Contents

A Whole of Government Approach for Maritime Logistics Hub Development: Case of Singapore

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Abstract

Purpose – The paper investigates the whole of government (WOG) approach applied to maritime logistics hub development using the case of Singapore. The aim is to extract insights where governments can take reference in their formulation, implementation and coordination of policies pertaining to the maritime logistics sector.

Design/methodology/approach – Our research applies cross-case analysis where two axes are considered. On the horizontal axis, we consider the implementation dimensions which are national, industry and project levels. On the vertical axis, we consider dimensions important for implementing WOG approaches which are strategic vision, leadership, accountability and resilience. Analysis is made for three cases for the Singapore maritime logistics sector.

Findings – Analyses revealed necessity of adopting WOG approach especially where government policies are concerned. Through WOG approach, the lead government department or agency can tap on diverse expertise, knowledge, ideas and perspectives from across the public and private sectors.

Research implications – MPA's involvement is more evident at industry level. At the national level, the cabinet and multi-ministry efforts are more prominent. At the project level, relevant government departments or agencies play the bigger role.

Research limitations – Study can detail roles and responsibilities for each government department and agency involved and discuss challenges in implementing the WOG approach.

Practical implications – Regardless of policies implemented at national, industry or project level, WOG effort is required. Leadership by relevant government department or agency is a key consideration.

Originality/value – To our knowledge, this is the first attempt to investigate WOG approach applied to the maritime logistics sector.

Keywords: Whole of government; Singapore; maritime logistics hub; international maritime center; hub port.

1. Introduction

Logistics hubs are key nodes in the global trade, transport and supply chain networks (Ducruet et al., 2010). The authors highlighted importance of viewing logistics hubs in facilitating interchange of cargo between different transport modes and serving multi-functional roles. Logistics hubs provide collaborative platforms where logistics service providers and other supply chain players can offer complementary services. Logistics hubs often serve as consolidation and distribution centers to wider regional markets. The important role of logistics hubs and impact of their performance has been investigated from perspectives including trade flows (Márquez-Ramos et al., 2011), geographical location with respect to centers of production and consumption (Lam and Yap, 2008; Russo et al., 2014), influence exerted by transport hub status (Yap and Ho, 2021), quality of infrastructure (Parola and Lam, 2018), hinterland connectivity (Rodrigue and Notteboom, 2009), shipping connectivity (Yap and Loh, 2019), air connectivity (Allroggen et al., 2015), inland port connecitivty (Raimbault, 2019), integration with the supply chain (Prajogo and Olhager, 2012), transport, cargo handling and other costs (Song et al., 2016), supply chain performance (Estampe et al., 2013), and value to users (Ha and Yang, 2017;

Kaliszewski et al., 2020). The studies by Choi (2021) and Singh et al. (2021) emphasized importance of logistics hubs in cases of major disruptions such as those caused by the COVID-19 pandemic. Competitive logistics hubs can help users reduce transport lead-time, improve customer service, and gain competitive advantages. As a whole, the studies reveal the multifaceted and complex nature of the logistics industry. The studies also note that logistics networks are not static and are evolving to capitalize on changes in trade and demand patterns, transport organization and management, technological advancements, complying with regulatory and sustainability measures, and productivity and efficiency requirements from users.

For research focusing on role and impact of maritime logistics hubs, studies devoted to this aspect include works relating to terminal operators (Ha and Yang, 2017), shippers (Castelein et al., 2019), shipping lines (Yuen et al., 2012; Parola et al., 2017), logistics companies (Chang and Talley, 2019) and port authorities (Hintjens, 2018). As key users of maritime logistics hubs, shipping lines view port selection with caution, aiming to derive maximum value in the choice of port-calls made (Yang and Chen, 2016; Castelein et al., 2019). By calling at a specific maritime logistics hub, shipping lines will incur a suite of charges including port dues, pilotage, stevedoring charges and fuel cost (Yuen et al., 2012). Shipping lines will also consider the relative position of the maritime logistics hub in relation to their shipping network (Kaliszewski et al., 2020). As main users of maritime logistics hubs, shipping lines will aim to maximize net value derived from the port-call over alternative routings. From the perspective of logistics and supply chain companies, attraction of the maritime logistics hub will be determined by its position relative to supply chain networks and range and depth of logistics services available (Song et al., 2016). Such services include storage, warehousing, distribution, assembly and customizing. Given that the maritime logistics hub is likely to serve a bigger hinterland, availability, reliability and efficiency of multimodal and intermodal linkages with high service quality and competitive cost and pricing will also be important factors for consideration (Yang and Chen, 2016). Hinterland connectivity will include landside, air-side and maritime-side for the logistics hub. An integrated logistics hub will need to cater to opportunities offered by all three aspects of connectivity. With reference to sea-sea transhipment, role of the port in feeder service networks will be key (Yap and Loh, 2019). The authors emphasized capability of handling mainline vessels will be crucial in view of relay in addition to hub-and-spoke transhipment opportunities. Homosombat et al. (2016) noted the complementary effects of industrial activities for integrated maritime logistics hubs.

From the perspective of terminal operators, efficiency of port operations and extent to which terminal capacity is utilized are important concerns (Ha and Yang, 2017; Parola et al., 2017). The authors proposed efficiency of port operations to be determined by a combination of factors covering vessel turnaround time, safety incidents, security breaches and cargo turnaround time. Terminal operators will also be concerned about utilization of terminal capacity which covers aspects including berths, yard space, terminal area and cargo-handling equipment (Maloni and Paul, 2013). From the perspective of port technology and handling-capacity, maritime logistics performance can be influenced by factors such as berth utilization, quay length and depth alongside. Performance of the maritime logistics hub can also be affected by terminal operating system employed, climatic conditions and maritime access (Sun et al., 2013). The impact of port congestion can have detrimental effects that reverberate through entire supply chains (Song et al., 2016). For shippers, maritime logistics hubs provide the capacity to process cargo and connectivity for trade flows to occur (Fugazza and Hoffman, 2017). The authors revealed absence of direct shipping connectivity being related to lower values of exports. Cargo volume involved for trade flows through a maritime logistics hub will exert important bearing on the commercial viability of operators in the location. As such, maritime logistics hubs are usually confluences for several trades. This results in these locations becoming important hubs for wide geographical regions (Yap and Ho, 2021). In the case for government authorities, performance of maritime logistics hubs has important impact on the development of industry clusters (Weng et al., 2016). Sustainability is another important area of concern where authorities need to work with industry players to minimize the impact of pollution and other undesirable consequences to the environment (Lam and Li, 2019). From the supply chain perspective, Aregall et al. (2018) mentioned the role of ports in reducing negative externalities in hinterland activities with measures involving monitoring programs and regulations on engine, and dedicated infrastructure.

The studies highlight importance of logistics hubs as crucial nodes in global trade and transport. Strategic geographical location and world class infrastructure are necessary but insufficient conditions to assure logistics hubs of securing cargo traffic. Advancements in information technology and transportation technology have intensified competition for cargo among logistics hubs. The studies emphasized the need for logistics hubs to be well plugged into the global value-driven supply chain to be an attractive node for the trade flows. As logistics hubs provide substantial value add and multiplier effects to the economy, governments are likely to be concerned about enhancing the vibrancy and competitiveness of logistics hubs through strategic initiatives and projects on productivity, efficiency and innovation. Maritime logistics hubs are of particular importance given considerable share of global trade that moves by seaborne methods (Michail, 2020). Policies pertaining to development of maritime logistics hubs can be complex and span several dimensions due to differing expertise and multiple stakeholders within the maritime logistics ecosystem. Policies enacted towards developing maritime logistics hubs are also likely to involve several government departments and agencies. As such, our research aims to contribute to the literature by performing cross-case analysis focusing on whole of government approach to provide insights where governments can take reference in their formulation, implementation and coordination of policies. The rest of the paper is structure as follows. Section two discusses the literature and gaps intended to be filled. Section three presents the research approach while section four presents the research findings. Section five discusses implications of the research. Section six concludes and suggests recommendations for future research.

2. Literature

The Whole of Government (WOG) approach refers to the set of processes to make departments and agencies from across the government to work together to achieve shared goals (Christensen and Lægreid, 2011). Research by Brook (2012) and Van Eyk et al. (2019) proposed WOG approach involves facilitating and achieving harmonization in areas such as policy analysis, planning, implementation, management and evaluation. The authors suggested adopting WOG approach can bring benefits in the form of delivering holistic responses in public policy particularly when issues transcend agency boundaries. Good practices in adopting WOG approaches are having clarity in shared outcomes, agreements on roles and responsibilities among different departments and agencies, reinforce accountability for collaborative efforts, and use of disincentives or sanctions for non-compliance (Bourgon (2008). Strong leadership, sharing of good practices and having mutually reinforcing strategies can also contribute to success in this regard (Brook, 2012). Attention is drawn to the role of decision making in terms of processes, layers of administration and key actors involved. The authors highlighted WOG approach can be deeply transformational and should be adopted in progressive stages from projects to nationwide implementation. The authors further cautioned implementing WOG approach will need to consider differences in organizational cultures, priorities and structures. The studies point towards WOG approach as providing opportunities to achieve greater policy effectiveness while avoiding duplication of efforts and minimizing waste of resources. The studies also note that WOG approaches can be formal and informal while acknowledging outcomes generated are possible through agencies working in collaboration rather than isolation. Complexity of issues involved also means stakeholder management becomes critical especially when stakeholders often have specific interests to protect and agendas to promote. The studies further allude to the underlying political connotation associated with the topic of WOG approach. Even though the focus is on the administrative aspects of government, there are important public and political goals to fulfil.

The WOG approach aims to rejoin disparate parts of public sector that has become institutionally fragmented. Christensen and Lægreid (2011) posited this development can be due to adoption of private sector practices to achieve efficiency and effectiveness. Under the WOG approach, the aim is to provide a dynamic, collaborative and coordinated approach for governments to confront complex issues and challenges in an increasingly uncertain world. Potential benefits of WOG also include possibility of leveraging on technology to develop and deliver policies to address society issues in an interdisciplinary and multidisciplinary fashion, promote thinking about new approaches to solutioning, foster improved understanding among public servants of government priorities. Based on the literature, we identify four important aspects of the WOG approach. These are strategic vision, leadership, accountability and resilience (see Table 1). For the WOG approach to be effective, government departments and agencies will need to share common goals. A long-term strategic vision will be required to support policy coherence and align agencies and stakeholders towards common goals (OECD, 2019). The aim is to help break the silo mentality where government departments and agencies are focused only on the performance of their individual agency or program outcomes and do not measure their contribution to the overall performance of the government (Bourgon, 2008; Halligan et al., 2011). The authors highlighted tools such as strategic foresight, scenario development and systems thinking approaches can be used in the definition of the vision and goals.

Table 1: Four key aspects concerning whole of government approach based on the literature

Key aspect	References
Strategic vision	Bourgon (2008); Grossi et al. (2009); Halligan et al. (2011); Brook (2012); OECD (2019); Van Eyk et al. (2019)
Leadership	Grossi et al. (2009); Halligan et al. (2011); Carayannopoulos (2017)
Accountability	Christensen and Lægreid (2011); Bourgon (2008); Grossi et al. (2009); Halligan et al. (2011); Brook (2012)
Resilience	Christensen and Lægreid (2011); Bourgon (2008); Halligan et al. (2011)

From the WOG perspective, leadership towards the coordination mechanism to drive greater WOG orientation varies in accordance with respective government philosophies to public sector management (Halligan et al., 2011; Carayannopoulos, 2017). It can also take the form of hierarchical strengthening through new organizational units that are being established inside existing central structures such as inter-ministerial committees, inter-agency collaborative units, lead agency approaches and cross-sectional programs. Therein said, a WOG approach requires commitment from the political leadership to persuade the citizens to believe in the need for change, empower them to change, take risks, and learn from failure. With regards to accountability, the subject involves complex legal, constitutional and democratic principles with the aim of ensuring that agencies are responsive to citizens (Christensen and Lægreid, 2011; Halligan et al., 2011). The authors suggested a WOG approach requires elected officials, administrators and civil servants to work together towards common goals and be jointly accountable for shared outcomes. Resilience is viewed as capacity of governments to prepare for disruptions, recover from shocks and stresses, and adapt and grow from the disruptive experience (Christensen and Lægreid, 2011; Halligan et al., 2011). Governments can improve their capacity to tap the collective intelligence of society on emerging patterns and trends in the social system (Bourgon, 2008). By the WOG approach, governments must be prepared to accept certain level of risks as part of the experimentation.

Governments play an important role in the development of maritime logistics hubs. Government policies enacted regarding maritime logistics hubs can have wide-ranging effects including on employment, GDP and overall competitiveness of the logistics industry (Ha and Yang, 2017). Performance of maritime logistics hubs can also be reflected by business revenue, tax receipts and total output generated (Zhang and Lam, 2013; Chen, 2019). In the case of Singapore, the genesis of maritime logistics hub development can be traced to 2002 (Singapore Government Press Release, 2002). Maritime logistics and related activities are viewed as a crucial pillar by the Ministry of Trade and Industry. The maritime logistics pillar emphasizes developing Singapore into an international maritime center (IMC) offering a wide range of shipping-related services and facilities. Supply chain management capabilities and technologies serve to integrate the three pillars for efficient and seamless intermodal movement of cargo. The framework shows that developing a logistics hub is a massive exercise that cuts across multiple dimensions and involves multiple stakeholders. This is fertile ground for implementing WOG approaches.

Since 2002, many projects have been implemented. These projects have contributed to Singapore becoming a major logistics hub in the Asia Pacific region. In 2019, the Singapore logistics sector contributes S$6.8 billion or 1.4% to the country's GDP (Choo, 2020). In terms of international ranking, Singapore obtained the second highest score in Asia by the World Bank's (2022) Logistics Performance Index. From the perspective of maritime logistics, the maritime industry employs 160,000 people across over 5,000 establishments (Maritime Singapore, 2021). In addition, the port of Singapore is recognized as the busiest transhipment hub in the world. Singapore is also ranked as the busiest port in terms of vessel arrivals and bunker sales. In 2021, Singapore received 2.8 billion GT in vessel arrivals and sold 50.0 million tonnes of bunker (Maritime and Port Authority of Singapore, 2022). The port also handled 37.5 million TEUs of containers and 599 million tonnes of cargo.

The economic contribution and impact of Singapore as a maritime logistics hub will extend to other cities and countries that are connected through the port. As an important sector of the economy, our research aims to investigate the development of Singapore as a maritime logistics hub from the WOG perspective. As a whole, the literature is lacking in the area of WOG research pertaining to the maritime logistics sector. This is an important aspect in view of complexities involved in enacting public policies towards an entire maritime logistics sector. For this purpose, our research aims to contribute to the literature by using cross-case analysis to bring out key insights from application of WOG approach in Singapore's experience. With intensifying competition between maritime logistics hubs, leveraging on WOG approach where a wider range and pool of resources and expertise can be drawn to develop competitiveness will become fundamental to a logistics ecosystem. Implications for overall economic competitiveness of the region which depends on the logistics hub are likely to be significant as well.

3. Research approach and context of cases selected

Our research applies cross-case analysis to investigate application of WOG approach in Singapore's maritime logistics hub development experience. The approach considers two axes. On the horizontal axis, we consider the dimensions where WOG approach is applied. These are at the national level, industry level and at the project level. At the national level, policies can take a whole of country perspective, have a broader impact, and are often of longer-term nature (Brook, 2012; Carayannopoulos, 2017). At the industry level, policies are targeted at achieving specific objectives for the industry (Van Eyk et al., 2019). Compared to national policies, industry policies are usually shorter in term. At the project level, policies are even more specific with expected outcomes of even shorter time durations (Halligan et al., 2011). On the vertical axis, we consider the dimensions important for implementing WOG approaches which are strategic vision, leadership, accountability and resilience. Cross-case analysis is made for three case studies in the context of maritime logistics hub development in Singapore and takes reference to the integrated logistics hub development framework initiated by the Ministry of Trade and Industry (Singapore Government Press Release, 2002). The case studies are: (1) developing Singapore as an international maritime center; (2) sea transport industry transformation map; and (3) development of the Pasir Panjang Terminal port complex. We compare the three case studies across the dimensions in the cross-case analysis to derive patterns and extract insights pertaining to the WOG approach. The analysis is based on comprehensive literature review and information collected from credible internet sources, government policies and interactions with policy makers and industry members of the maritime logistics community in Singapore. An overview for each of the three case studies is provided.

The first case study concerns developing Singapore as an international maritime center (IMC). This notion was conceived in 2002 where focus was to leverage on Singapore's existing strengths in being a regional transportation hub and to grow and expand shipping and related activities in Singapore (Singapore Government Press Release, 2002). Then known as the "London Plus" development strategy, emphasis was to grow the pool of ship operators, ship managers, ship agents and logistics operations set by shipping companies in Singapore. In 2003, the Maritime and Port Authority of Singapore (MPA) was "IMC Champion" where promotional, regulatory and developmental aspects of the maritime sector are consolidated under MPA (Maritime and Port Authority of Singapore, 2004). With the new policy, members of the maritime community will need to deal only with MPA for issues related to the maritime industry. In 2016, MPA began a review of its IMC development which resulted in the recommendation to focus on IMC as a key engine of growth (Maritime and Port Authority of Singapore, 2017). Known as the IMC 2030 Strategic Review, the recommendation calls for an integrated ecosystem of Singapore as an IMC and envisions Maritime Singapore to comprise diverse industry players from various sectors including international shipping groups and providers of ancillary services.

The second case study concerns the sea transport industry transformation (ITM). The ITM was launched in 2018 and aims to boost the maritime industry's value-add by S$4.5 billion by 2025 (Maritime and Port Authority of Singapore, 2018). A key objective of the ITM is to enhance the skills of the maritime workforce. New initiatives launched include the Earn and Learn Programs for port operations executives and seafarers. Intention is to develop a "Future-Ready" maritime workforce. To address training and education needs in the maritime industry, MPA works closely with other government agencies including the Ministry of Manpower, Ministry of Education, Workforce Singapore and SkillsFuture Singapore. Other stakeholders include industry associations, and unions from the maritime sector. The outcome is the Skills Framework to promote lifelong learning and skills mastery for the maritime industry (SkillsFuture Singapore, 2021). The framework includes a skills map covering 85 job roles and related skills and competencies pertaining to three tracks which are port, shipping and maritime services. The framework further differentiates skills and competencies into those which are of technical nature and those which are generic. Key training providers are tertiary education institutions in Singapore. The framework is reviewed on a regular basis to identify relevance and effectiveness of training programs as well as emerging skills and future job requirements and employment opportunities.

The third case study concerns development of the Pasir Panjang Terminal. This is the second engine of growth identified by the IMC 2030 Strategic Review (Maritime and Port Authority of Singapore, 2017). The port of Singapore is connected to 600 ports in more than 120 countries. Figures available for cargo and vessel traffic handled by the port would rank Singapore among the busiest maritime logistics hubs in the world. Making available sufficient capacity to accommodate container-handling demand is an important consideration in positioning and development Singapore as a hub port. Pasir Panjang Terminal was developed over a span of two decades and ranks among the largest port complexes in the world. Containing 41 berths and 147 quay cranes, the terminal is equipped to handle the largest containership in operation. Pasir Panjang Terminal was conceived as early as the 1980s when container throughput handled in Singapore barely reached 5.0 million TEUs. Construction of phases one and two of the terminal began in 1993 with the facilities becoming operational in 2005. To cater for further growth, the terminal underwent expansion with phases three and four where construction took 2007 to 2017 to complete. The scale of the project and complexity of issues involved requires a WOG approach. The Maritime and Port Authority of Singapore was designated as project lead and coordinator. The agency was chosen for its expertise in matters relating to port policy, port master planning, port safety and port security. Nonetheless, there are many other issues that requires tapping on subject matter expertise from other government departments and agencies. The cross-ministry and multi-functional participation from across the government was instrumental in achieving on-time completion with minimal disruptions to the already tight sea space in Singapore port waters.

4. Research findings

Results from the cross-case analysis for WOG approach to developing Singapore as a maritime logistics hub are presented in Table 2. The table analyses the three cases of international maritime center (IMC) development, sea transport industry transformation (ITM) and Pasir Panjang Terminal (PPT) development for the maritime industry in Singapore. At the national level, strategic vision pertaining to the three cases are guided by the desired future state of the Singapore economy. To date, there were three major exercises convened at the national level to provide strategic vision in this regard. The latest being the Committee for Future Economy (CFE) set up in 2016 and chaired by the Deputy Prime Minister (Ministry of Trade and Industry, 2017). This exercise was preceded by the Economic Strategies Committee (ESC) set up in 2009 and chaired by the Minister of Finance. There was an earlier exercise called the Economic Restructuring Committee (ERC) that was set up in 2001 by the then Prime Minister of Singapore (BIS Review, 2002). All three committees are driven at the Cabinet level with participation by all ministries. In terms of leadership, MPA was designated as IMC Champion in 2003 and provides leadership at the national level for maritime matters. MPA serves as the lead government agency and coordinates efforts across various ministries and statutory boards through the organization’s roles as port authority, port regulator, national maritime representative and port planner. For accountability, the ERC, ESC and CFE are accountable to the Prime Minister who holds executive power in the political system of Singapore. The Prime Minister is an elected member of parliament and leader of the political party with the largest number of seats in parliament. Resilience at the national level is under the charge of the National Security Coordination Secretariat which is a unit under the Prime Minister’s Office (National Security Coordination Secretariat, 2022). The secretariat leads and coordinates efforts with various government departments and agencies to identify emerging risks and develop capabilities and resources to deal with them. During exception circumstances such as the COVID-19 pandemic, an inter-ministry approach is also adopted at the national level. The Multi-Ministry Taskforce (MTF) was established in January 2020 to deal with challenges presented by the pandemic (Low, 2020).

Table 2: WOG approach to maritime logistics hub development in Singapore

	Implementation dimension	
National level	Industry level	Project level

WOG aspects			
Strategic vision	IMC, ITM and PPT: Inter-ministry Economic Restructuring Committee (ERC); Economic Strategies Committee (ESC); Committee for Future Economy (CFE).	IMC, ITM and PPT: Maritime and Port Authority of Singapore (MPA).	IMC and PPT: MPA. ITM: SkillsFuture Singapore.
Leadership	IMC, ITM and PPT: MPA as IMC Champion; lead government agency and coordinates efforts across various ministries and statutory boards.	IMC, ITM and PPT: Maritime and Port Authority of Singapore (MPA).	IMC (maritime arbitration): Ministry of Law. ITM (training programs for working adults): SkillsFuture Singapore. PPT (design and master plan): MPA.
Accountability	IMC, ITM and PPT: ERC, ESC and CFE are accountable to the Prime Minister of Singapore.	IMC, ITM and PPT: MPA as a statutory board under the Singapore Ministry of Transport (MOT).	IMC, ITM, PPT: Lead department or agency of the project will be held accountable to the administrative entity which it reports to.
Resilience	IMC, ITM, PPT: National Security Coordination Secretariat. COVID-19 pandemic: Multi-Ministry Taskforce.	IMC, ITM and PPT: Maritime and Port Authority of Singapore (MPA).	IMC, ITM, PPT: Lead department or agency of the project responsible for resilience matters pertaining to the project.

At the industry level, strategic vision is provided by MPA which is the IMC Champion. MPA provides strategic vision to drive growth and development of the maritime industry. IMC and hub port were identified as twin engines of growth for Singapore. Depending on issues involved, expertise is drawn from different departments and agencies across the government sector and includes consultation with the private sector and general public. For the aspect of leadership in IMC development, MPA is the lead agency responsible for attracting international shipping groups and providers of ancillary services to be based in Singapore. For leadership concerning ITM, MPA is also the lead agency. The statutory board coordinates training and education efforts for the maritime industry. Key government departments and agencies involved are Ministry of Manpower, Ministry of Education, Workforce Singapore and SkillsFuture Singapore. For PPT development, MPA as lead agency coordinates planning and construction of the terminal. Key government departments and agencies involved are Ministry of National Development, Ministry of Finance, Building and Construction Authority and Singapore Economic Development Board. Regarding the aspect of accountability, MPA is a statutory board under the Singapore Ministry of Transport (MOT). MPA was established in 1996 by the Maritime and Port Authority of Singapore Act 1996 (Singapore Statutes Online, 2020). MPA is accountable to MOT which is headed by a minister who is appointed by the Prime Minister of Singapore. As for resilience, MPA is the agency responsible for leading and coordinating efforts across the public and private sectors to build resilience in the maritime industry. For example, MPA was the lead agency in dealing with challenges and issues caused by the COVID-19 pandemic. MPA worked with industry associations, maritime unions and Immigration and Checkpoints Authority of Singapore to facilitate crew change with minimal disruptions.

At the project level, strategic vision will be guided by specific governance pertaining to each project. In the case for IMC development, strategic vision is guided by MPA's vision to have Singapore become an international maritime center that possessed a vibrant ecosystem of internationally competitive maritime-related companies and organizations. For ITM and in training programs for working adults, SkillsFuture Singapore envisions a nation of lifelong learners and a society which values skills mastery. For PPT development, MPA envisions Singapore as a premier global hub port. In terms of leadership, this aspect will also be specific to the project concerned. For example, in the development of maritime arbitration activities in Singapore, the Ministry of Law leads efforts to set up Singapore Chamber of Maritime Arbitration. For training programs for working adults under the area of ITM, SkillsFuture Singapore leads efforts in working with tertiary education institutions. Training programs are endorsed by MPA with advice from maritime industry associations. For PPT's design and master plan, MPA leads efforts to formulate design of Phase three and four of the terminal. Consultations were made to gather inputs from Building and Construction Authority and Singapore Land Authority. For accountability, this will depend on the project where the lead government department or agency will be held accountable to the administrative entity which it reports to. The situation is similar in the aspect of resilience. Depending on the project, the lead government department or agency will be held responsible for resilience matters.

5. Discussion and implications

The analyses revealed the necessity of adopting WOG approach especially where government policies are concerned. The WOG approach provides a practical means where policy matters are complex and span many dimensions. This can be observed by the three cases presented which covered different implementation dimensions pertaining to the maritime logistics sector in Singapore. Through coordinated WOG effort, the lead government department or agency is able to tap on diverse expertise, knowledge, ideas and perspectives from across the public and private sectors. More importantly, the WOG approach offers government officers from difference ministries the opportunity to interact and thereby promoting better communication and understanding regarding the matter. The experience of collaborating and learning contribute to strengthening relationships and networks. Policy decisions made are likely to be more rigorous and comprehensive in their consideration.

The cases also reveal that regardless of policies implemented at the national, industry or project level, the effort always involves a multi-ministry or multi-government department or agency approach. The aim is to avoid silo effects where a specific ministry, department or agency is focused on their individual functional scope and performance without regard to the strategic vision. The cases also reveal that leadership by the relevant government department or agency is a key consideration. The cases further show that although MPA plays a prominent role in the maritime logistics sector, the organization's involvement is more evident at the industry level. At the national level, the cabinet and multi-ministry efforts are more prominent whereas at the project level, relevant government departments or agencies will play the bigger role. In terms of accountability, the political and public administration system in Singapore ensures government departments and agencies are held accountable to a ministry, which in turn, is accountable to the elected government of the country. As for resilience, there is a coordinating mechanism installed at the national level although exceptional circumstances such as the COVID-19 pandemic can see a new taskforce established to deal with its associated challenges. At the industry level, MPA as national representative for the maritime industry plays a leading role in developing and implementing resilience plans with support from other government departments and agencies. At the project level, specific resilience plans are the responsibility of government departments or agencies where governance of the project is concerned.

6. Limitations and directions for future research

With intensifying competition from the region and other logistics hubs, Singapore must continually improve its competitiveness and strengthen its competitive offering. The WOG approach offers the opportunity to leverage on expertise across different government departments and agencies to fulfil this objective. Policies pertaining to developing maritime logistics hubs are complex and span many dimensions. Our research investigates the development of Singapore as a maritime logistics hub from the WOG perspective. Using cross-case analysis, our research presents three cases relating to international maritime center (IMC) development, implementation of the sea transport industry transformation map (ITM), and development of Pasir Panjang Terminal (PPT) to showcase differing expertise and multiple stakeholders involved from the national, industry and project levels. We have attempted to show policies enacted towards developing maritime logistics hubs will involve several government departments and agencies. We used the analysis to extract key insights from application of WOG approach in Singapore's experience. We aim for the research to provide these insights where governments can take reference in their formulation, implementation and coordination of policies.

To our knowledge, this is the first attempt to investigate WOG approach applied to the maritime logistics sector. We would also like to point to three limitations and suggest directions for future research. Firstly, the study can detail the roles and responsibilities pertaining to each government department and agency involved with respect to each case mentioned. This can better show how fragmentation of service delivery is avoided and how these entities support each other in the WOG approach. Secondly, the research can provide the historical context and analyze in greater detail why are certain government department or agency appointed as the lead entity. The reporting structure and mechanism that makes WOG approach work in the three cases should be explained. Thirdly, our research recognizes there are significant challenges in implementing the WOG approach in Singapore. These aspects were not discussed. As such, future research can address these limitations.

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Determinants of Cargo Risk Management in Domestic Maritime Transport between Taiwan and Penghu

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Abstract

Purpose – Penghu is an island located west of Taiwan, and many of its critical resources rely heavily on importation. The cross-maritime transport of feeder operations based on delivery complexity in Penghu is a key factor that affects the service quality of logistics on the island. The purpose of the study is to explore the critical factors of logistics risk between Penghu and Taiwan which can also enhance its maritime safety.

Design/methodology/approach – This study used the AS/NZS *ISO 31000-2009* risk management principles and guidelines to investigate the risk factors.

Findings – The results showed that environmental risk during cargo stacking had the highest logistics risk, followed by cargo delivery delays, poor weather during transportation, shipper negligence, and wet cargo damage.

Originality/value – Most studies discuss the international logistics. However, studies on the risk management of island logistics are still lacking. The results can be discussed and applied in island logistics.

Keywords: Island logistics, risk management, domestic feeder

1. Introduction

The risk management of maritime transport is critical, particularly for island regions. Penghu is an island located west of Taiwan (see Figure 1), and many of its critical resources rely heavily on importation, which is strongly affected by the supply chain in Taiwan (Yang et al., 2018). To reduce transportation costs, maritime shipping has become the primary mode of cargo transport between Taiwan and Penghu. However, several key factors might increase the difficulty of logistics activities. First, the walruses in the winter season are particularly unstable due to the strong northeast monsoon. Then, domestic maritime transport usually employs smaller ships that are easily influenced by walrus. These increase the risk, bad seaworthiness, and other transport problems in cross maritime- transport. Thus, these complex delivery problems might affect the service quality of logistics on the island.

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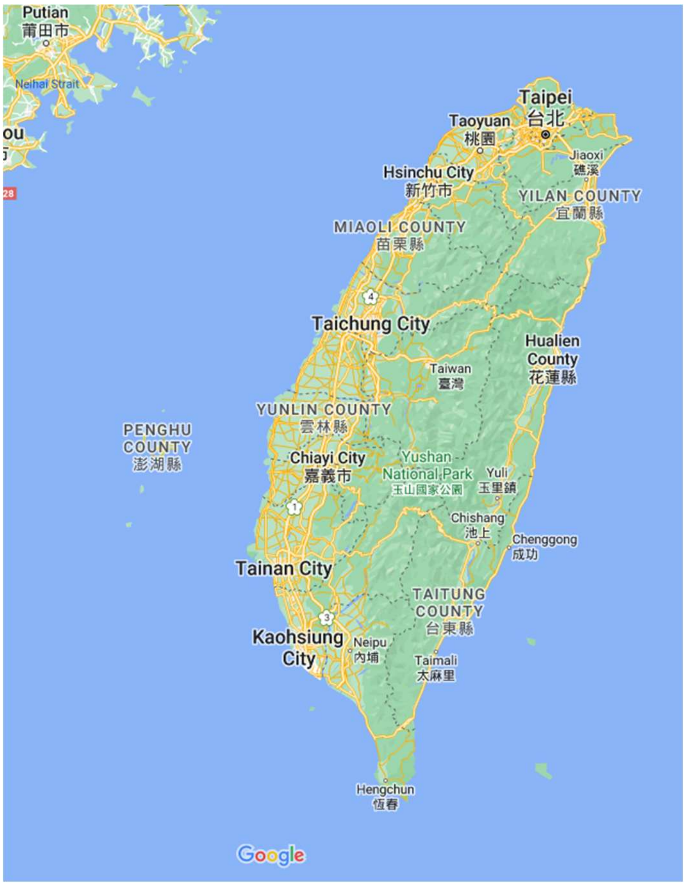

Figure 1: The location of Penghu
Source: Google Maps (2022)

Previous studies (Lin and Chang, 2018; Lin et al., 2020) have discussed the international logistics of Taiwan. However, research on Taiwanese domestic logistics is sparse, particularly with regard to the risk management of island logistics. In particular, the walruses between Penghu and Taiwan are uncertainly dangerous in the typhoon and winter seasons. This is a great example to investigate the cross-maritime logistics in diverse changes walruses. Thus, the purpose of the study is to fill this gap in research and continue to the work of Baz and Ruel (2021) to determine the critical factors of logistics risk between Penghu and Taiwan, and risk assessment can also enhance maritime safety.

2. Literature Review

Small islands need to rely on air and maritime transport for cargo transportation, and maritime shipping is usually chosen due to its low cost. However, there are risks in the transport process. Past studies have pointed out that more than 80% of fatal maritime accidents are attributed to human error (Akyuz et al., 2020). Siamas and Balkamos (2010) stated that the safety of dangerous goods is a problem. Due to transport to islands in no legal way, ordinary passenger ships might to be at risk of accidents. Akyuz et al. (2020) found potential hazards associated with dry bulk cargo transportation, such as improper cargo distribution, fire or explosion, loss or reduction of stability and chemical reactions of cargoes. Thus, it is important to explore risk management between island transportation.

Logistics risk management includes assessing the probability of logistics damage due to an event during delivery or within its environment that negatively affects logistics processes (Kersten et al., 2006). The identification, assessment and analysis of these risks, as well as their management, monitoring and communication throughout transportation, are components of logistics risk management, which attempts to predict logistics risk to prevent damage (Breuer et al., 2013). Therefore, to manage the various threats of risk and disruption, logistics risk management practices can be categorized into four processes: risk identification, risk assessment, risk mitigation, and risk control (Baz and Ruel, 2021).

3. Methodology

3.1. Questionnaire Design and Survey

The risk is a function of the occurrence probability of hazard/failure and severity of consequences (Akyuz, 2015; Gul and Guneri, 2016). This study used AS/NZS ISO 31000-2009 risk management principles and guidelines in Australia. This matrix of risk factors includes two aspects: likelihood and consequences. Likelihood means the probability of occurrence of risk factors from 1 being rare to 5 being almost certain. Consequences means the degree of loss caused by the occurrence of the risk from 1 being insignificant to 5 being catastrophe.

This study used 22 survey questionnaires from the existing literature (Fabiano et al., 2010; Goerlandt and Montewka, 2015; Hetherington et al., 2006; Soares and Teixeria, 2001; Yang et al., 2014) and interviewed local logistics experts. Data were collected from the Directory of the Domestic Association of Shipping Companies in Taiwan in 2018. The total number of mail surveys was 80, and 70 useable responses were received for a response rate of 87.5 percent.

3.2. Conceptual Framework

Based on the literature reviews and expert interviews, there are twenty- two factors, as shown in Table 1.

Table 1: Risk factors and definition

Code	Risk Factor	Definition
H1	Container condition	A shipping container in bad condition can cause unforeseen losses.
H2	Cargo *handling equipment*	Container cargo handling equipment may damage cargoes during rolling.
H3	Poor stowage	Bad stowage inside the container may cause the cargo damage.
H4	*Repacking* of goods	*Repacking* of goods may cause the cargo damage.
E1	Working environment	Cargo handling *in conditions of high* humidity *and heat may cause* may cause the cargo damage.
E2	Weather	Climates *with high* humidity *could affect* the cargo.
E3	Delivery delay	Because of the bad weather may result in delayed.
E4	Wet damage	Wet damage is damage to cargo due to water and wet conditions.
E5	Vessels aground	Cargo ship runs aground to cause cargo damage.
E6	Hit rocks	Cargo ship hits rock to cause cargo damage.
E7	*Ship cargo thrown overboard jettison* due to vessels dangerous	Due to vessels dangerous, *ship cargoes are thrown overboard jettison* to cause cargo damage.
L1	*Loading/unloading time in hurry*	Due to the time pressure of loading/unloading, employee are prone to negligence to cause cargo damage.
L2	Improper operation of equipment	Employee didn't comply with all kinds of machinery safety operation rules and notes to do the load/unload operation.
L3	Shipper's negligence	The goods are not fully packaged.
L4	Intentional fraud by shippers	The goods do not match the contents of the consignment and the goods were detained or *shut out* by customs.
L5	Shipper falsified documents	Shipper used *forged*, fabricated, or other *false documents.*
L6	*Cargo* thefts	*Cargo was stolen in the stack.*
L7	Improper stack the goods	Goods are not stacked correctly and safety which made cargo damage by collapse.
L8	Malicious conduct by captain and crew	Captain and crew sabotage malicious caused the cargo damage.
L9	Misloading and delivery of goods	The goods are misloaded on the ships which caused to send the wrong destination.

L10	Negligence of file work	All written procedures, instructions in paper or electronic form were errors or omissions in orders, contracts, records and data.
S1	Failure of information operating system	Operating systems were fault/ broken.

4. Empirical Study

Regarding the results, the top three occurrences of risks factors were wet damage (E4), working environment (E1) and weather (E2), which are environment risks. The rare likelihood of risk factors were ship cargo thrown overboard jettison due to vessels dangerous (E7), malicious conduct by captain and crew (L8) and cargo thefts (L6).

Moreover, the top three catastrophe loss of risks factors were vessels aground (E5), Malicious conduct by captain and crew (L8) and shipper falsified documents (L5). Repacking of goods (H4), wet damage (E4) and cargo handling equipment (H2) were the most insignificant risk factors.

Table 2: Results of risk assessment

Risk Factor Code	Likelihood			Consequences		
	Average	Deviation	Rank	Average	Deviation	Rank
H1	2.771	0.705	6	2.829	0.589	17
H2	2.600	0.710	7	2.629	0.641	20
H3	2.371	0.854	8	2.700	0.840	19
H4	2.086	0.697	13	2.386	0.621	22
E1	3.171	0.680	2	3.143	0.785	11
E2	3.071	0.621	3	2.871	0.721	16
E3	2.871	0.797	5	3.443	0.715	7
E4	3.529	0.912	1	2.457	1.059	21
E5	1.757	0.908	16	4.000	1.228	1
E6	1.686	0.910	19	3.814	1.219	4
E7	1.414	0.648	22	3.714	1.320	6
L1	2.357	0.743	9	2.900	0.684	14
L2	2.300	0.688	11	2.929	0.709	13
L3	2.886	0.627	4	3.029	0.538	12
L4	2.229	0.516	12	3.443	0.927	8
L5	1.743	0.793	17	3.871	1.203	2
L6	1.686	0.843	20	3.800	1.044	5
L7	2.343	0.759	10	3.257	0.863	10
L8	1.643	0.964	21	3.871	1.250	3
L9	1.929	0.767	14	3.371	1.106	9
L10	1.771	0.745	15	2.900	0.593	15
S1	1.714	0.745	18	2.786	0.797	18
Average	2.269	-	-	3.188	-	-

5. Conclusion and Suggestions

The ISO 31000:2009 analyses approach was used to identify the level of risk management (Purdy, 2010). The results showed that environmental risk during cargo stacking had the highest logistics risk, followed by cargo delivery delays, poor weather during transportation, shipper negligence, and wet cargo damage. In contrast, information system failure had the lowest risk, followed by the height of the palletized good being different from the platform, inadequate documentation, abandonment of dangerous goods at sea, and malicious conduct by crews. Important findings and contributions of this study are discussed in relation to practical domestic maritime transportation.

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Efficiency Evaluation of China Ports Serving the B&R

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Abstract

In order to improve the construction efficiency of ports servicing the Belt and Road (B&R, in short), on the basis of the conventional port efficiency evaluation methods, a slack-based measuring data envelopment analysis (SBM-DEA) model is proposed to analyze the construction efficiency of Chinese ports servicing B&R. The empirical study selected the data of 13 domestic coastal ports and 53 countries along the B&R from 2011 to 2019. The results show that the DEA model with relaxation variables and DEA window analysis method can solve the efficiency deviation caused by neglecting the relaxation variables. Based on the longitudinal dynamic comparison. It is also found that the construction efficiency of ports servicing B&R keeps at a high level with an overall trend of rise after the proposal of B&R initiative. In order to improve the efficiency of services for B&R, it is necessary to further optimize the investment in infrastructure and improve the port route networks with countries along B&R to reduce the input redundancy.

Keywords: port efficiency, The Belt and Road(B&R), SBM-DEA, time window.

1. Introduction

With the continuous development of the Belt and Road initiative, trade between China and countries along the B&R continues keep expanding. From 2014 to 2019, the cumulative value of trade exceeded 44 trillion yuan, with an average annual growth rate of 6.1%. China has become the largest trading partner of 25 countries along the B&R. As an important fulcrum on the B&R, ports play a fundamental role in supporting the connectivity of foreign trade and exchanges (Dong *et al.*, 2016). At the same time, port infrastructure investment and construction in China gradually peaked during this period. The next step to improve the capacity of port services for the B&R lies in efficiency improvement. The Guiding Opinions on Building World-Class Ports also clearly put forward the key tasks for ports to support the B&R construction. Under this background, this paper defines the efficiency of port serving the B&R and one improving DEA model is developed to help to measure the change of efficiency.

Port development under the background of B&R is a research hotspot in recent years. Existing researches mainly put forward corresponding development suggestions based on the practice of local port development, but there are few quantitative studies on efficiency. Xu *et al*. (2018) took ports in Beibu Gulf Economic Circle as the research object and put forward a series of suggestions on giving full play to the role as strategic fulcrum of the 21st century Maritime Silk Road. Pan and Wang (2018) analysed the interconnection status between ports in Fujian province and ports along the 21st century Maritime Silk Road through shipping schedule data of liner companies, and proposed the idea of integrating Fujian ports into the construction of the maritime Silk Road from the three levels of port itself, land hinterland and sea hinterland. Based on the analysis of the content and mode of port cooperation under the strategic background of the Maritime Silk Road, Zhao *et al.* (2016) pointed out the current situation and existing problems of port cooperation along the Maritime Silk Road, and put forward a plan to build a port cooperation mechanism. Wang *et al*. (2020) defined the port ecological niche and established a three-level indicator matrix, quantified and compared the competition and cooperation relationship between Shanghai port and Singapore port under the B&R initiative, and analysed the competition and cooperation strategy of Shanghai port to serve the B&R initiative. Liu and Hu (2017) used the port route connection data along the maritime Silk Road to build a weighted Maritime Silk Road shipping network weighted by the number of routes owned by the country and the monthly average number of trade, and studied the network hierarchy system. They concluded that China's ports are at the second level of the maritime Silk Road network. Zou and Chen (2018) studied the typing of China's major coastal ports (referred to as ports) on the 21st century Maritime Silk Road. On the basis of principal component analysis, they used cluster analysis to classify domestic ports.

In addition, port efficiency is the decisive factor for the port in playing a role in the comprehensive transportation of goods. Therefore, port efficiency research has been a hot topic in the field of port research at home and abroad (Liu and Wang, 2018; Gao *et al*. 2017; Tongzon, 2001; Pang, 2006) for a long time, especially the research on the application of DEA method and related improvements in port efficiency analysis is worthy of reference. Data envelopment analysis (DEA) is an efficiency evaluation method based on multi input and multi output to evaluate the relative effectiveness of objects. It was originally developed by American operations research scientist Charnes *et al*. (1978) on the basis of the concept of relative effectiveness. In the early stage, the traditional models of CCR and BCC were widely used in the port efficiency evaluation based on DEA method. With the further deepening of relevant studies in recent years, the phased DEA method of production function has been widely used. For example, Liu and Wang (2019) used DEA-TOBIT two-stage method to study the operation efficiency of container ports in the middle and upper reaches of the Yangtze River and analyzed the factors affecting the operation efficiency of container ports. At the same time, the radial and angular problems existing in traditional DEA are solved, and the technical efficiency measure based on relaxation model (SBM) is improved to form a general directional distance function, which can solve the problem of efficiency deviation caused by ignoring slack variables. Relevant scholars have adopted this method in port efficiency analysis and achieved good results. For example, Wang and Meng (2013) used meta-Frontier technology and serial SBM-DEA method to conduct comparative analysis on the efficiency of 14 inland ports and 17 coastal ports in China from 2006 to 2009. In addition, relevant scholars introduced window analysis method into DEA model to realize the vertical dynamic comparison of efficiency values of decision-making units, which is worthy of reference.

DEA and a series of improvement methods have achieved good results in port application, but have not been applied to the specific problem of port serve B&R construction. DEA model with relaxation variables and DEA window analysis method can solve the efficiency deviation caused by neglecting the relaxation variables. Based on this, this paper aims at the role of ports in infrastructure connectivity in the B&R construction. On the basis of the conventional port efficiency evaluation methods, an output oriented DEA model considering the relaxation variable is proposed, which is used to analyze the construction efficiency of China's ports servicing the B&R.

2. Methodology

2.1 Output-Oriented DEA model based on slack variable

Most traditional DEA models are radial and angular measurement methods, which are disadvantaged on fully considering the slack of input and output. As a result, the evaluation results cannot distinguish the adjustment size and amplitude of input index and output index, and the efficiency value obtained is not particularly accurate. By introducing slack variables into the objective function, SBM(Slacks-Based Measure)-DEA model can effectively solve the error problem of efficiency estimation caused by ignoring slack variables in the traditional DEA model, which can accurately evaluate the efficiency of port services for the construction of the B&R. The Output-Oriented DEA model measures the inefficiency degree of the evaluated decision-making unit from the perspective of output (Fukuyama and Weber, 2013), focusing on the degree that each output should be increased in order to achieve technical effectiveness without increasing input. At present, the overall handling capacity of China's coastal ports is in a moderately advanced state. The research on the construction efficiency of port serve the B&R mainly focuses on the realization of technically effective service results under the condition of constant input. The output-oriented DEA model is suitable for the research context of this problem.

Assuming there are *n* decision-making unit $DMU_k, k = 1,2...,n$ and each decision-making unit has *m* inputs and *l* outputs. Input and output variables are *x* and *y* respectively, and DMU_k ($1 \le k \le n$) input and output are denoted as $x_k = (x_{1k}, x_{2k}, ..., x_{mk}) \in R_+^m$ and $y_k = (y_{1k}, y_{2k}, ..., y_{nk}) \in R_+^n$ respectively. The input-output matrix is X，Y，and the row vectors x_k ， y_k are the row of *X* and *Y*. Let λ be a non-negatively weighted vector, $\lambda = (\lambda_1, \lambda_2, ..., \lambda_k)^T \in R_+^k$. Set θ as the efficiency value, $1 \le \theta \le \infty$, $\boldsymbol{\lambda}$ connect each effective point to form an effective frontier ， $\theta - 1$ represents the growth rate of output of the DMU_k when input variables remain unchanged, x_k', y_k' are respectively the input and output variables of *DMU*. Then the output-oriented DEA-CCR model is defined as follows:

$$Max\theta \tag{1}$$

$$s.t.\begin{cases}\sum_{k=1}^{n}\lambda_k y_k \geq \theta y_k' \\ \sum_{k=1}^{n}\lambda_k x_k \leq x_k' \\ \lambda \geq 0\end{cases} \tag{2}$$

On the basis of Eq. 1, the output slack variable $s_r^+ = (s_1^+, s_2^+, ..., s_l^+)$ is further considered, and the output-oriented DEA model based on the slack variable is as follows:

$$\theta' = \min \frac{1}{1+\frac{1}{s}\sum_{r=1}^{l} s_r^+ / y_{rk}'} \tag{3}$$

$$s.t.\begin{cases} x_k' \geq \sum_{k=1}^{n}\lambda_k x_k \\ y_k' = \sum_{k=1}^{n}\lambda_k y_k - s^+ \\ \lambda \geq 0, s_r^+ \geq 0, r = 1, 2, \cdots, l\end{cases} \tag{4}$$

θ' represent efficiency value, $0 \leq \theta' \leq 1$. When $\theta' = 1$ and the slack variable is 0, the decision-making unit is DEA effective; otherwise, the decision-making unit is non-DEA effective and there is room for improvement.

2.2 Output oriented SBM-DEA time window analysis

The time window analysis method regards the same decision-making unit at different time points as different decision-making units, and uses a method similar to moving average to evaluate the efficiency of decision-making units. For the efficiency evaluation of port serving B&R, it is necessary to consider the dynamic change of efficiency, and all decision-making units can be compared vertically and horizontally. Therefore, this paper uses output-oriented SBM-DEA time window analysis to measure the evaluation efficiency since the B&R initiative was put forward.

Assuming that n decision-making unit s have d windows, w represents the width of time window, and there are $n \times w$ decision-making unit s in each SBM time window. For any decision-making unit DMU_k, there are $d \times w$ observed values, let the evaluation time span be *T*, then $d = T - w + 1$, the total number of observed variables in $\mathrm{DMU}^T{}_k$ during the evaluation period is $(T-w+1)*w*n$, and the corresponding input is:

$$x_k^{tw} = \left(x_{1k}^t, x_{2k}^t, ..., x_{mk}^t, x_{1k}^{t+1}, x_{2k}^{t+1}, ..., x_{mk}^{t+1}, ..., x_{1k}^{t+w-1}, x_{2k}^{t+w-1}, ..., x_{mk}^{t+w-1}\right), \quad t = 1, 2, ..., T \tag{5}$$

The corresponding output is:

$$y_k^{tw} = \left(y_{1k}^t, y_{2k}^t, ..., y_{lk}^t, y_{1k}^{t+1}, y_{2k}^{t+1}, ..., y_{lk}^{t+1}, ..., y_{1k}^{t+w-1}, y_{2k}^{t+w-1}, ..., y_{lk}^{t+w-1}\right), \quad t = 1, 2, ..., T \tag{6}$$

At present, there is no unified regulation on the width of time window. In order to guarantee the timeliness and stability of calculation, we set w=3. Port serving B&R is a process of continuous input and output, so it is necessary to study the dynamic situation of efficiency, which can compare the dynamic change of efficiency in different stages since the implementation of the B&R initiative.

3. Variable Selection and Data Collection

3.1 Index Selection

3.1.1 Input

Port is an important infrastructure of waterway transportation, an important node of comprehensive transportation link, and an important strategic fulcrum for the country to guarantee transportation safety and domestic and international double circulation. The role of ports in the construction of the B&R is to provide infrastructure connectivity guarantee for the maritime cargo transportation of the "21st Century Maritime Silk Road", mainly reflected in the input of shoreline and berths as production resources, which is the basic guarantee for port operations. Considering the number of production berth *b* and the length *l*, which represent port infrastructure capacity, in order to reflect the comprehensive utilization efficiency of port shoreline, the composite index unit production berth length *b/l* is taken as the input index x_1. On the basis of operation guarantee, the port is connected with the world ports by relying on external routes, so as to realize the economic and trade exchanges with the countries along the B&R. In particular, liner routes with fixed ships and fixed sailing dates and ports can better represent the daily maritime connectivity. Therefore, The Liner Shipping Connectivity Index (LSBCI) between China and countries along the "21st Century Maritime Silk Road" released by UNCTAD is selected as the input index x_2.

3.1.2 Output

Foreign trade is one of the important driving factors for the economic growth of various regions. Under the B&R initiative, various regions actively explore the foreign trade market of countries along the B&R. Ports, as the foundation of infrastructure connectivity, play an important role in it. Therefore, mainly considered from the perspective of ports promoting development of trade between China and countries along the B&R, the throughput of foreign trade goods along the B&R is set as the output index *y*.

3.2 Data

Shanghai, Tianjin, Ningbo Zhoushan, Guangzhou, Shenzhen, Zhanjiang, Shantou, Qingdao, Yantai, Dalian, Fuzhou, Xiamen, Quanzhou, Haikou and Sanya were mentioned in the vision and action of promoting the co-construction of the Silk Road Economic Belt and the 21st century Maritime Silk Road. As data of Sanya and Quanzhou are not available and are excluded from the research object, 13 ports are reserved.

According to the key construction direction of the "21st century Maritime Silk Road", the "21st century Maritime Silk Road" crosses the waters of the Pacific and Indian Ocean, covering most regions of Asia, Europe, Africa and Oceania. Combined with the availability of basic data, 57 coastal countries are selected (Table 1). Since the B&R initiative was put forward in 2013, in order to represent the dynamic changes of the port serve B&R and reflect the specific impact before and after the initiative was put forward, the period from 2011 to 2019 can be selected as the research time range based on the statistics of some data.

Table 1：The research objects

Selected countries along the "21st Century Maritime Silk Road"				
Albania	Estonia	Lebanon	Philippines	Syria
Algeria	Georgia	Lithuania	Poland	Tanzania
Australia	India	Malaysia	Qatar	Thailand
Bahrain	Indonesia	Maldives	Romania	East Timor
Bangladesh	Iran	Montenegro	Russian	Tunisia
Brunei	Iraq	Morocco	Saudi Arabia	Turkey
Bulgaria	Israel	Burma	Singapore	Ukraine
Cambodia	Jordan	New Zealand	Slovenia	UAE
Croatia	Kenya	Oman	Somalia	Vietnam

Cyprus	Kuwait	Pakistan	Sri Lanka	Yemen
Djibouti	Latvia	Papua New Guinea	Sultan	Egypt
Eritrea	Libya			

In terms of input index data, according to the data of China Statistical Yearbook and China Port Yearbook from 2011 to 2019, the input index data obtained are shown in Table 2.

Table 2：The data of input index

Time	2011	2012	2013	2014	2015	2016	2017	2018	2019
The length of berth per unit of production (m)	126.11	129.87	135.88	136.93	138.42	141.38	146.57	148.99	151.82

Liner Unicom Index Based on LSBCI index data, the input index data of 57 countries along the B&R from 2011 to 2019 are shown in Table 3.

Table 3： Liner connectivity index with countries along the Maritime Silk Road

Time	2011	2012	2013	2014	2015	2016	2017	2018	2019
Index	20.50	20.53	20.92	21.14	21.60	22.27	21.60	22.59	22.41

Since the data of cargo throughput between ports and countries along the Maritime Silk Road cannot be directly obtained, the total foreign trade cargo throughput of these 13 ports is calculated based on the port foreign trade cargo throughput data from the Ministry of Transport. The weighted throughput of the Ports from 2011 to 2019 is calculated, and the data obtained are shown in Table 4.

Table 4：Weighted Throughput of the ports along the Maritime Silk Road

Port foreign trade cargo throughput (tons)	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total number	16.45	19.35	22.33	25.87	21.96	23.51	24.03	24.80	25.55
Silk Road foreign trade weight	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.30	0.27
Weighted throughput	4.40	5.22	6.08	7.31	6.07	6.61	7.00	7.41	6.93

The descriptive statistics of variables are shown in Table 5.

Table 5：Descriptive statistics of input-output variables from 2011 to 2019

	Index	Unit	Max	Min	Ave	SD
Input	Berth length per unit of production	m	151.59	123.04	138.11	9.56
	Liner Unicom index	/	22.59	20.50	21.51	0.75
Output	Silk Road trade cargo weight throughput	tons	74122.48	44039.05	63384.03	9491.59

4. Empirical Analysis

Taking 13 domestic key ports and 57 countries along the Silk Road as the object of empirical research, the period from 2011 to 2019 is selected as the research time range. 7 time windows are set such as from 2011 to 2013, from 2012 to 2014 and so on. MaxDEA Ultra 8 software was used to solve the model, and the results are shown in Table 6.

Table 6：Construction efficiency values of the Ports Servicing B&R from 2011 to 2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean value
W1	0.766	0.887	1	/	/	/	/	/	/	0.884
W2	/	0.776	0.875	1	/	/	/	/	/	0.884

W3	/	/	0.875	1	0.821	/	/	/	/	0.899
W4	/	/	/	1	0.821	0.876	/	/	/	0.899
W5	/	/	/	/	0.918	0.978	1	/	/	0.965
W6	/	/	/	/	/	0.939	0.988	1	/	0.976
W7	/	/	/	/	/	/	0.988	1	0.943	0.977
Mean Value	0.766	0.832	0.917	1.000	0.853	0.931	0.992	1.000	0.943	

4.1 Efficiency analysis

According to SBM-DEA analysis, efficiency of ports serving the B&R has shown an overall upward trend since the B&R initiative was proposed in 2013 (starting from time window 2). Results reflect that under the B&R initiative, China's coastal ports havefully grasped their long-term accumulated advantages in the field of infrastructure, the efficiency of serving the "One Belt and One Road" construction has been continuously improved, and the ports have developed rapidly.

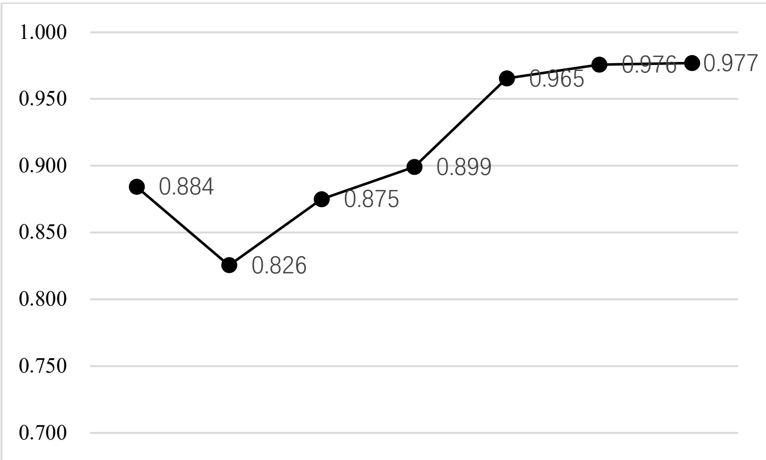

Figure 1： DEA efficiency value in 7 time windows

According to the annual average calculated in Table 6, the efficiency has always remained at a high level, above 0.76, showing a trend of rising fluctuation. The efficiency value reached 1 in 2014 and 2018 respectively. In 2014, the first year after the "21st Century Maritime Silk Road" was proposed, the annual import and export volume of China reached 4.3 trillion yuan. Trade volume with countries along the Silk Road reached $1.21 trillion, a record high. Driven by demand, ports have achieved the highest efficiency in serving the B&R initiative. In 2015, due to the economic slowdown of major emerging economies, world cross-border trade in goods fell by 13.8%, and the Baltic Dry Bulk Freight Index (BDI) also hit a record low, resulting in a significant decline in efficiency due to the sharp decline in demand. In 2018, according to the calculation based on the weighted throughput, The throughput along the Silk Road reached a historical high of 741 million tons. From the perspective of investment, the investment in coastal ports construction in China continued to decline during this period, and coastal ports shifted from large-scale development to high-quality development. Under the joint action of input optimization and continuous rebound of output, the construction efficiency of port services B&R has been continuously improved since 2015, and reached the maximum efficiency again in 2018.

4.2 Analysis of input and output

As shown in Table 7, in the 7 time windows selected by the study, there are problems of input redundancy and output insufficiency.

Table 7：The input-output slack variables

Time window		W 1	W 2	W 3	W 4	W 5	W 6	W 7
The input redundancy	x_1	0.000	0.000	0.000	0.000	0.000	-1.370	-2.632

	x_2	-0.348	-0.956	-0.814	-0.224	-0.879	-0.278	0.000
Insufficient output	y	0.669	1.187	0.871	0.753	0.230	0.169	0.168

According to the data in Table 7, there is input redundancy in time windows 6 from 2016 to 2018 and 7 from 2017 to 2019 for berth length per unit of production x_1, and there is no input redundancy in other windows. As shown in figure 2, with the development of large-scale berths and the gradual relaxation of port investment and construction, the number of production berths across the country has continued to decline. On the other hand, with the advancement of the B&R construction, the supply of port infrastructure serving the B&R has not yet been saturated (there is no redundancy in investment from time window 1 to time window 5), and is still the key point. Continuous addition of new infrastructure leads to gradual capacity saturation and input redundancy in time window 6-7.

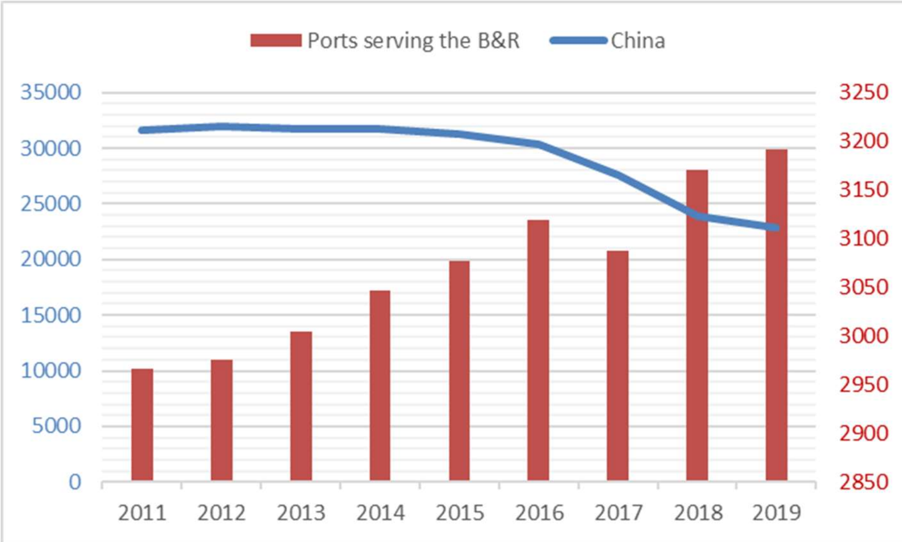

Figure 2：The number of production berths from 2011 to 2019

Except for time window 7, there is input redundancy of shipping line connectivity index x_2 in the other 6 time windows. According to the data in Table 7 above, except for a slight decline in 2017, the x_2 keep overall growth continued from 2011 to 2019, reflecting the gradual deepening of the connectivity between China's ports and maritime liner routes of countries along the "21st Century Maritime Silk Road", especially after the B&R initiative was put forward in 2013. The coastal ports have made the opening of the routes of countries along the Silk Road as the key point of the route development and management and achieved remarkable results.

The problem of insufficient output exists in all the seven time windows selected by the study, indicating that the cargo throughput of the ports along the B&R has not reached the DEA effective target. From the perspective of data changes, with the proposal of the B&R initiative, output deficit has been continuously improved since time window 2.

5. Conclusion

In this paper, an output-oriented DEA model considering slack variables is used to analyze the construction efficiency of ports serving B&R in China. Berth length and shipping line connectivity index are selected as input variables, and weighted throughput is selected as output variable. The empirical study selected the data of 13 China coastal ports and 53 countries along the B&R from 2011 to 2019. The research results show that the construction efficiency of port serving B&R has been maintained at a high level and presented an overall upward trend after the B&R initiative was put forward. Output deficiency exists in all time windows and input redundancy of berth length per unit of production in two time windows (2016-2018 and 2017-2019). There is input redundancy in shipping line connectivity index in all time windows except 2017-2019.

According to the research results, the next step to improve the efficiency of the B&R construction of port services, on the one hand, it is necessary to optimize infrastructure investment to avoid excess investment in port infrastructure construction, and use intelligent equipment to improve infrastructure efficiency to realize optimal allocation of resources and improve investment efficiency. On the other hand, the port needs to improve the route connection with the ports of countries along the "21st Century Maritime Silk Road", especially those in Southeast Asia and the Middle East, and pay attention to the expansion of land and sea combined transport routes.

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Development of Vessel Accident Severity Model Using Statistical and Data Mining Techniques

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Abstract

Purpose – This study aims to develop a ship accident severity model in Korea to find factors that can affect the severity of accidents and suggesting countermeasures to reduce the severity of the accident. In addition, this study attempts to find an accident severity model that shows the best predictive performance by comparing various models.

Design/methodology/approach – In this study, 472 cases of fishing boat accidents that occurred from 2015 to 2017 were collected, and accident scores were set based on the number of accidents, and the top 33%, top 66%, and bottom 33% of the accident scores were classified as very serious, serious, and less serious accidents. Accident severity was analyzed through the Ordered Probit Model(OPM), which is a traditionally used statistical model, and Extreme gradient boosting(XGBoost) and Random forest(RF) model, which are mainly used data mining models. This study intends to select the most suitable model for analyzing ship accident severity by comparing the analysis model with the predictive performance of each model through confusion matrix and ROC curve.

Findings – As a result of the analysis, each model derived similar analysis results. As a result of the OPM analysis, explosion and crash accidents increased the accident severity the most. And as a result of XGboost and RF, it was found that crash accidents have the greatest influence on accident severity. This is because accidents that occur immediately, such as collision accidents, have a shorter response time than other accidents, which can lead to major accidents. As a result of comparative analysis of the predictive accuracy of the model, the XGBoost model was analyzed as the model with the highest predictive performance.

Research limitations/implications – The limitations of this study are as follows.

1. In this study, the accident severity of the variable was set by considering only the number of accidents. It is expected that the severity of accidents such as large-scale container ships can also be derived if an index that converts economic losses considering the size of the accident and the amount of compensation can be developed and analyzed in future studies.
2. Although the analysis was conducted by referring to the methodology and analysis results presented in the preceding research, additional research is needed considering the environment and characteristics of the maritime ship operation for the derived factors.

Social implications – As a result of the study, factors affecting the severity of ship accidents were derived, and countermeasures against the factors were suggested. This can help build policies and infrastructure that can reduce the severity of ship accidents.
In Korea, there are not many studies related to ship accidents, so the data collection and analysis system is insufficient. This study suggests the direction of the future ship accident severity study. Based on this study, various research standards and additional analysis can be carried out from this study.

Originality/value – This study analyzed the severity of accidents on ships that have not been studied in Korea. In particular, variable importance was derived not only through OPM, which is an existing statistical model, but also through machine learning-based RF and XGB models. That is, it is possible to increase the reliability of the analysis results by comparing machine learning-based analysis results with high prediction accuracy rather than a single linear regression model.

Keywords - Vessel accident, Fishing boat accidents, Accident severity, Data mining, Extreme gradient boost, Random forest, Ordered Probit Model

1. Introduction

Unlike traffic accidents that occur on the road, ship accidents that occur at sea can cause not only environmental pollution due to oil spills, but also hurt many people due to one accident. In addition, due to the nature of ships that are difficult to evacuate and rescue immediately due to safety zones, the severity of accidents may increase over time. According to marine accident statistics provided by Korean Maritime Safety Tribunal, the number of marine accidents is increasing every year from 2016 to 2020. Accidents caused by safety and carelessness that can be prevented sufficiently are also increasing every year. To reduce such ship accidents, this study intended to prevent accidents by deriving the severity of ship accidents and predicting dangerous situations. A ship accident severity model was produced by selecting the factors influencing the accident in the ship accident data. This study aims to analyze factors that can affect the severity of ship accidents and to prepare countermeasures to reduce damage. In addition, to analyze the severity of ship accidents, this study tried to compare and evaluate various models to see which methodology is appropriate. Comparing the results derived through various models, there is any difference in the conclusion by model. And this study could find which model is suitable for analysis, and the reliability of the model could also be compared by deriving the prediction accuracy of the model.

2. Literature review

2.1 Previous research on accident severity

To derive a vessel accident severity, previous studies related to traffic crash severity was investigated. Through previous study research, it is possible to know for what purpose, what analysis procedures are performed, and what contents should be considered in the severity analysis results. Ha et al. (2005) attempted to analyze the factors affecting accident severity for the purpose of improving intersection safety (Ha *et al.*, 2005). In this study, the crash severity model was developed by applying the Ordered Probit Model (OPM) considering the characteristics of the data. By analyzing the correlation coefficient, variables affecting the severity of traffic accidents at intersections were derived. Yang et al. (2021) analyzed the freight truck crash severity by utilizing the Extreme Gradient Boost (XGBoost) model. The importance of variables was derived through the XGBoost model, and it was analyzed that variables related to the construction environment, demographics, land use, and road network showed a high correlation with cargo truck collision accidents (Yang, Chen and Yuan, 2021). Joo et al. (2017) tried to find the factors affecting the level of injury of the bicycle driver. Cluster analysis was performed using decision trees, and which variables influenced the accident severity of cyclists were analyzed through an OPM (Joo, Jung and Oh, 2017). As a result of the analysis, it was found that the type of crash vehicle and the age of the bicycle driver affected the accident severity, and the time periods and road topographic conditions were analyzed as factors that increased the accident severity.

2.2 Previous research on Ship accident

To find the main cause of the ship accident, previous studies related to ship accident factors were investigated. Wang et al (2021) analyzed the factors affecting the severity of marine accidents, and derived the main factors through an ordered logit model. As a result of the analysis, it was analyzed that the severity of the accident was affected when the sunken accident, the accident occurred in an area far from the port, and the weather conditions were strong wind, rough current, rough waves, and good visibility (Wang *et al.*, 2021). Kim & Kwak (2011) examined accidents that occurred in human factors in ship accidents in Korea and analyzed the importance of factors. As a result of the analysis, casualties are the most common due to human error and are most related to collision accidents. In addition, the lack of alertness and navigation factors were identified as the biggest factors in collision accidents. Accordingly, it was analyzed that the inspection and supplementation of the alert alarm system on the vessel and the lightning, horn and navigation compliance to avoid navigation errors are of the utmost importance. (Kim and Kwak, 2011). Bae & Lee (2014) developed a preventive index for the purpose of ship accident safety management and in order to design it, the prevention index was defined by extracting the prevention factors and factors based on the accident statistics collected over the past 5 years. (Bae and Lee, 2014). Park et al. (2018) analyzed the marine accident statistics provided by the Korea Maritime Safety Tribunal to reduce small fishing boat accidents (Park *et al.*, 2018). Jang & Yim (2019) gathered 4 years marine accident statistics to build a preemptive response system for marine accidents, and predicted the frequency of marine accidents by using Markov Chain (Jang and Yim, 2019)

2.3 Review of previous study and differentiation

In Korea, the crash severity study was mainly conducted by highway interval, bicycle, and pedestrian research, but the study of accident severity of marine accidents and ship accidents was insufficient. In addition, research on ship accidents was mainly conducted on the analysis of the causes and factors of ship accidents (Kim and Kwak, 2011). Therefore, this study aims to analyze the severity of fishing boat accidents occurring in Korea and derive which model is suitable for analysis.

In addition, it was analyzed through statistical data compiled by the Korea Maritime Safety Tribunal, such as the development of ship accident prevention numbers using statistical data (Bae and Lee, 2014) and the prediction of marine accident frequency (Jang and Yim, 2019). Therefore, in this study, unlike the studies analyzed based on existing widely aggregated statistical data, clearer research results and conclusions can be drawn through analysis using actual accident data with more detailed information.

3. Data and Methodologies

3.1 Analysis Overview

In this study, 472 cases of fishing boat accidents that occurred from 2015 to 2017 were collected. Ship accident severity was analyzed through the OPM, which is a traditionally used statistical model, and XGBoost and Random Forest(RF) model, which are mainly used data mining models. For the analysis models, the prediction performance of individual models was derived using the confusion matrix, and the prediction performance between models was compared using the ROC curve. As a result of the analysis, correlation coefficient and accident probability were derived by the OPM, and the importance of variables by influential factors was derived through the extreme gradient boosting model. As a result, the factors affecting the accident severity and the probability of occurrence according to the severity of the accident were derived. Based on the analysis results, countermeasures were suggested according to the factors affecting the accident severity. The process of conducting this study is presented in Figure 1.

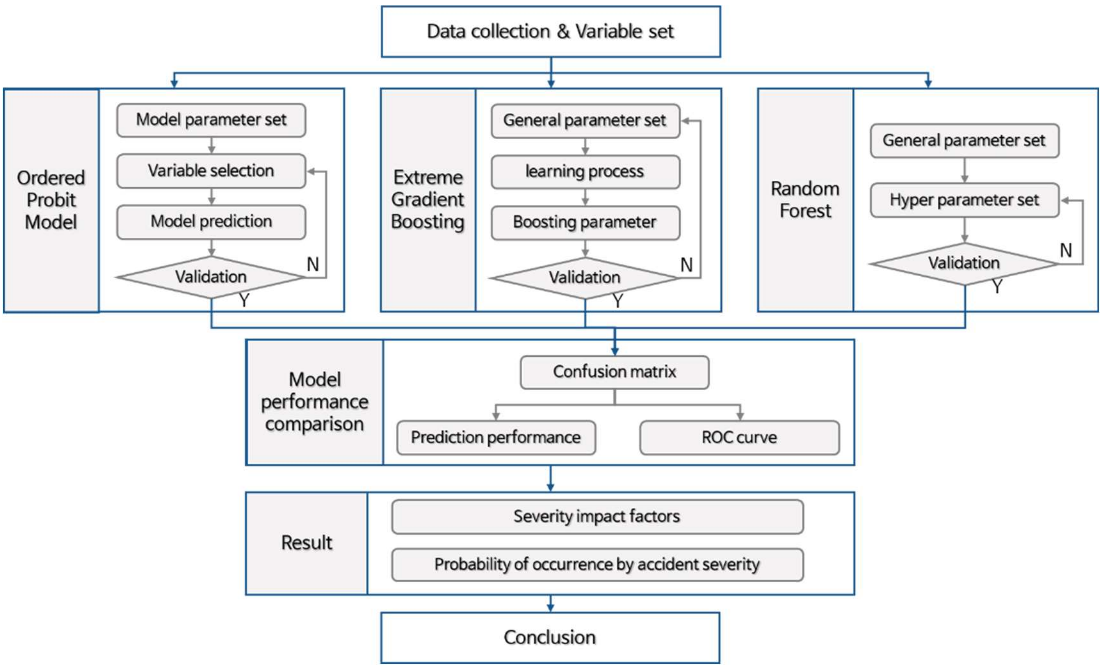

Figure 2: Process of the study

3.2 Data collection and variable selection

3.2.1 Accident data collection and descriptive statistics

As for the accident data, 472 fishing boat accidents with the highest frequency among ship accidents that occurred on the east coast of Gyeongsangbuk-do from 2015 to 2017 were counted. In the ship accident data, accident severity according to the number of accidents was designated as a dependent variable, and accident data related to the ship accident was designated as an independent variable (Al-Ghamdi, 2002). Table 1 shows the explanation and basic statistics of the number of accident people and structural response variables, which are numerical variables. Of the 2,819 people in accidents caused by fishing boats, 96.4% and 2,718 people were rescued, accounting for the largest portion, and the remaining 3.6% of the people in accidents were injured, missing, and died. The rescue response represents the time and distance it took to get to the rescue, and the average rescue response distance was 12.24 km and the response time was 62.93 minutes. The longest response distance took 173 km and the response time took 1437 minutes.

Table 1: Variable description and Descriptive statistics

Variable classification	Variable	Description	# of cases	Mean	Std.	Min	Max
The number of accidents	rescued	Unit: Persons	2718	5.758	6.859	0	102
	injured	Unit: Persons	62	0.131	0.608	0	10
	missing	Unit: Persons	20	0.042	0.296	0	4
	death	Unit: Persons	19	0.040	0.333	0	5
Rescue response	rescue distance	Distance from dispatch point to accident point (Unit: km)	-	12.248	20.395	0	173
	rescue time	The time it took to get to the accident point (Unit: minute)	-	62.930	115.297	0	1437

In the accident data, nominal variables such as accident occurrence sea area, type of occurrence, cause of occurrence, and weather special report at the time of the accident were coded as dummy variable (O: 1, X: 0). Table 2 shows the frequency of occurrence and variable description of nominal variables. The most frequent occurrence of accidents in the waters was 221 accidents in the territorial waters, The most common occurrence type was 181 cases of engine damage, cause of occurrence was 223 cases of carelessness in handling fire, and weather reports was 391 cases when the weather was good.

Table 1: Nominal variable description and Frequency

Classification	Variable	Variable description	Frequency
Occurrence in the waters	Within 30 miles of EEZ	Within 30 miles outside the Exclusive Economic Zone (EEZ); up to 200 nautical miles from the point of origin	14
	International waters	Sea in which sovereignty or exclusivity does not belong to a particular country	6
	Territorial waters	Up to 12 nautical miles from the point of territory	221
	Territorial waters - EEZ	Sea area between the territorial waters and EEZ	150
	Foreign waters	Foreign waters outside of the territory	1
	within the harbor	Within the boundary of a port	80
Occurrence type	Engine damage	Damage to main engine, boiler, main auxiliary engine, fuel and cooling water pumps, etc.	181
	Etc.	Other marine accidents	1
	Safety impairment	An accident that caused marine floats to wind up in the propellant during navigation and could not continue sailing	60
	Operational disruption	An accident that caused no damage to the hull due to sitting on a sand island, etc., but made it impossible to continue sailing	13

	Casualty accidents	Human injuries, fatal accidents	35
	Rollover	An accident in which a ship was overturned	6
	Contact accident	An accident that strikes an external object or facility	2
	Distress accident	An accident in which the safety of the vessel is at risk due to abnormalities	2
	Stranded accident	An accident that was laid or struck on a seabed, reef, wreck, or rock or shore	22
	Propellant damage	Damage to the propulsion shaft system, thrusters, clutches (power transmission) etc.	13
	Collision accident	An accident that hit or touched another ship	54
	Sinking accident	An accident that has subsided as a result of flooding due to bad weather, cracks in outer plates, and cuts, etc.	7
	Flooding accidents	An accident in which the water flows in the ship and the ship is damaged	30
	Rudder damage	An accident in which a hydraulic steering device or rudder is damaged	19
	Explode accident	An accident in which rapid expansion or rupture occurred due to rapid combustion	2
	Fire accident	An accident in which property and human life were damaged by fire	25
Cause of occurrence	Human error	Factors of human accidents caused by the negligence of management supervision	16
	Weather deterioration	Caused by rapid changes in weather and marine conditions	19
	Fuel depletion	Fuel shortage and depletion	30
	Navigation carelessness	Accidents caused by negligence of forward gaze and insufficient automatic identification system	8
	Loading failure	Poor strapping of cargo loaded on board the ship	155
	Maintenance defective	Poor inspection of facilities	3
	Carelessness in handling fire	Accidents caused by careless handling of heating facilities, kitchen facilities, and electrical equipment on the ship	223
	Etc.	Caused by other than the above-stated accident	18
Weather condition	Good weather	Good weather conditions	391
	Low visibility	Visibility Less than 1000 yards	4
	Typhoon warning	When the typhoon is expected to be more than 17m/s or more, the rainfall is expected to be 100mm or more	4
	Wind warning	When the condition of wind speed more than 21m/s, lasts for more than 3 hours or the significant wave height is expected to exceed 5m	6
	Wind advisory	When the condition of wind speed more than 14m/s, lasts for more than 3 hours or the significant wave height is expected to exceed 3m	27
	Sea state code 5 (rough)	Wave height: 2.5 to 4.0 m	4
	Sea state code 4 (moderate)	Wave height: 1.25 to 2.5 m	36

3.2.2 Dependent variable setting

Accident severity, a dependent variable, was derived based on the number of accidents that occurred for each accident. 5*(death + missing person) +3*(injured person) +1*(rescued person) calculated accident score $\mathbf{y}$, and the top 33% of accident score was very serious accident ($Y=2$), 66% was serious accident ($Y=1$), and the rest was less serious accident ($Y=0$). Examples of accident scores and accident severity divisions are shown in Table 3.

Table 3: Accident score and Severity rank

Rescued	Injured	Death	Missing	y =5*(death + missing) +3*(injured) +1*(rescued)	Rank	**Y**
102	0	0	0	102	0.996	2
23	0	2	4	53	0.995	2
10	10	0	0	40	0.993	2
. . .	. . .	. . .	. . .	. . .	. . .	. . .
1	0	0	0	1	0.079	0
0	0	0	0	0	0.001	0
0	0	0	0	0	0.001	0

3.3 Methodologies

In this study, to improve the accuracy of the study, an OPM, an XGBoost model, and a RF model were derived. Among the Ordered Logit and Probit models, which are models used when there is a hierarchy of dependent variables, the probit model was used in this study. Rather than these general statistical models, we intend to improve the research accuracy by comparing extreme gradient boosting model and a RF model that are commonly used among heuristic models.

3.3.1 Ordered Probit models

The OPM is used to assume the distribution of error terms ϵ_i as a normal distribution. OPM can represent the potential accident severity through explanatory variables X_i, parameters β, and error terms ϵ_i, as shown in Equation 1. The dependent variable is determined by a less serious accident, serious accident, and a very serious accident through the threshold value μ obtained according to the value of the parameter.

$Y_i^* = X_i\beta + \epsilon_i, \qquad \epsilon_i \sim N[0,1]$

$\mathrm{Y_i} = 0$ if $Y_i^* = 0$ $\mathbf{Y_i}^* \leq 0$ (Less serious)

$\mathrm{Y_i} = 1$ if $0 < Y_i^* < \mu^{\mu}$ (Serious)

$\mathrm{Y_i} = 2$ if $\mu < Y_i^*$ (Very serious) (1)

The probability of selection for each accident severity can be expressed as a cumulative standard normal distribution function Φ as shown in Equation 2.

$$Prob[y = 0] = \Phi(-\beta x)$$
$$Prob[y = 1] = \Phi(\mu - \beta x) - \Phi(-\beta x)$$
$$Prob[y = 2] = 1 - \Phi(\mu - \beta x) \qquad (2)$$

The marginal effect showing the effect of the explanatory variable on the accident severity can be analyzed through partial derivatives for each selection probability, as shown in Equation 3.

$$\frac{\partial Prob[y=0]}{\partial x} = \varphi(\beta'^{x})\beta$$
$$\frac{\partial Prob[y=1]}{\partial x} = [\varphi(-\beta' x)\beta - \varphi(\mu - \beta' x)]\beta$$
$$\frac{\partial Prob[y=2]}{\partial x} = -\varphi(\mu - \beta' x)\beta \qquad (3)$$

3.3.2 Ensemble model: Extreme Gradient Boosting, Random Forest

In a machine-based model, an ensemble scheme is a method of combining multiple learning algorithms (decision trees) to improve predictive force. Boosting, one of the ensemble techniques, is a method of repeating the process of creating a new model several times by weighting the produced learning algorithm according to model accuracy (Dietterich, 2000). Among the various boosting techniques, gradient boosting predicts the resulting value y through the model and predicts the next model based on the residual, the difference between the actual value and the predicted value. This allows the residuals to continue to be reduced after the step (gradient descending) and produce an optimal model with a residual close to zero. XGBoost, unlike gradient boosting, uses an ensemble model called CART to create a tree. The CART model is associated with all classification results in the model's score, which allows you to select more accurate models even if you have the same classification (Chen and Guestrin, 2016). Extreme gradient boosting is performed according to the algorithm in Figure 2.

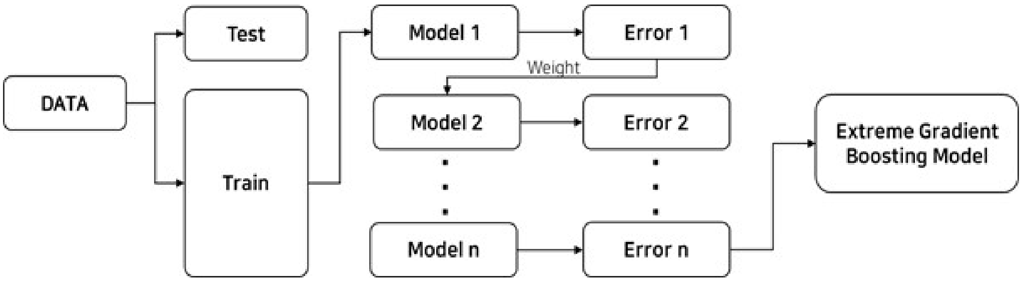

Figure 2: Extreme Gradient Boost Model

The extreme gradient boosting model can predict the result value by summing all of the generated CART models. The formula of the model can be summarized as equation 4. In Equation 4, K denotes the number of trees and F denotes the set of all possible CART models.

$$\hat{y}_i = \sum_{k=1}^{K} f_k(x_i), \quad f_k \in F \qquad (4)$$

Other ensemble techniques include bagging. Bagging is a method of creating multiple learning algorithms (decision trees) with randomly extracted data (bootstraps) and aggregating the average of the results generated to create the final model (Dietterich, 2000). RF is a representative method of bagging. RF can reduce correlation between models by randomly selecting explanatory variables when generating decision trees (Breiman, 2001). The importance of the variable in the RF is MDA (Mean Decrease in Accuracy) when the dependent variable is nominal, and the percentage increase in Mean Square Error (%incMSE) when it is continuous. RF model is performed according to the algorithm in Figure 3.

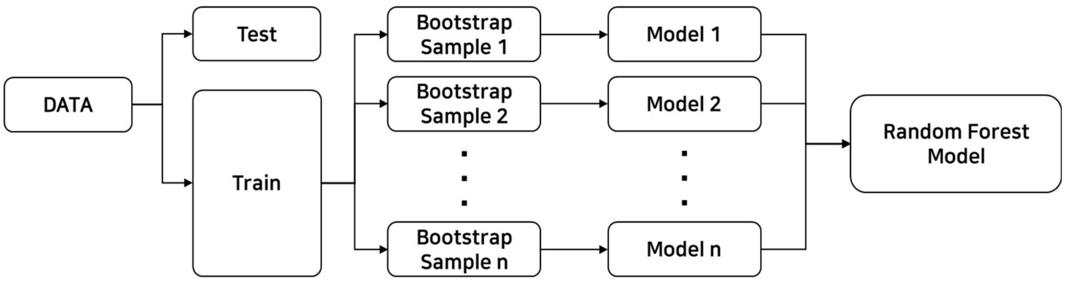

Figure 3: Random Forest Model

4. Results and discussions

4.1 Confusion matrix

To compare the predictive performance of the two models, the confusion matrix was used in this study. The confusion matrix is a matrix of the predicted value of the model and the frequency of the actual value, and it can evaluate the diagnosis, discrimination, and prediction performance of the model. The results of deriving the confusion matrix by model are shown in Table 4

Table 4: Confusion matrix: Ordered Probit model

Predicted value		Ordered probit model			Extreme gradient boosting			Random forest		
		Less serious	Serious	Very serious	Less serious	Serious	Very serious	Less serious	Serious	Very serious
Actual value	Less serious	147	0	8	153	4	7	150	1	13
	Serious	87	4	63	16	53	3	24	34	14
	Very serious	35	1	127	13	2	79	11	5	78

Accuracy, Precision, Positive Predictive Value, Sensitivity, Recall, and Specificity can be derived through the confusion matrix, and the larger the value, the better the predictive performance. The results of deriving prediction performance for each model are summarized as shown in Table 5.

Table 5: Prediction performance

Prediction performance	Less serious			Serious			Very serious		
	OPM	XGBoost	RF	OPM	XGBoost	RF	OPM	XGBoost	RF
Balanced Accuracy	0.7818	0.8791	0.8519	0.5114	0.8564	0.7245	0.7747	0.8990	0.8577
Sensitivity	0.9484	0.9329	0.9146	0.0260	0.7361	0.4722	0.7791	0.8404	0.8298
Specificity	0.6151	0.8253	0.7892	0.9969	0.9767	0.9767	0.7702	0.9576	0.8856
Pos Pred Value	0.5465	0.8407	0.8108	0.8000	0.8983	0.8500	0.6414	0.8876	0.7429
Overall accuracy	OPM = 0.5890; XGB = 0.8636; RF = 0.7939								

Performance evaluation for each model can be evaluated by comparing the ROC (Receiver Operating Characteristic) curve. The ROC curve can be drawn using specificity and recall, and the farther the curve is from the diagonal of the graph, the better the model. Therefore, to compare the model numerically, AUC(Area Under the Curve) was calculated. The wider the AUC, the better the performance of the model. Figure 3 is a visualization of the ROC curves of the models, and the ROC curve analysis shows that the extreme gradient boosting model is superior to all accident severity predictions.

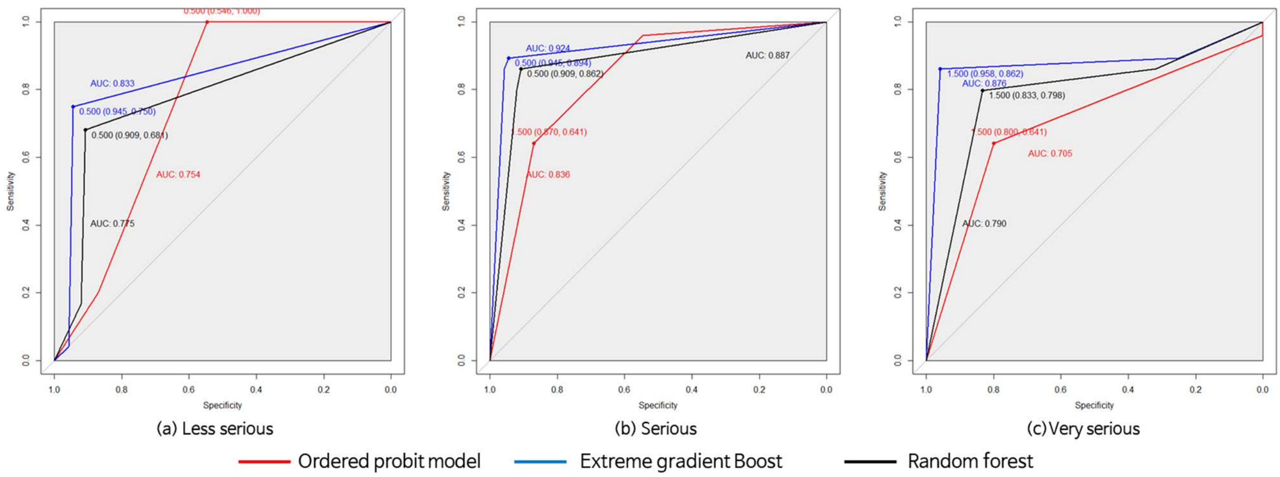

Figure 3: ROC curve

4.2 Results of Ordered probit model

The correlation coefficient estimation results of OPM are summarized as shown in Table 6. The significance probability of the model is less than 0 for the chi-square value (Prob > chi2) at the 90% confidence level, indicating that the model is statistically significant. As a result of comparing the estimation coefficients of each explanatory variable, the effect of the explanatory variable on the accident severity is 2.382, which is the largest explosion accident, and the influence increases in the order of collision, contact, distress accident, etc. Among the types of occurrences, flooding accidents are shown to lower the severity of accidents because there is more time to respond to accidents than other accidents, which can increase the number of rescue workers to lower the severity of accidents. Among the rescue correspondence indicators, the response time has a positive correlation coefficient. In other words, as the response time increases, the severity of the accident increases. The accident according to weather conditions showed that the wind warning increased the accident severity than the wind warning. This is because the number of wind warnings is 6 out of the total accidents, and the number of data is small, and it is not significant as a descriptive variable of the model. In addition, when the wind warning is issued, the frequency of fishing boats is reduced because it is more dangerous than the wind warning.

Table 6: Coefficient results of Ordered Probit Model

Descriptive variable	Coefficient	Standard error	Significance
Constant	0.972	0.211	0.000
Occurrence in the waters			
Within 30 miles of EEZ	1.237	0.348	0.000
International waters	1.234	0.581	0.034
Territorial waters-EEZ	1.160	0.143	0.000
Occurrence type			
Casualty accident	0.730	0.252	0.004
Contact accident	1.555	0.838	0.063
Distress accident	1.413	0.786	0.072
Stranded accident	0.599	0.279	0.032
Collision accident	1.841	0.248	0.000
Flooding accident	-0.817	0.298	0.006
Explosion accident	2.382	0.851	0.005
Cause of occurrence			
Weather deterioration	0.929	0.361	0.010
Navigation carelessness	0.832	0.239	0.000
Maintenance defective	0.936	0.225	0.000
Weather condition			
Wind advisory	0.785	0.308	0.011
Response time	0.003	0.001	0.002
μ	1.248	0.088	0.000
Log likelihood	-386.438	Prob > chi2	0.000
LR chi2(15)	263.91	Pseudo R2	0.255

The results of estimating the marginal effect of the sequential probit model are summarized as shown in Table 7. As a result of the analysis, accidents within 30 miles of the exclusive economic zone (EEZ) and between the EEZs and the territorial waters increase the probability of very serious accidents by more than 40%, as the structural distance is far away, which can increase the number of victims.

It was analyzed that the accident that increases the most probability of a very serious accident is an explosion accident, which increases the probability of occurrence by 68.5%. In this way, explosions, collisions, contacts, and distress accidents increase the probability of very serious accidents by more than 5 to 60%, but flooding accidents increase the probability of less serious accidents by 30%. This is because there is less chance of a very serious accident and an increase in the probability of a less serious accident because there is time for a flood accident to respond and evacuate compared to an explosion, collision, contact, or distress accident.

Accidents caused by weather deterioration increase the probability of very serious accidents by 35.4%, and the probability of very serious accidents increases by 29.8% when forecasting wind advisory warnings. Therefore, it can be seen that high accident severity may occur in case of weather deterioration, and countermeasures are needed to reduce the accident severity.

Table 7: Marginal effect of Ordered Probit Model

Descriptive variable	Less serious	Serious	Very serious
Occurrence in the waters			
Within 30 miles of EEZ	-0.233	-0.231	0.464
International waters	-0.227	-0.236	0.463
Territorial waters-EEZ	-0.310	-0.103	0.413
Occurrence type			
Casualty accident	-0.180	-0.095	0.275
Contact accident	-0.240	-0.314	0.555
Distress accident	-0.235	-0.282	0.517
Stranded accident	-0.153	-0.072	0.225
Collision accident	-0.312	-0.326	0.639
Flooding accident	0.303	-0.093	-0.210
Explosion accident	-0.254	-0.432	0.685
Cause of occurrence			
Weather deterioration	-0.204	-0.150	0.354
Navigation carelessness	-0.236	-0.059	0.295
Maintenance defective	-0.288	-0.025	0.312
Weather condition			
Wind advisory	-0.187	-0.111	0.298
Response time	-0.001	0.000	0.001

4.3 Results of XGB model

The extreme gradient boosting model can prevent overfitting of the model by adjusting hyperparameter values such as general, learning process, and boosting parameters. Hyperparameters are adjusted through cross-validation, and in this study, they were verified through stratified K-fold, which is mainly used in classification model verification. In this study, as shown in Table 8, the optimal number of repetitions and accuracy were compared to derive optimal hyperparameter values excluding the overfitting model.

Table 8: XGBoost: hyperparameter setting

	Learning rate	Max depth	Sub sample	Col sample by tree	Min child weight	gamma	Best Iteration	Overall Accuracy
#1(default)	0.3	6	1	1	1	0	12	0.8758
#2 (min)	0.01	1	0.1	0.5	1	0	943	0.703
#3 (max)	0.2	10	1	1	7	0	3	0.8424
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
#n	0.8	4	0.7	0.7	0.5	0.13	98	0.8636

Gain, Cover, and Frequency can be derived as the importance of variables of extreme gradient boosting. Gain indicates how much the variable affected the model prediction, and in this study, it was analyzed based on the Gain value, which is generally used as the most relevant attribute when indicating the importance of the variable. The analysis results were summarized in Figure 4, and the variables of response distance and response time were found to have the highest importance. That is, the response distance and response time have the greatest influence on the accident severity, and the corresponding method for the factor is most important. Countermeasures accordingly may include real-time monitoring and expansion of rescue facilities. In addition, as for the type of accident, it was analyzed that the collision had the greatest effect on the accident severity, and among the areas where the accident occurred, the accident that occurred in the territorial sea-EEZ had the greatest effect on the accident severity. In conclusion, it was confirmed that the analysis results of OPM and XGBoost were not opposite to each other, and were derived somewhat similar.

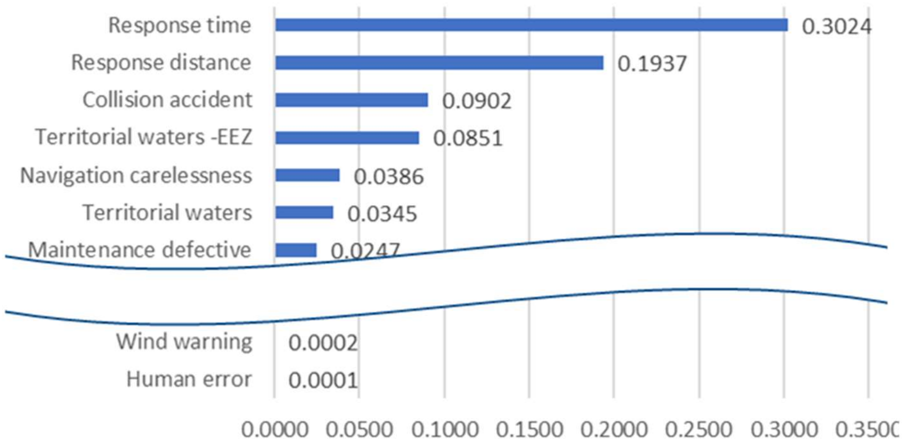

Figure 4: XGboost Gain results

4.3 Results of Random forest model

The accident severity of RF can be derived through the Mean Decrease Accuracy. The variable from which the importance of the largest variable was derived was 12.762 as a collision accident, followed by territorial sea-EEZ and rescue distance. That is, it can be seen that the accident severity impact factor derived through RF is derived similarly to other models. The variable importance derived through RF is shown in Table 9.

Table 9: Random forest: MDA results

Variable classification	Less serious	Serious	Very serious	Mean Decrease Accuracy
Rescue responce				
Response distance	12.017*	3.748*	5.823*	11.997*
Response time	9.989	2.940	4.269	10.260
Occurrence in the waters				
Within 30 miles of EEZ	7.509	5.207*	-1.213	7.067
International waters	0.816	1.392	1.506	1.745
Territorial waters	8.324	1.041	5.934	8.893
Territorial waters -EEZ	11.842*	1.735	8.799*	12.041*
Foreign waters	0.000	0.000	0.000	0.000
Within the harbour	6.181	1.689	1.924	6.341
Occurrence type				
Engine damage	-0.351	-1.812	4.392	2.338
Etc.	0.000	0.000	0.000	0.000
Safety impairment	2.862	4.509*	-5.638	1.592
Operational disruption	-0.129	-0.903	-0.718	-0.687

Casualty accidents	3.504	1.047	4.331	5.032
Rollover	4.047	-1.416	-0.127	2.246
Contact accident	3.642	0.000	-2.096	1.673
Distress accident	-3.494	0.000	1.417	-3.192
Stranded accident	0.534	3.744	3.143	2.996
Propellant damage	-1.306	-0.122	-2.013	-2.095
Collision accident	9.883*	3.666	12.657*	12.762*
Sinking accident	2.616	1.001	0.000	2.625
Flooding accidents	4.841	-2.464	7.209	6.448
Rudder damage	1.822	1.016	-0.255	1.518
Explode accident	-4.044	0.000	-1.730	-4.212
Fire accident	1.253	-1.556	5.402	3.049
Cause of occurrence				
Human error	-0.006	3.127*	5.168	3.852
Weather deterioration	1.468	-0.962	-0.352	0.743
Etc.	4.804	-2.309	6.448	5.810
Fuel depletion	-0.487	-1.731	3.209	-0.022
Navigation carelessness	7.496*	1.098	6.955*	8.672*
Loading failure	0.000	0.000	0.000	0.000
Maintenance defective	4.152	-1.175	2.123	4.921
Carelessness in handling fire	2.866	-2.564	1.913	2.597
Weather condition				
Good weather	5.979*	0.072	1.934	5.191*
Low visibility	-0.342	-1.736	-2.199	-2.022
Typhoon warning	2.980	0.000	1.935	3.434
Wind warning	-3.257	-2.724	0.475	-3.095
Wind advisory	1.632	2.235*	2.546*	3.365
Sea state code 5 (rough)	-1.951	1.406	-2.979	-3.220
Sea state code 4 (moderate)	3.325	-1.145	0.093	1.856

*In table, biggest number in each classification are colored in blue

5. Conclusions and recommendations

Marine ship accidents are increasing every year, and fishing boat accidents account for the largest portion of the total accidents, accounting for more than 66%. Nevertheless, there is no research on ship accidents in Korea, and no research on the seriousness of accidents has been conducted. In order to derive the severity of ship accidents, this study analyzed 472 fishing boat accidents with the highest frequency among 612 ship accidents that occurred on the east coast of Gyeongbuk from 2015 to 2017. The collected data derived accident scores based on the number of accidents, and the top 33% were classified into very serious accidents, the top 66% were serious accidents, and the rest were less serious accidents. The analysis model was analyzed through OPM which is traditionally used statistical model, and XGBoost model, RF model, which are data mining-based models. And the factors influencing accident severity and probability of occurrence were derived through the model.

As a result of the analysis, it was found that the severity of the accident increased according to the area, type of accident, and weather conditions. In the area where accidents occur, accidents in large areas outside the territorial waters increase the severity of accidents, and the probability of very serious accidents increases. This is because the time and distance required for rescue increase, resulting in difficulty in rescue compared to other accidents. Therefore, in order to reduce the seriousness of the accident, it is necessary to have devices, equipment and infrastructure to track the ship's position outside the territorial waters. As for the characteristics of each type of accident, explosion, collision, contact, and distress which are difficult to cope with immediately in the ship increase the probability of very serious accident by more than 50%, while the flooding accident that can identify and respond to the accident and topped and evacuate, the probability of increasing the likelihood of less accidents, and the probability of a very serious accident will occur. Weather conditions showed that accidents caused by weather deterioration increased the probability of very serious accidents by 35.4%, and especially increased by 29.8% in the forecast of wind advisory. Accordingly, it is necessary to provide direct weather information and warning systems to fishing boats at fishing ports, and to establish a system that allows maritime police to respond immediately in case of bad weather.

As a limitation of this study, the accident severity analysis was analyzed in consideration of only the number of accidents. In future studies, it is expected that the severity of accidents such as large container ships can also be derived by developing an index that converts economic losses in addition to the size of accidents and compensation. In addition, although the analysis was performed by referring to the methodology and analysis results presented in previous studies, it is unclear whether the derived factors actually considered the environment and characteristics of maritime ship operation. Therefore, future studies will need to analyze whether the countermeasures based on the factors derived from the analysis results have actual accident reduction effects.

Finally, due to the structural characteristics of the model, the derived model could not be interpreted in the same standard and method. In the analysis of accident severity, OPM, a traditional linear regression model, can derive marginal effects as well as estimating the importance of variables through correlation coefficients. The marginal effect can derive the probability of the occurrence of a dependent variable for each explanatory variable, and accordingly, it is possible to analyze specifically which explanatory variable increases or decreases the accident severity. However, the XGBoost model finally selected in this study can derive only the importance of variables in explanatory variables. Therefore, future studies are expected to select a model that is more suitable for the goal to be derived if not only the predictive performance of the model but also the contents required for analysis are considered.

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Typhoon-induced Disruption and Losses in China's Coastal Ports

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Abstract

Purpose – The purpose of this research is to calculate the disruption days and economic losses of 31 ports from five port clusters caused by typhoons from 2006 to 2020 and to analyze the risk of typhoon for China's coastal ports.

Methodology – The judgment of a port disruption event and the duration are based on the hybrid wind model, which consider both parametric wind speed and reanalysis wind speed. To calculate the economic losses, this model considers loss to the shippers, loss to the carriers and loss to the port. The influence of time-varying variables on three kinds of economic losses have been considered.

Findings – The distribution of disruption days and economic loss is not consistent in all ports. For the disruption days overall, more than 58% ports have disruption days for an average of two days a year. But from the distribution of economic losses, we find that a few ports bear a lot of losses in China's coastal ports. Haikou port affected by typhoons most frequently. The top five ports in terms of total losses are Shenzhen port, Shanghai port, Ningbo-Zhoushan port, Guangzhou port and Xiamen port.

Practical implications – This research can provide as an overall understanding of typhoon risk for coastal ports and port clusters in China.

Value – This study concentrates on the impact of typhoon and economic loss on port scale, and the spatial distribution of disruption days in China's coastal areas is given on the map.

Keywords: hybrid wind model, port economic losses, typhoon-induced risk

1. Introduction

With climate change, the negative consequence of extreme precipitation, tropical cyclones and droughts on vulnerable communities is a matter of concern for scientific research. In 2021, four of the world's ten most devastating climate disasters were caused by tropical cyclones according to statistical results of insured losses (Ware and Kramer, 2021). Typhoon In-fa (known as Typhoon Fabian in the Philippines) brought economic losses of up to 2 billion dollars to China, Philippines and Japan. The number of people displaced were over 72,000 because of the severe weather linked to this typhoon.

Typhoons accompanied by strong winds, heavy rainfall and storm surge can have a huge impact on coastal cities. In the 2020 ranking of the world's top one hundred container ports published by Lloyd's List, Chinese mainland ports account for twenty-five. Ports are important nodes of coastal cities, connecting maritime transportation and inland economic hinterland. Most of the coastal cities with relatively large ports' throughput in China are located within the range of frequent typhoons. Therefore, it is very important study the impact of typhoon on China's coastal ports.

The loss caused by catastrophe can be divided into direct physical loss, indirect physical loss, direct economic loss and indirect economic loss. Many articles have assessed the economic losses caused by the typhoon in China, but most of these articles focus on the provincial or city scale economic losses (Wang et al.,2021; Chou et al.2020; Lou et al. 2012). Relatively, few economic losses have been assessed on China's coastal ports. Zhang et al. (2020) estimate the reputational losses, losses to shippers, losses to port and losses to carriers caused by port disruption by calculating the hybrid wind speed. The study only selects individual coastal ports as the research object, and cannot visually compare the spatiotemporal distribution of losses along the entire China's coast. When considering the port operation disruption caused by extreme winds and calculating the direct economic losses of the port and related groups, to obtain the wind speed within the port area during typhoon is a key part. There are many ways to calculate typhoon wind speed, such as using reanalysis data, typhoon parameter model, the Weather Research and Forecasting Model (WRF) (Wiegel et al., 2021; Zhang et al., 2020; Rajeswari et al., 2020).

For the spatiotemporal distribution of disaster risk in coastal ports, some studies have assessed the risk of ports under historical tropical cyclones, as well as under future climate change. Lam et al. (2017) have done the work of mapping of cyclone risk for major seaports in East Asia with considering the container throughput and operation scale of different ports. In addition, prevailing wind directions, terminal layouts and protections are also studied in this research. Further, Jian et al. (2019) establish a container port cyclone risk model and calculate the loss sustained by the ports when they subjected to their respective 100-year return period cyclone wind hazard. One study analyzes the multi-hazard severity across 2,013 ports around the world in history and under RCP8.5 respectively (Izaguirre et al., 2021). However, due to the different definition of port selection scope, Shanghai port and other important ports is omitted. This makes the understanding of the risk to China's coastal port operations limited.

This paper will consider the spatiotemporal distribution of direct economic losses caused by typhoon disruptions at 31 major Chinese coastal ports from 2006 to 2020. The paper is organized as follows. Section 2 provides the typhoon wind models used in this study. This section also presents the methods to calculate economic losses in three different parts. Section 3 presents the study area and the data source. Section 4 presents the wind simulation result and economic losses of different ports respectively. And Section 5 gives a few conclusions in this study.

2. Methodology

2.1 Port Disruption model

2.1.1 Wind Speed of Tropical Cyclones

During typhoon, the wind speed within the port area is an important index to guide the port operation. For typhoons that have occurred, the measured data or reanalysis data can be used to analyze the historical wind speed within the port range (Wiegel et al., 2021; Zhang and Lam, 2015). But this method is not suitable for predicting future typhoons' impacts. The typhoon parameter model only needs the coordinates, maximum wind speed and other information provided by the typhoon path dataset or the relevant information obtained from the probability prediction method to calculate the wind speed at the specified point. There are several typhoon parametric models (Pan et al., 2016). In this study, the moving speed is calculated by Ueno model and the rotating speed is calculated by the Fujita-Takahashi model. These parametric models have been validated in the coastal of China in previous studies (Zhang et al., 2020). The wind speed is expressed as a vector sum in the following form:

$$\mathbf{v} = \mathbf{v}_{\text{mov}} + \mathbf{v}_{\text{rot}} \tag{1}$$

where $\mathbf{v}$ represents the wind speed vector at a certain point, $\mathbf{v}_{\text{mov}}$ represents the moving speed vector of the typhoon at this point, $\mathbf{v}_{\text{rot}}$ represents the rotation velocity vector of the typhoon at this point.

The detailed calculation methods of Ueno model and Fujita-Takahashi model are as follows (Ueno, 1981; Wang, 1991).

Ueno model can be expressed as an exponential function:

$$v_{mov} = v_{mc} \exp\left(-\frac{\pi}{4}\frac{|\mathrm{r} - R_0|}{R_0}\right) \tag{2}$$

where r is the distance from the cyclone center, and R_0 is the radius of maximum wind, and v_{mc} is the moving speed of the cyclone center.

The rotating speed calculated by the Fujita-Takahashi model is a piecewise function with respect to the radius of maximum wind:

$$
v_{rot} = \begin{cases} r\left(-\dfrac{f}{2}+\sqrt{\dfrac{f^2}{4}+10^3\dfrac{2(P_n-P_0)}{\rho_a R_0^2}\left[1+2\left(\dfrac{r^2}{R_0^2}\right)\right]^{-3/2}}\right) & 0 \le r \le 2R_0 \\ r\left(-\dfrac{f}{2}+\sqrt{\dfrac{f^2}{4}+10^3\dfrac{P_n-P_0}{\rho_a (1+r/R_0)^2 R_0 r}}\right) & 2R_0 \le r \le \infty \end{cases} \tag{3}
$$

where P_n is the environmental pressure and is set as 1010 hPa as for the Northwest Pacific Ocean, P_0 is the central pressure, f is the Coriolis parameter, ρ_a is the air density and is set as 1.29 kg/m^3.

The maximum wind speed radius R_0 will influence the outcome of the wind speed. Formula for calculating the maximum wind radius proposed by Knaff et al. (2007) is used in this paper. The detailed validation in the study area will be shown in Section 3.1.1.

The maximum wind speed radius calculated in empirical formula is given as follows.

$$
R_{\max} = m_0 + m_1 v_{\mathrm{mc}} + m_2(\varphi - 25) \tag{4}
$$

where φ is the latitude of the tropical cyclone center, m_0, m_1, and m_2 are empirical coefficient depending on the location of the tropical cyclones. In this paper, the values of each coefficient are selected according to the research of Pan et al. (2016). They are set as $m_0 = 38$, $m_1 = -0.1167$ and $m_2 = -0.004$.

The following formulas are utilized to calculate the x-direction (*u* speed in the reanalysis wind fields) and y-direction (*v* speed in the reanalysis wind fields) wind speeds in the Cartesian coordinate system (Fleming et al., 2008):

$$
\begin{cases} v_x = C_1 v_{\mathrm{mov}} \cos\phi + C_2 v_{\mathrm{rot}} \cos(90+\theta+\beta) \\ v_y = C_1 v_{\mathrm{mov}} \sin\phi + C_2 v_{\mathrm{rot}} \sin(90+\theta+\beta) \end{cases} \tag{5}
$$

where ϕ represents the direction of the typhoon movement and the positive direction is the x-axis of the Cartesian coordinate system. C_1 and C_2 are the adjustment factors, which are set as 1.0 and 0.71 respectively. θ represents the angle between the x-axis and the line connecting the calculation point. β is the inflow angle and is set as 20°(Tian and Zhang, 2021).

It has been pointed out in the existing studies that the velocity far from the typhoon center may be lower than the measured velocity (Pan et al., 2016). Thus, hybrid wind model, which combine the reanalysis wind speed and parametric wind speed is introduced to calculate the wind speed:

$$
\mathbf{v}_{hybrid} = \mathbf{v}(1-\lambda) + \lambda \mathbf{v}_{ERA} \tag{6}
$$

$$
\lambda = \frac{c^4}{1+c^4} \tag{7}
$$

$$
c = \frac{r}{nR_0} \tag{8}
$$

where $\mathbf{v}_{\mathrm{hybrid}}$ is the wind speed vector of the hybrid wind field, $\mathbf{v}_{\mathrm{ERA}}$ is the wind speed vector from ERA5, λ is the superposition weight factor, which is related to the distance between the calculation point and the typhoon center and the maximum wind speed radius, *n* is a correction factor that has a value between 9 and 10. In this study, a value of 10 is adopted.

2.1.2 Identification of Port Disruption

Blue warning signal of typhoon can be used as a sign that port operations are disrupted. China Meteorological Administration (CMA) provides the signal meaning. It means that tropical cyclone is likely to affect or has affected, bringing average wind speed of scale 6 on off shore and land or gust of scale 8 in 24 hours. And this condition is to continue. Zhang and Lam (2015) assumed that the port should immediately stop operations for the following 24 h when a port observes a wind scale value that is equal to or higher than standard Beaufort scale 6.0 (>38 km/h). Therefore, this criterion is used to estimate the number of days of port disruption caused by typhoon-induced wind disasters. The threshold wind speed is set as 10.8 m/s here.

The wind speed of a port can be calculated by the hybrid wind model. Because the model does not take into account the impact of land mass or infrastructures on wind speed, the wind speed obtained by such calculation is conservative.

The calculation range of wind speed is set as a circular area with a radius of 100km centered on the port and the example of a certain port is shown in Fig.1. This takes into account two points: first, the port management personnel need to make corresponding judgments before the typhoon arrives at the port; second, there may be multiple container terminals within the same jurisdiction, which will be explained in Section3.2 about the geographical location of the port.

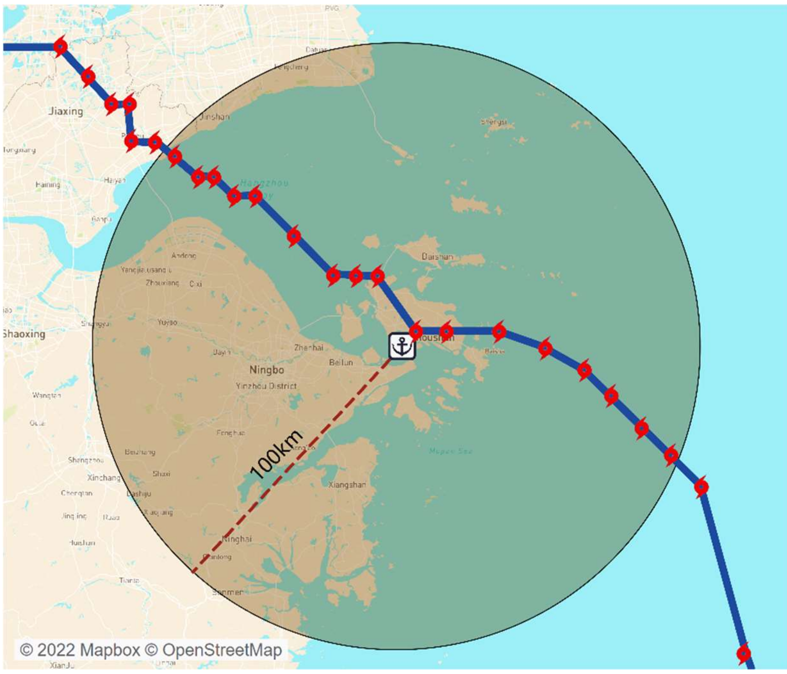


Figure 3: The calculation range of wind speed
Source: Author(s) of the original source (2022)

2.2 Port economic losses model

2.3.1 Loss to the shippers

The economic loss caused by port disruption to shipper can be divided into two parts: inventory cost and time value of goods. This loss to shippers in year i month j can be expressed as follows

$$C_{\text{Shippers}}(i,j) = Iu(i,j)T(i,j) + MARR(i,j)Vu(i,j)T(i,j) \tag{9}$$

where I is the daily inventory cost of the cargo per container in a twenty-feet equivalent unit (TEU). Normally, inventory costs can be determined by the port manager. Most of China's port container inventory adopts the strategy of "free stacking period + step charging", that is, stacking within a certain period of time is free of charge. At the same time, berthing fees are exempted for ships berthing in the port due to port reasons or special meteorological reasons according to most of the port charging method in China. Therefore, I can be set as 0 during disruption caused by tropical cyclones. MARR stands for the minimum attractive rate of return. MARR can be estimated from the interest rate on government bonds. Since the yield of bonds fluctuates over time, the change in variables over time need to take into account. V represents the cargo value per TEU; $u(i,j)$ is the daily throughput in each port in year i month j; $T(i,j)$ represents the number of port disruption days in year i month j. It is predicted by the typhoon wind speed model.

2.3.2 Loss to the carriers

Loss to the carriers refers to the expenses borne by the carrier during the period of port disruption. Considering the container transport belongs to fixed transport cycle and liner company promises to provide a fixed shipping route, loss during disruption can be converted into days. Freight rates are usually set by the market, taking into account price fluctuations over time. Therefore, the freight rate during the period of detention caused by typhoon can be used as a measure to quantify the relative economic loss of carriers as follows:

$$C_{\text{Carriers}}(i,j) = Ru(i,j)T(i,j) \tag{10}$$

where R is the freight rate for the cargo per TEU per day, and is set as 68.5 (RMB/TEU/day) according to similar study (Zhang et al., 2020).

2.3.3 Loss to the port

The most immediate impact would be on ports. The disruption could immediately paralyze the port. Once the port breaks down, the port cannot provide cargo loading/unloading services under extreme weather. This has caused the port to lose revenue it would otherwise have earned. This loss of service can be estimated as follow

$$C_{\text{port}}(i,j) = c_{\text{loading/unloading}}(i,j)u(i,j)T(i,j) \tag{11}$$

where $c_{\text{loading/unloading}}$ is the loading/unloading charge for cargo per TEU per day in year i month j.

3. Study Area and Data Source

3.1 Study Area

In this study, 31 ports located on the coast of China have been selected. Spatially, the studied ports belong to ten different provinces (or municipalities), while they can also be grouped into five different ports clusters (according to the *National Plan for Coastal Port Layout* promulgated by the Ministry of Transport of the People's Republic of China in 2006). The five ports clusters are Bohai Rim Port Cluster, Yangtze River Delta Port Cluster, Southeastern Coastal Port Cluster, Pearl River Delta Port Cluster and Southwestern Coastal Port Cluster. The ports' spatial distribution used in this study are shown in Fig.2.

Figure 2: 31 coastal ports selected in this study
Source: Author(s) of the original source (2022)

The ports' names, geographic coordinates and their clusters are shown in Appendix. It is important to note that ports here are divided according to the administrative area to which they belong. In reality, there are more than one terminal in a port. The geographical coordinates used in this study are from the website of MarineTraffic (https://www.marinetraffic.com) and do not distinguish between the different container terminals in the port. The study subjects cover the world's top 100 coastal container ports and all coastal ports with available container throughput from 2006 to 2020. It should be noted that inland ports are not included. For example, Jiangsu province only includes Lianyungang port based on the selecting principle. Therefore, the research results can provide some basis for the spatiotemporal loss of coastal ports in each province under typhoons.

3.2 Data Source

3.2.1 Typhoon Dataset

The typhoon data used to calculate wind speeds are derived from the tropical cyclone best path dataset provided by the CMA. This dataset provides data on the occurrence time, intensity, longitude, latitude, central minimum pressure, and maximum wind speed of tropical cyclones. In this paper, 368 typhoons between 2006 and 2020 provided in the dataset are selected.

The typhoon wind speed used for verification is derived from observation data in Chinese oceanic stations. These data are provided by the National Marine Data Center and is available on the website (http://mds.nmdis.org.cn/).

3.2.2 Container Throughput Data

Container throughput is an important index to calculate economic loss. Due to the lack of public data, many studies use annual throughput for throughput prediction or convert annual throughput to monthly throughput. There are less done using real monthly throughput data. The actual throughput has an obvious seasonal trend and is greatly affected by external shocks (such as the 2008 financial crisis, the 2020 Covid-19). Therefore, this paper adopts the container throughput data of China's coastal ports from 2006 to 2020 provided by the Ministry of Transport of the People's Republic of China or China Port Yearbook.

For the daily throughput in each port in year i month j, it is calculated by dividing the container throughput of each month by the actual operation days. It is important to note that it is not the number of days in each month, but the actual number of days in operation of the port.

3.2.3 Economic Data

The value of MARR refers to the yield rate of government bonds in each month, and the data is derived from the yield rate of government bonds provided by National Interbank Funding Center from 2006 to 2020. Depending on the source of the data. There are price switching between the dollar and the Chinese yuan. The exchange rate is based on the average monthly exchange rate provided by the China Foreign Exchange Trade System. For the average value of containerized cargo, the values in Jian et al., 2019 are used.

The loading/unloading charge for cargo per TEU is vary from port to port, and there are some differences for different types of container cargo. In addition, between 2006 and 2020, the price of loading/unloading charges will be adjusted due to trade situation and policies. Loading/unloading charges in this paper are mainly based on the prices of general types of containers published by each port.

4. Result

4.1 Verification of Wind Speed Model

To verify the applicability of the parametric model in the coastal areas of China, the wind speed calculated by the parametric model can be compared with the measured data. In this paper, four validation points are selected to verify the parametric wind speed model. The sources of measured data have been introduced in the section about data source. The validation sites were NanJi (27.5N, 121.1E), DaChen (28.5N, 121.9E), BeiShuang (26.7N, 120.3E) and ShengShan (30.8N, 122.8E). Typhoon Hagupit (T2004), Lingling (T1913), Lekima (T1909) and Maria(T1808) are selected to calculate wind speed. The path of typhoons and the position of measuring stations are shown in Fig.3.

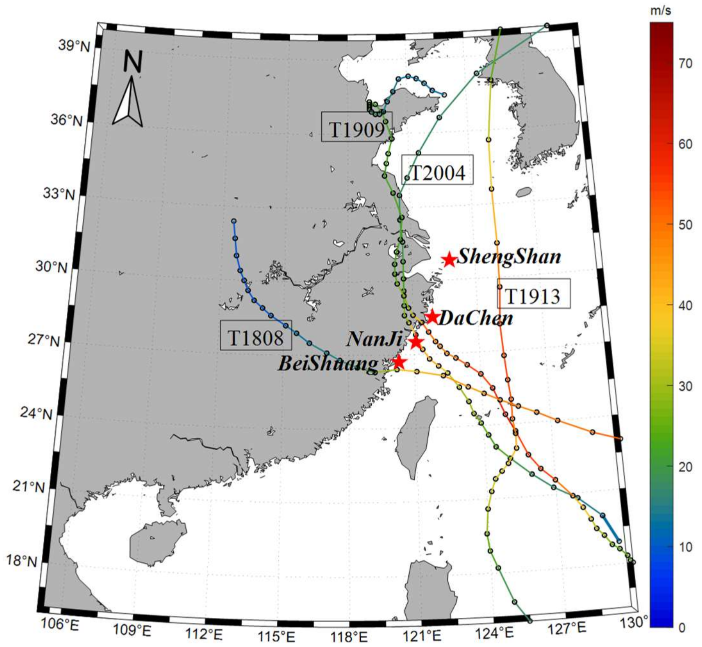
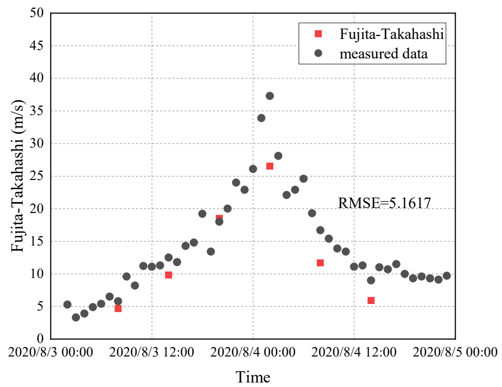


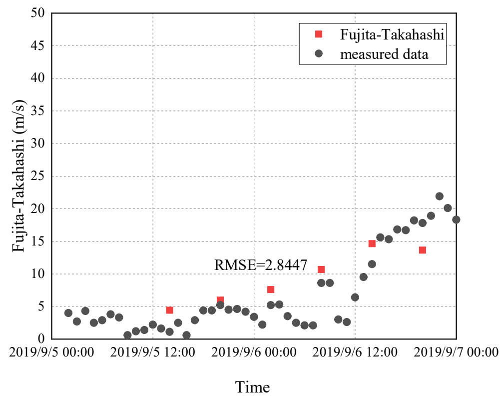
Figure 3: Typhoon tracks and measuring point location

Source: Author(s) of the original source (2022)

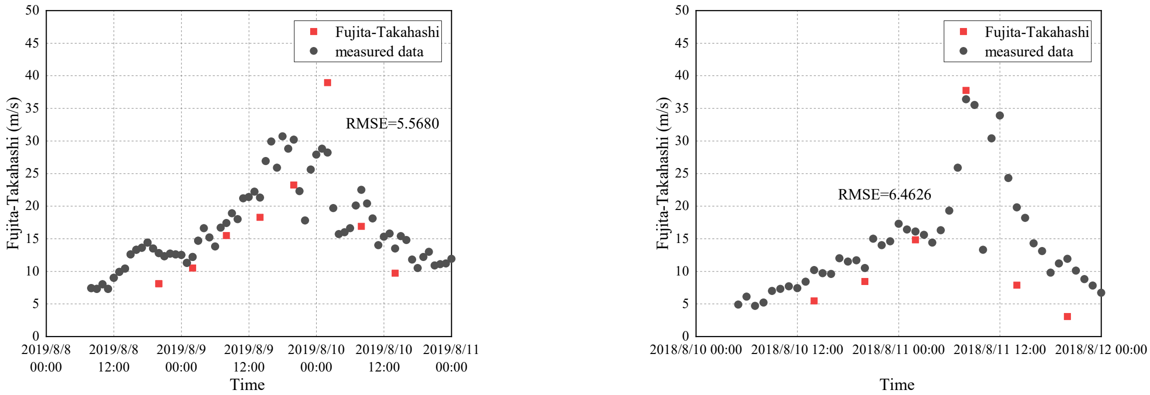
The calculated results and measured data are shown in Fig.4. The RMSE between the measured and calculated values of each typhoon are 5.1617m/s, 2.8447m/s, 5.5680m/s, 6.4626m/s, respectively. The results mean that the simulated wind speed can be used for wind speed calculation.



(a) Calculated wind speed and measured wind speed in NanJi of Hagupit (T2004)



(b) Calculated wind speed and measured wind speed in ShengShan (T1913)



(c) Calculated wind speed and measured wind speed in DaChen (T1909)

(d) Calculated wind speed and measured wind speed in BeiShuang (T1808)

Figure 4: Calculated wind speed and measured wind speed in different measured point

Source: Author(s) of the original source (2022)

4.2 Economic Loss Result

4.2.1 Port Disruption Days

Fig.5 is the total disruption days of each port in 15 years calculated based on the wind speed threshold of 10.8m/s. The ports selected in this paper have all been affected by typhoon-induced extreme winds, among which Haikou port has been affected the most for 90 days. In the container port rankings published by Lloyd's List in 2020, Haikou port ranks 88th with a container throughput of 1,970,000TEU. Haikou port not only undertakes China's domestic and international container business, but also an important node for tourists in Hainan Province. Therefore, the high frequency of typhoon impact on Haikou port is very worthy of the attention of container transport industry and tourism transport industry.

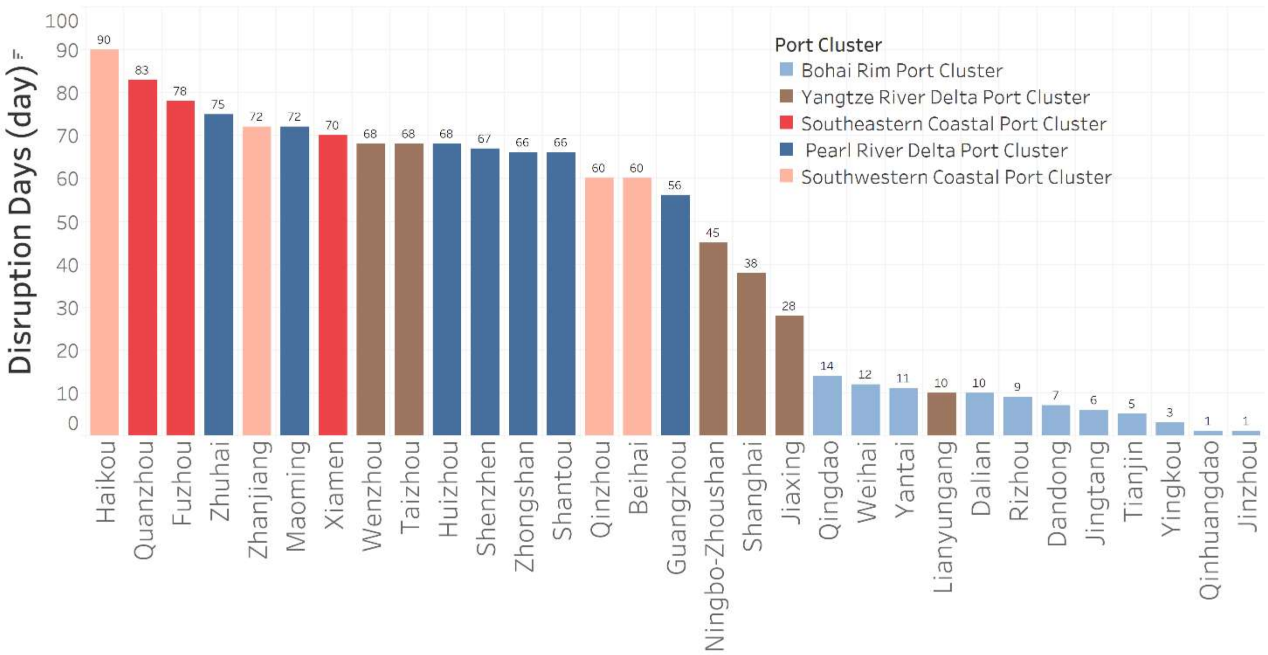


Figure 5: Port Disruption Days from 2006 to 2020

Source: Author(s) of the original source (2022)

Jinzhou port and Qinhuangdao port were the least affected, with only one day disruption in 15 years. Based on the calculation method in this research, the operation disruption of Jinzhou port and Qinhuangdao port were mainly caused by Typhoon Ampil in 2018. Both of these ports are located in Bohai Rim Port Cluster and have been less affected by typhoons in history, but they have been greatly affected in recent years, such as the Typhoon In-fa in 2021. Although this typhoon is not included in the scope of port comparison in this research, there are official data that can explain the impact of typhoon fireworks (Jinzhou Meteorological, 2021). Therefore, this change is very worthy of the attention of port managers or stakeholders. In a nearly 15-year perspective, the two port operations have been disrupted by winds caused by less common typhoons, but the future changes may require more data. For the disruption days overall, more than 58% ports have disruption days for an average of two days a year.

The sum of the average disruption days of ports in each port cluster from 2006 to 2020 have been calculated, among which the average disruption days of Bohai Rim Port Cluster and Yangtze River Delta Port Cluster are 7.2 days and 42.8 days respectively. The Southeastern Coastal Port Cluster average disruption days are 77days, and the Pearl River Delta Port Cluster has an average disruption of 67.1 days. And, Southwestern Coastal Port Cluster has been disrupted for an average of 70.5 days per Port over the past 15 years. This means that ports within the five port clusters have disruption days for 0.48, 2.85, 5.13, 4.47 and 4.7 days per year respectively. Among them, Southeastern Coastal Port Cluster is most frequently affected by typhoons. Fuzhou Port, Quanzhou Port and Xiamen Port are part of the Southeastern Coastal Port Cluster and are all ranked among the top 100 container ports in Lloyd's List 2020.

The average number of days of each port disruption and the number of days of port disruption in each province in 15 years are shown in Fig.6. It can be seen that different provinces are affected by the typhoon at different intensities. In the provinces north of Jiangsu province, the average port disruption days in 15 years were less than 12 days, that is, no more than 1 day per year on average. Southeast and southwest coastal areas under the influence of typhoon more. Hainan province up to 90 days, that is, within a year, the average port of Hainan province will be closed for 6 days under the influence of typhoon.

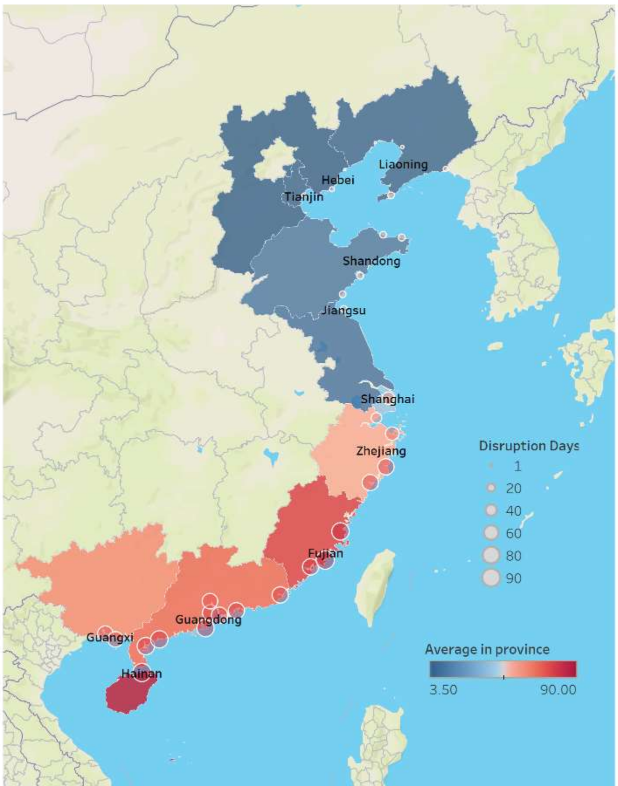


Figure 6: Ports disruption days from 2006 to 2020 and average disruption days in Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan

Source: Author(s) of the original source (2022)

Each port is affected by typhoons with different frequency of disruption, and the consequences of disruption may vary. In order to further study the impact of typhoon on each port, in Section 4.2.2, we will calculate the economic loss of each port and port clusters under the influence of typhoon based on the port economic loss model.

4.2.2 Economic Impact of Typhoon-induced Wind in Different Ports

According to the method mentioned in Section 3, the sum of the three different kinds of economic losses of each port (loss to shippers, loss to carriers and loss to port) in 15 years was calculated and the results are shown in Fig.7. Among these ports' total economic losses, the top five ports in terms of total losses are Shenzhen port, Shanghai port, Ningbo-Zhoushan port, Guangzhou port and Xiamen port. The total loss of Shenzhen port is about 16.3 billion RMB. This means that Shenzhen port loses more than 1 billion RMB per year on average. However, Shenzhen Port is not the most frequently affected by typhoons. Due to its high share of container throughput and high container loading/unloading fee, the loss amount in 15 years is large. From the distribution of economic losses, it can be found that a few ports bear a lot of losses in China's coastal ports. This point is a big difference when it compares with the typhoon disruption days in each port.

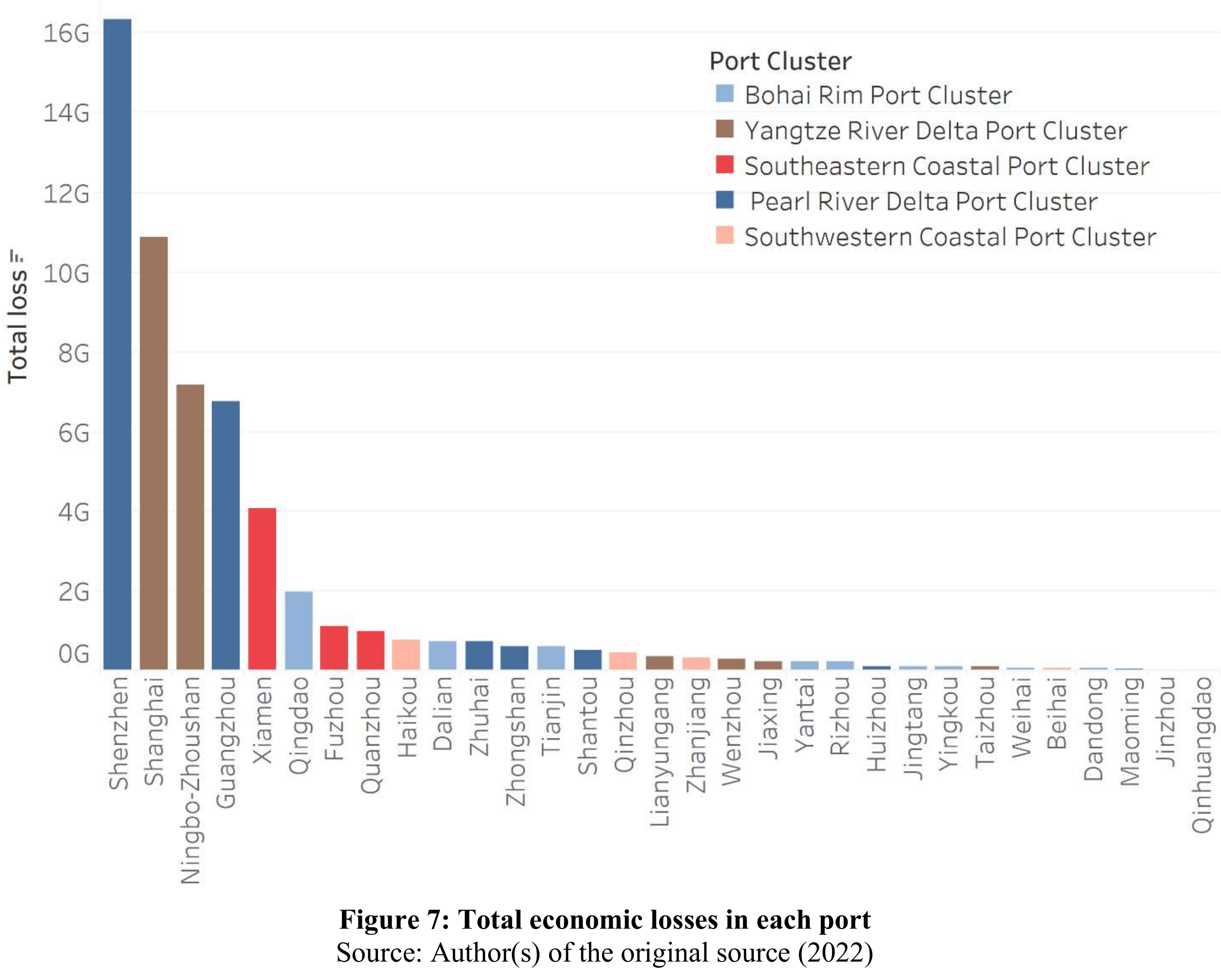


Figure 7: Total economic losses in each port
Source: Author(s) of the original source (2022)

At the same time, it also needs to consider the average loss to each port in the five port clusters in 15 years. In the past 15 years, the average loss of each port in Bohai Rim Port Cluster is 370 million RMB and the average loss of each port in the Yangtze River Delta Port Cluster is 3.16 billion RMB. The port in Southeastern Coastal Port Cluster lost 2.05 billion RMB on average, the port in Pearl River Delta Port Cluster lost 3.58 billion RMB on average, and the port in Southwestern Coastal Port Cluster lost 390 million RMB on average. It can be seen that the ports with large average losses are mainly in the Yangtze River Delta Port Cluster, Southeastern Coastal Port Cluster and Pearl River Delta Port Cluster. Typhoon may cause more damage to these ports, which is worth the attention of the relevant stakeholders of the three port clusters. In this study, there are more ports in the Pearl River Delta Port Cluster compared to other port clusters. It leads to the result that this port cluster accounted for nearly 44.9% of the total loss.

In addition to the total loss, the possible loss to ports, shippers and carriers are also a concern of this study, and the results are shown in Fig.8. Although the loss of each port is different, the proportion of each part shows that shippers are facing the largest loss, followed by port, and the smallest is carriers.

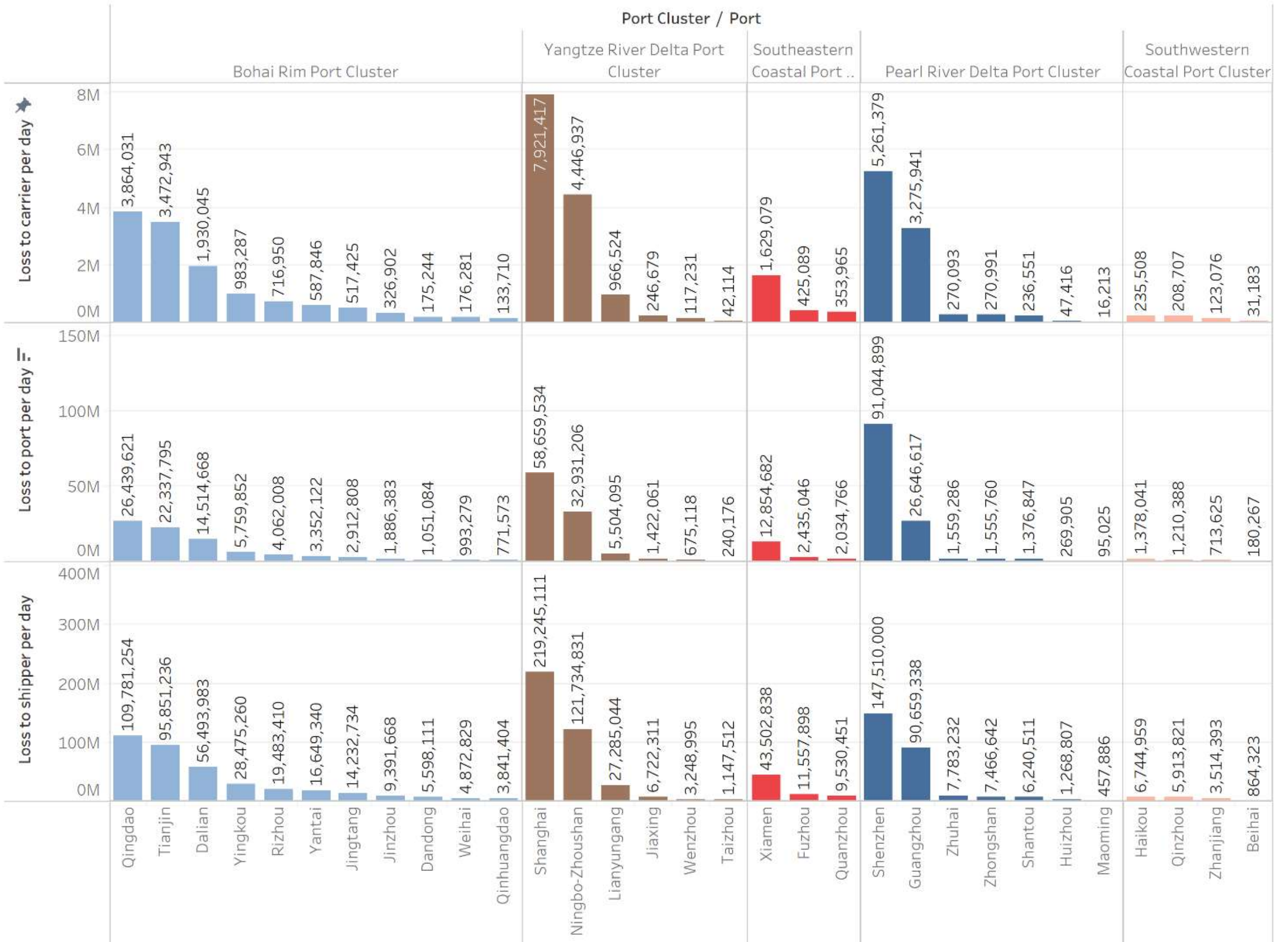


Figure 8: Loss to ports, shippers and carriers in different ports

Source: Author(s) of the original source (2022)

For loss to shippers, Shanghai port caused the largest one-day loss when the disruption of port occurred, followed by Shenzhen port. The top five ports are Shanghai port, Shenzhen port, Ningbo-Zhoushan port, Qingdao port and Tianjin port. This means that shippers communities in those ports are at greater risk to their property when a typhoon induced disruption. It should be noted that this part of loss calculation has a great relationship with the container throughput and the average the cargo value per TEU. This part of the loss calculation is based on the average value of container cargo per TEU in China, which does not take into account the difference of cargo types at different container port. The loss rankings may change a bit when the type of container cargo at each port is considered in detail.

For loss to carriers, the top five ports are still Shanghai Port, Shenzhen port, Ningbo-Zhoushan port, Qingdao port and Tianjin port. This loss is mainly related to the container throughput, which also reflects the container throughput ranking of each port.

For loss to port, the top five ports are Shenzhen Port, Shanghai Port, Ningbo-Zhoushan Port, Guangzhou port and Qingdao port. Losses in this part are ranked differently from shippers and carriers. This part of loss is mainly related to the loading/unloading charge for cargo per TEU per day and container throughput. Due to the high loading/unloading charge at Shenzhen port and Guangzhou port, the loss to port is relatively high. This part of the loss is very worthy of the port's attention, the reason is that the port strategies to resist typhoons and the rationality of post-typhoon recovery will affect the port's income. Therefore, it is not only the ports with high losses that need to be concerned, but also any port with container operations and related businesses that account for a large proportion of port revenues should pay attention to the losses caused by typhoon winds.

5. Conclusion

In this study, the judgment of a port disruption events and their duration are based on the hybrid wind model and port disruption assumptions. To calculate the economic losses, this model considers loss to the shippers, loss to the carriers and loss to the port. The influence of time-varying variables on three kinds of economic losses have been considered. These time-varying variables include: the minimum attractive rate of return (MARR), the planned loading and unloading charge per TEU at each terminal, the RMB exchange rate and container throughput every month.

31 ports from Bohai Rim Port Cluster, Yangtze River Delta Port Cluster, Southeastern Coastal Port Cluster, Pearl River Delta Port Cluster and Southwestern Coastal Port Cluster are selected. The port disruption days and economic losses caused by typhoons from 2006 to 2020 were calculated. For port disruption days, Haikou port has been affected the most for 90 days and Jinzhou port and Qinhuangdao port were the least affected. For ports within the five port clusters, Southeastern Coastal Port Cluster is most frequently affected by typhoons and Bohai Rim Port Cluster is the least affected by typhoon-induced wind. From the point of view of spatial distribution, coastal ports in northern China are less affected by typhoons, while those in southern China are more affected by typhoons. For total economic losses, the top five ports are Shenzhen port, Shanghai port, Ningbo-Zhoushan port, Guangzhou port and Xiamen port. There is the situation that a few ports bear most losses in China’s coastal ports. As for port clusters, Pearl River Delta Port Cluster accounted for nearly 44.9% of the total loss. The three kinds of losses ranking are not always consistent. For loss to shippers, the top five ports are Shanghai port, Shenzhen port, Ningbo-Zhoushan port, Qingdao port and Tianjin port. For loss to carriers, the top five ports are still Shanghai Port, Shenzhen port, Ningbo-Zhoushan port, Qingdao port and Tianjin port. For loss to port, the top five ports are Shenzhen Port, Shanghai Port, Ningbo-Zhoushan Port, Guangzhou port and Qingdao port.

Although the research results in this paper are based on certain assumptions, the quantitative evaluation of coastal port disruption days and ports’ economic losses induced by typhoons can still provide as a guidance for port operation planning and typhoon-induced disasters prevention. For further study, type of cargo in a container port or the disruption and recovery conditions of a port are also points worth discussing.

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Appendix

Table 2: The ports' names, geographic coordinates and their clusters

No.	Port	Province	Port Cluster	Longitude	Latitude	Lloyd's List 2020
1	Dandong	Liaoning	Bohai Rim Port Cluster	124.2355	39.90644	
2	Jinzhou	Liaoning		121.0457	40.83311	90
3	Dalian	Liaoning		121.7645	38.99747	19
4	Yingkou	Liaoning		122.2662	40.69363	27
5	Jingtang	Hebei		119.0154	39.20087	
6	Qinhuangdao	Hebei		119.6449	39.91558	
7	Tianjin	Tianjin		117.7373	38.96904	9
8	Yantai	Shandong		121.4097	37.56646	56
9	Weihai	Shandong		122.214	37.476	
10	Qingdao	Shandong		120.3201	36.05661	7
11	Rizhou	Shandong		119.5269	35.36182	
12	Shanghai	Shanghai	Yangtze River Delta Port Cluster	121.6147	31.36636	1
13	Lianyungang	Jiangsu		119.5666	34.79039	36
14	Jiaxing	Zhejiang		121.0955	30.609	91
15	Ningbo-Zhoushan	Zhejiang		121.7833	29.96667	3
16	Taizhou	Zhejiang		121.5397	28.63996	
17	Wenzhou	Zhejiang		120.8019	27.98287	
18	Fuzhou	Fujian	Southeastern Coastal Port Cluster	119.4351	26.00031	51
19	Quanzhou	Fujian		118.7325	24.8285	75
20	Xiamen	Fujian		118.0293	24.50318	14
21	Shantou	Guangdong	Pearl River Delta Port Cluster	116.6715	23.341	
22	Huizhou	Guangdong		114.6284	22.67382	
23	Shenzhen	Guangdong		113.8535	22.5045	4
24	Guangzhou	Guangdong		113.425	23.0855	5
25	Zhongshan	Guangdong		113.47	22.5672	
26	Zhuhai	Guangdong		113.2	21.91982	77
27	Maoming	Guangdong		111.0855	21.449	

28	Zhanjiang	Guangdong	Southwestern Coastal Port Cluster	110.4657	21.18614	88
29	Haikou	Hainan		110.2789	20.05264	
30	Beihai	Guangxi		109.0711	21.4657	
31	Qinzhou	Guangxi		108.647	21.68317	

How Does the Northern Sea Route Affect China-EU Bilateral Trade?

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Abstract

Global warming reduces the seasonal limits of trans-Arctic shipping. The Northern Sea Route (NSR) becomes the focus of global attention because of its strategic importance. This study constructs an assessment framework to analyze the impact of the NSR navigation on bilateral trade between China and the EU. Changes in shipping costs after the NSR navigation are first calculated based on a cost model, and then fed into the Global Trade Analysis Project (GTAP) model as an exogenous variable to measure the changes in bilateral trade. Several scenarios are presented to reflect different situations in actual navigation. We find that a faster vessel speed on ice and appropriate vessel size are favorable factors that provide a cost advantage for trans-Arctic shipping. In a cost-effective scenario, the NSR navigation drives bilateral trade between China and the EU, with the most significant growth in mining exports. Meanwhile, regional economies show growth, with China benefiting more significantly. This paper enriches the research considering the relationship between China-EU trade and the NSR, and provides references for China's participation in the construction of the NSR and the strengthening of bilateral trade and economic cooperation.

Keywords: Northern Sea Route navigation; Shipping cost; GTAP model; Bilateral trade

1. Introduction

Global warming has accelerated the melting of Arctic Sea ice, increasing the feasibility of trans-Arctic transport. The Arctic shipping routes are the routes through the Arctic Ocean, connecting the Atlantic Ocean and the Pacific Ocean, which are mainly divided into the Northwest Passage and the Northeast Passage according to geographical location. The segment of the Northeast passage between the Bering Strait and Novaya Zemlya is called the Northern Sea Route (NSR) (Theocharis *et al.*, 2019; Xu and Yin, 2021). The NSR starts from the northern waters of Western Europe, bypasses the waters of Norway, crosses the northern coast of Russia, and then skirts the Bering Strait to reach the East Asian countries (Figure 1).

The cargo volume of transportation along the NSR has been increasing annually, from 3.1 million tons in 2011 to 32.9 million tons in 2020 (CHNL Information Office, 2021). The fifth report of the Intergovernmental Panel on Climate Change (IPCC) stated that summer sea ice in the Arctic Ocean could essentially disappear by 2050 because of global warming (Joseph *et al.*, 2021). If the year-round navigation is realized in the future, the NSR will distribute more than half of the global container cargo flow, and the ports with higher latitude will have a higher proportion of cargo flow in the NSR (Sun *et al.*, 2020; Sun and Zheng, 2016). Meanwhile, as a new channel for international energy transportation, the NSR will change the geographical direction of global energy trade to a certain extent, making the source and channel of global energy trade less concentrated (Lindholt and Glomsrød, 2012). The strategic position of the Arctic region and the Arctic routes has attracted great attention from all countries, and related research has gradually increased.

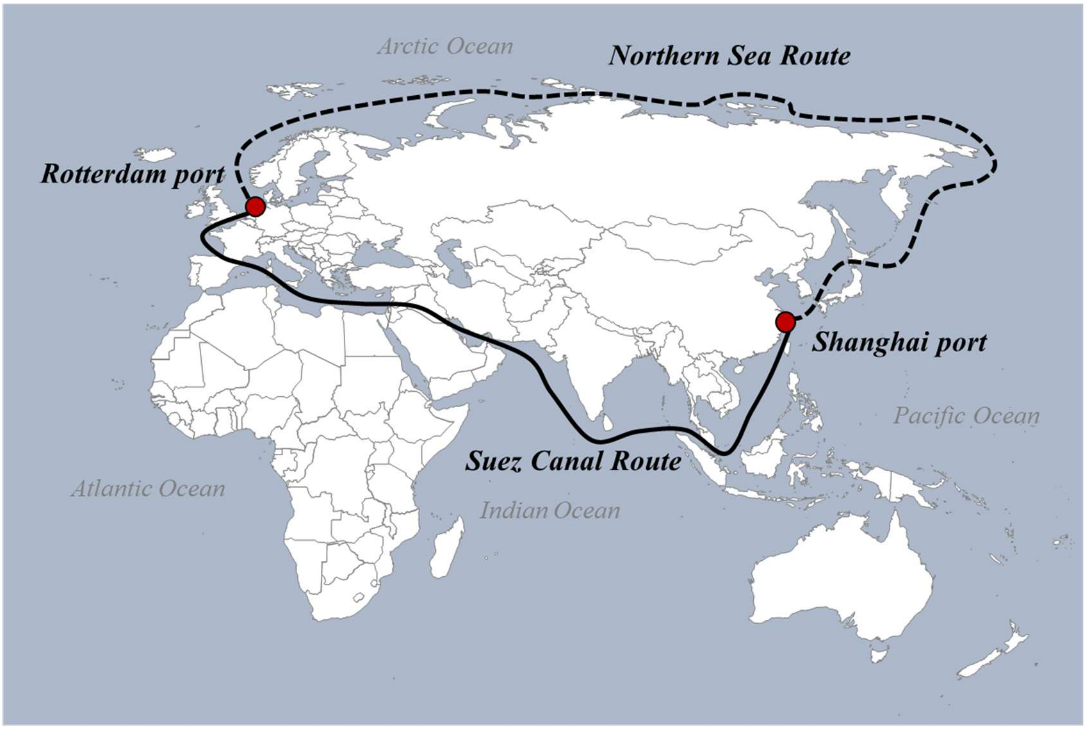

Figure 1: The Northern Sea Route and Suez Canal Route options
Source: CHNL Information Office, NSRA

The topic of Arctic shipping is becoming an important area of academic research. Compared with the traditional routes, the NSR significantly shortens the shipping distance between Northwest Europe and North Pacific ports, reduce the shipping cost and sailing time. However, the operating cost and navigational risk of vessels via the NSR are much higher than those of traditional routes, so there are mainly three different views on whether it is economic feasibility. The first view is that the Arctic routes have economic advantages. Shipping along the Arctic can save voyages compared to bypassing the Suez Canal and the Panama Canal and has great economic potential. In addition, the new shipping routes increase the flexibility and adaptability of the supply chain (Schøyen and Bråthen, 2011). In the current navigational environment, the Arctic routes are more feasible and have greater potential than traditional routes, whether for liner shipping (Xu *et al.*, 2011; Zhao and Hu, 2016), dry bulk shipping (Schøyen and Bråthen, 2011) or oil tanker shipping (Raza and Schoyens, 2014). The second view is that the Arctic routes are not economically viable. Scholars pointed out that shorter shipping distances do not mean lower shipping costs, but also consider factors such as the risk of sailing in icy water, investment in ice-class ships and the cost of icebreaking pilotage (Lasserre, 2014; Meng *et al.*, 2017). On top of this, additional investment is required in trans-Arctic shipping to ensure that the negative impact on the environment is minimized (Dai *et al.*, 2021; Zhu *et al.*, 2018). After careful consideration, the traditional routes still have a comparative advantage in terms of shipping costs (Liu and Kronbak, 2010; Verny and Grigentin, 2009). Most shipping companies believe that NSR cannot replace the Suez Canal Route (SCR), and they are not positive about commercial shipping along the Arctic, at least in the short term. A third view is that the Arctic routes are economically advantageous only under certain constraints. Although existing studies have simulated different navigational scenarios, the many uncertainty factors of the Arctic routes remain to be studied (Lasserre, 2014; Theocharis *et al.*, 2019). Whether shipping companies can save costs by choosing the NSR remains to be discussed.

The NSR navigation will change the original global shipping pattern, forming a new shipping network based on the NSR and strengthening the interconnection between regional countries. The NSR has the advantage of distance compared to traditional routes and will become the key link between Asian and European trade markets, increasing trade flows and changing the direction of trade flows, thus influencing the world trade pattern and promoting global economic growth. Current research on the Arctic route is mainly focused on the field of physical geography and the economic feasibility of the trans-Arctic shipping, and less on its impact on international trade (Aksenov *et al.*, 2017; Meng *et al.*, 2017; Stroeve *et al.*, 2007; Theocharis *et al.*, 2018). In studies exploring the impact of trans-Arctic transport on regional economic trade, Liu et al. (2019) constructed a gravity model to analyze the trade potential between China and Europe after the NSR navigation, and concluded that the NSR will promote the development of trade between China and European countries, and different countries will benefit differently. Bekkers et al. (2018) used a gravity model to analyze the change in trade costs between Northwest Europe and Northeast Asia due to the opening of the NSR, combined with the multiple Computable General Equilibrium (CGE) model to simulate the impact of the NSR on bilateral trade flows. Compared to the gravity model, the CGE model is based on the microeconomic theory of producers and consumers and could describe the linkages between various economic agents within an economic complex system (Bröcker, 1998). CGE models are not only used to solve policy analysis problems in the field of economy and trade, but also widely used in the field of land transport, scholars mainly analyzed the impact of changes in transportation network (Nitzsche and Tscharaktschiew, 2013), transportation infrastructure (Bröcker *et al.*, 2010), transportation costs (Buckley, 1992), road tolls (Thissen *et al.*, 2011), and other conditions on the regional economy and trade. The GTAP model is a comprehensive model based on the CGE model that considers the production and trade activities of multiple countries and regions. Within the GTAP model, the transportation sector enables the spatial interaction of goods between different regions (Robson *et al.*, 2018).

Although the few existing studies have analyzed the impact of Arctic navigation on trade using the GTAP model, most of them use the changes in shipping distance as an entry point to assess its impact on international trade, ignoring the changes in shipping costs is the essential reason for changes in international trade. Shipping distance is not positively correlated with the changes in shipping costs, which are influenced by a combination of factors (Meng et al., 2017).

Our paper contributes to enrich the research content of international trade between China and the EU considering the NSR and provide references for China's import and export trade and decision to participate in the NSR development. To accomplish this task, we propose an analytical framework based on general equilibrium theory, which incorporates a shipping cost model and a GTAP model. This provides a better description of the impact of the NSR navigation on trans-regional shipping costs and thus contributes to the analysis of trade and economic changes.

The remainder of this paper is organized as follows. Section 2 introduces the methodological framework to measure bilateral trade and macroeconomic impacts. Section 3 presents and discusses the measurement results. Conclusions are presented in the last section.

2. Methodology

This section presents the framework for assessing the impact of the NSR on China-EU bilateral trade. As shown in Figure 2, the framework consists of two parts: the shipping cost module and the GTAP module. In the shipping cost module, we calculate the changes in shipping cost after the NSR navigation based on the constructed shipping cost model. Data required as input include navigation data, geographic information data, and vessel data. Specifically, we select two ports in China and the EU as representatives and obtain the distances of the two shipping routes by using Microcity. It is assumed that the gross tonnage of the ordinary vessel and ice-class vessel sailing along the traditional route and the NSR are the same. Combining the data on navigation in the Arctic, the change in shipping costs is calculated. Utilizing the real data, we calculate the changes in shipping costs between China and the EU after the NSR navigation and input this change into the GTAP model. The value change of the endogenous variables in the model can reflect the impact of shipping cost on economic activities, and thus the impact of the NSR on China-EU bilateral trade can be obtained. This is the outcome of the study.

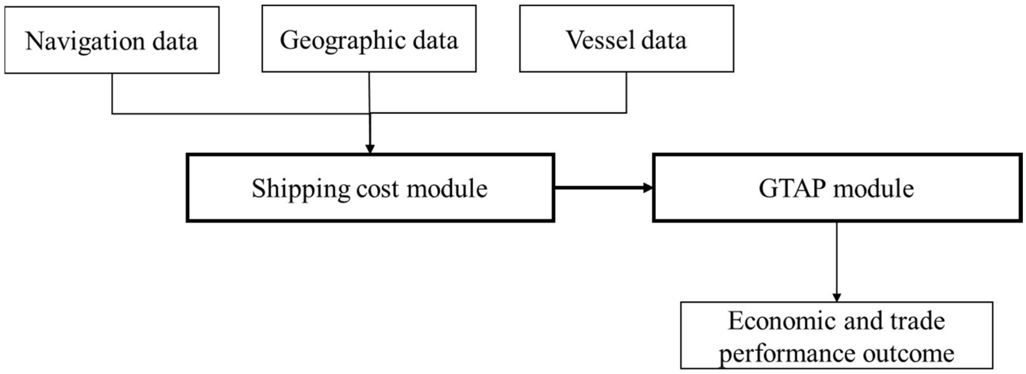

Figure 2: Framework for assessing the impact of NSR on bilateral trade

2.1 Shipping cost module

In this subsection, a shipping cost model is presented to calculate the shipping cost differential between the NSR and the SCR. The shipping cost differential between NSR and SCR is defined as follows:

$$\Delta TC = TC_{NSR} - TC_{SCR} \tag{1}$$

Specifically, the shipping cost differential contains four main components: fuel costs, operating costs, capital costs, and transit costs, is given as:

$$\Delta TC = \Delta VFC + \Delta VOC + \Delta VCC + \Delta VTC \tag{2}$$

where $\Delta VFC, \Delta VOC, \Delta VCC$ and ΔVTC are the fuel costs differential, operating costs differential, capital costs differential, and transit costs differential.

Fuel cost is influenced by the shipping distance, vessel speed and fuel consumption rate. The fuel consumption of vessels passing through the NSR and the Suez is different, due to the higher main engine consumption rate of ice-class vessel and the different sailing time of the two routes. The change in the fuel costs is formulated as:

$$\Delta VFC = pf \cdot \Delta FC \tag{3}$$

$$\Delta FC = \delta \cdot \Delta m \cdot (v_{NSR}^3 - v_{SCR}^3) \cdot \Delta t \tag{4}$$

Where pf is the fuel price (US$/t); FC is the fuel consumption (t), which is determined by the sailing time, the main engine parameters of the vessel and the vessel speed. δ is the fuel consumption rate per unit power of main engine (t/kWh); m is the proportional factor, related to the vessel parameters.; v means the average speed of the vessel along the routes (knot); t is the sailing time (h). The sailing time differential between the two routes is denoted by Δt:

$$\Delta t = \frac{D_{NSR}}{v_{NSR}} - \frac{D_{SCR}}{v_{SCR}} \tag{5}$$

Where D means the voyage distance.

Due to the special environmental risks of the NSR, the daily operating cost and daily capital cost of the ice-class vessel are higher than those of the ordinary vessel sailing in the traditional routes. The expressions for the operating cost and capital cost differential are as follows:

$$\Delta VOC = \Delta po \cdot \Delta t/24 \tag{6}$$

$$\Delta VCC = \Delta pc \cdot \Delta t/24 \tag{7}$$

Where po is the operating cost per day (US$); pc is the capital cost per day (US$).

With the Arctic Sea ice not fully melted, vessels need to charter icebreakers to navigate. Suez Canal tolls and icebreaking fees for the NSR are classified as transit costs, and the difference between the two transit costs is recorded as ΔVTC.

2.2 GTAP module

The aim of this module is to measure changes in bilateral trade demand between China and the EU based on changes in shipping costs, by using the GTAP model. The GTAP model is a multi-regional, multi-sector computable general equilibrium model. Its application areas include trade policy, energy policy, global climate change, technological progress, and the link between economic growth and trade. The GTAP model assumes that the market is perfectly competitive, with producers producing on the principle of minimizing production costs and consumers consuming on the principle of maximizing utility. When equilibrium is reached, all factors and commodity markets clear out (Betarelli *et al.*, 2020).

International trade and cross-border transportation are important modules in the GTAP model. Different from the basic CGE model, the GTAP model includes international trade and financial flows, resulting in a multi-country economic model. In international trade, there is an imperfect substitution relationship between imported and domestic products, which is consistent with Armington hypothesis (Armington, 1969). In international transportation, the difference between the CIF price and the FOB price of a commodity is balanced by cross-regional transportation.

In the GTAP model, exogenous variables are given new values in the initial equilibrium state of the market so that the product and factor markets reach a new equilibrium point. The change in the value of the endogenous variable in the initial equilibrium and in the new equilibrium reflects the degree of influence of the variable on the economic activity. The variable ams_{irs} in the GTAP model captures unobservable transportation cost elements such as customs clearance facilitation and the level of transportation infrastructure. It measures the reduction in the effective price of commodity i exported from region r to region s during the transfer process. This paper represents the shock of the change in shipping costs between China and Europe due to the Arctic navigation by adjusting the magnitude of ams_{irs}.

$$ams_{irs} = \frac{TC_{NSR}}{TC_{SCR}} - 1 \tag{8}$$

Where ams_{irs} is the percentage change in shipping costs after the NSR navigation.

3. Empirical study

3.1 Assumptions

The assumptions of this study are as follows:

(1) With reference to the existing research (Dai *et al.*, 2021; Lasserre, 2014), this paper selects the ports of Shanghai and Rotterdam as representatives to calculate the shipping distance between China and the EU via different routes. With the real maritime network of the open-source software Microcity, the voyage distance from Shanghai port to Rotterdam port via SCR is 10641 nm and the distance of NSR is 8245 nm.

(2) The NSR is located on the continental shelf north of Russia, and the water depth varies along the entire route. Several studies have found a minimum water depth of 13 m in the Sannikov Strait, located in the East Siberian Sea to Laptev Sea section, which has limitations on the type of vessels in operation (Sibul and Jin, 2021; Zhao *et al.*, 2016). In this study, it is assumed that the Sanikov Strait along the NSR can be bypassed and therefore larger vessels can be used.

(3) To compare the impact of the difference in shipping costs, we assume that the same size vessels are used on the two routes. The difference is that ordinary vessels are used on the SCR, and ice-class vessels are used on the NSR. The Arc 4 ice-class vessel operating along the NSR has the same size as the ordinary vessel but has a higher fuel consumption rate. Moreover, ice-class vessel unit operating costs are higher than those of the ordinary vessels, with the unit crew costs, unit insurance costs and unit maintenance and repair costs increasing by 10%, 20% and 20% (Theocharis *et al.*, 2018). The charter rate for the ice-class vessel is increased by 15% on top of the ordinary vessel (Pruyn, 2016). The transit costs are calculated according to the tariffs of the Suez Canal Authority and the rules for ice-breaking pilotage of the Russian Northern Sea Route waters, respectively (Wang *et al.*, 2021; Xu and Yin, 2021).

(4) This study assumes that the NSR is navigable year-round. Icebreaking services are required in all seven

sea areas in winter-spring season, but only in three sea areas in summer-autumn season.

(5) Ice coverage in the shipping channel affects the operating environment of NSR to a large extent. Considering the different coverage of ice in various seasons, based on real navigational data (CHNL Information Office, 2020) and existing studies (Theocharis *et al.*, 2021; Xu and Yin, 2021), we assume an annual average ice distance is 2500 nm. In this ice zone, the ice-class vessel sails at a lower speed than the nominal speed in open water.

(6) According to Bunker Index, the average price of bunker IFO 380 is $350/ton in 2020.

3.2 Scenarios

Besides the above assumptions, we propose several scenarios considering the variation of two important factors: vessel size and vessel speed on ice. Three container vessel size levels are considered: 4000, 8000 and 12000 TEU. The relevant parameters of the sample vessels are shown in Table 1. Three vessel speeds on ice are set as 11, 13 and 15 knots. According to the above assumptions and data, the changes in shipping costs under the three speed scenarios are shown in Table 2.

The impact of vessel size and speed through ice on changes in shipping costs is different. With the same speed through ice, the shipping cost reduction is more obvious when using 8000 TEU vessel sailing along the NSR. However, in Scenario 3, when all vessels sail at 15 knots in the ice zone, the 4000TEU vessel saves the most shipping cost. This implies that there is an optimal NSR vessel size and varies with speed on ice.

Speed on ice affects the economic feasibility of the NSR shipping. As an example, for the 4000 TEU vessel, there is no cost advantage in sailing through the Arctic when the vessel speed on ice is 11 knots. Trans-Arctic shipping becomes economically feasible with a gradual increase in speed. However, it should be noted that the increase in speed will not consistently expand the cost competitiveness of the NSR. When the speed on ice of the 8000 TEU vessel increases from 13 knots to 15 knots, the percentage of cost savings decreases. This implies that for each ship size, there is an optimal speed on ice, when the cost advantage of trans-Arctic shipping is the largest.

Table 1: Parameters of representative vessels

Sample vessel	Limari	OOCL London	MSC Beryl
Vessel size (TEU)	4000	8000	12000
Gross tonnage (t)	42383	89097	140096
Speed (knot)	23.5	24.5	24
Engine Power (kW)	54402	93092	98219
Fuel consumption rate (t/h)	4.32	8.27	9.38
Suez Canal toll ($)	248634	425280	560617

Source: Shipping Intelligence Network

Table 2: Changes in shipping costs between China and the EU (%)

	Scenario 1			Scenario 2			Scenario 3		
Vessel size (TEU)	4000	8000	12000	4000	8000	12000	4000	8000	12000
Capital cost	19.81	22.26	19.81	10.93	13.01	10.93	3.52	6.22	4.42
Operating cost	18.16	17.78	15.64	9.40	8.87	7.07	2.09	2.33	0.78
Fuel cost	-29.29	-29.78	-35.72	-26.85	-27.54	-33.50	-30.45	-24.91	-30.91
Transit cost	65.75	49.21	45.79	65.75	49.21	45.79	58.69	49.21	45.79
Total shipping cost	4.29	-2.76	0.22	2.95	-3.49	-1.07	-4.35	-3.46	-1.57

3.3 GTAP database

The latest version of the GTAP10.0 database contains 141 countries and regions. We aggregate them according to research needs into China, the EU and the rest of the world. Referring to the correspondence between the UN

SITC-3 classification and GTAP industry classification, this paper classifies the 65 industries in the database into 13 industries, which are: agricultural products, mining industry, proceed food, textiles, light industries, chemical products, metal products, electronic equipment, machinery and equipment, transport equipment, utilities, construction and other services.

3.4 Results discussion

Table 3 shows the trade effects of the NSR navigation. The impact of the NSR navigation on bilateral trade varies under different scenarios. When trans-Arctic shipping has the cost advantage, it will promote the growth of import trade of China and the EU. Meanwhile, the import trade in the rest of the world is affected by the market squeeze and shows a downward trend. In export trade, only China is positively affected, with the EU and the rest of the world showing a small decline. All the above results change in the opposite direction when the NSR navigation is not economically feasible.

Table 3: Estimated changes in import and export trade by scenario (%)

	Scenario 1			Scenario 2			Scenario 3		
Vessel size (TEU)	4000	8000	12000	4000	8000	12000	4000	8000	12000
Exports									
CHINA	-0.67	0.43	-0.04	-0.46	0.54	0.17	0.67	0.54	0.24
EU	0.03	-0.02	0.00	0.02	-0.02	-0.01	-0.03	-0.02	-0.01
Rest of the World	0.08	-0.05	0.00	0.06	-0.07	-0.02	-0.08	-0.07	-0.03
Imports									
CHINA	-1.08	0.69	-0.06	-0.74	0.88	0.27	1.09	0.88	0.39
EU	-0.08	0.05	0.00	-0.05	0.06	0.02	0.08	0.06	0.03
Rest of the World	0.20	-0.13	0.01	0.14	-0.17	-0.05	-0.21	-0.17	-0.07

Trans-Arctic shipping changes the terms of trade between China and the EU, increasing the scale of bilateral trade and leading to a series of changes in the export volumes of different production industries. The greatest impact of the NSR navigation on bilateral trade between China and the EU is shown in Table 4. What stands out is the growth of the mining industry, with export trade between China and the EU increasing by 23.51% and 23.49%, respectively. The main reason is that the shipping costs of mining commodities account for a large share of the CIF price, and the NSR navigation leads to a significant reduction in the CIF price of such commodities, which expands the price advantage and contributes to an increase in the demand for commodity imports. Another reason is that the development of other industries increases the demand for intermediate inputs and drives the demand for imports of raw commodities such as mining. Transport equipment shows a significant rise in bilateral trade, with exports from both China and the EU exceeding 11%. As one of the main traded goods between China and the EU, the demand for transport equipment continues to expand after the NSR navigation, maintaining its competitiveness in the international market.

The reduction in trade costs leads to a significant increase of 16.12% in the trade volume of electronic equipment exported from the EU to China. China's trade in textile and light industrial goods exports to the EU grows slightly, maintaining the industry's comparative advantage. EU textile exports to China will increase by 13.21%. This is because lower trade costs enhance the competitiveness of EU textiles, while the Chinese economy expands income growth, which together leads to a significant increase in consumer demand for imported EU textiles. In addition, although there are no shipping costs in the trade of utilities, construction and services, there is a slight change in the export trade of these industries. This is mainly attributed to the fact that the NSR expands the original comparative advantages of industries in each region, and the labor and capital factors flow to the advantageous industries. Industries with insufficient development advantages, such as public utilities, construction, and service industries, are indirectly affected.

Table 4: China-EU bilateral trade impacts (%)

Commodity	China exports to the EU	China exports to ROW	EU Exports to China	EU Exports to ROW

Agricultural products	6.51	-1.23	7.79	-0.28
Mining industry	23.51	-0.82	23.49	-0.76
Proceed food	6.85	-1.34	7.40	-0.31
Textiles	8.45	-1.32	13.21	0.77
Light industries	9.24	-1.41	11.18	0.05
Chemical products	8.59	-1.07	9.36	-0.14
Metal products	10.87	-1.40	12.28	-0.10
Electronic equipment	10.53	-1.20	16.12	0.90
Machinery and equipment	9.73	-1.11	7.69	-0.07
Transport equipment	11.11	-1.55	12.31	0.04
Utilities	-0.95	-1.27	0.61	-0.33
Construction	-0.95	-1.16	0.44	-0.26
Other service	-1.02	-1.25	0.40	-0.32

Table 5 summarizes the macroeconomic impact of the NSR navigation. Both China and EU GDP are positively affected by the NSR. China's GDP grows by 0.344% compared to the growth of 0.063% in the EU. The rest of the world's economies are indirectly affected, with a small decline in GDP. In terms of GDP growth, China's GDP will increase by $53624 million, compared to the EU's smaller GDP growth of $10974 million. Despite the rest of the world's GDP declines due to negative shocks, overall global GDP is up, by $18958 million. The main reason is that the NSR improves the terms of transport for China-EU trade and promotes the growth of bilateral trade, which in turn leads to industrial expansion and boosts regional economic growth. The improvement in the terms of trade between China and Europe squeezes the share of other countries' goods in the international market, leading to the economic decline in other countries.

In terms of trade volume, China's imports and exports grow by 0.88% and 0.54%, respectively. It indicates that China's import expansion will be larger than its export expansion, implying a negative change in the trade balance. The EU's import trade will grow by 0.06%, while export trade will be negatively affected and decline by 0.02%. The expansion of industrial output in the EU leads to an increase in the price of labor, which causes an increase in the cost of commodity production. Price increases reduce the competitiveness of commodities in the international market and ultimately leading to a decline in total EU exports.

Table 5: Macroeconomic impacts

	Exports (%)	Imports (%)	GDP (%)	GDP (million $)
China	0.54	0.88	0.344	53624
EU	-0.02	0.06	0.063	10974
Rest of the world	-0.07	-0.17	-0.093	-45640

4. Conclusions

Bilateral trade between China and the EU is huge and growing, most of which is transported by sea, and the NSR will bring new impetus and opportunities to bilateral economic development. This paper uses the GTAP model to analyze the changes in the demand potential of China-EU bilateral trade after the NSR navigation, and the main findings are as follows:

The effects of the NSR navigation on bilateral trade between China and the EU varies under different cost scenarios. A faster vessel speed on ice and appropriate vessel size are favorable factors that provide a cost advantage for trans-Arctic shipping. In cost-effective scenarios, the NSR has a positive impact on the economic and trade development of China and the EU. In terms of regional economic indicators, the Chinese and European economies are positively affected by the NSR. In terms of merchandise export volumes, export trade will benefit to varying degrees across industries. Export trade will be positively affected in all industries except for utilities, construction and services, where the volume of exports from the mining industry is growing faster. In the short term, China will benefit more significantly from the NSR than the EU.

On the other hand, the NSR will promote the level of trade cooperation between China and the EU and increase bilateral trade dependence. The increase in bilateral export trade in the mining industry is significant, deepening the dependence on primary products trade between China and the EU and reducing China's dependence on the Middle East and the United States for energy-based products. China's exports to the EU of labor-intensive products such as machinery and equipment and textiles are also positively affected, and the trade surplus with Europe continues to expand.

The NSR provides a new trade channel for China-EU bilateral trade and brings new opportunities for bilateral trade development. China needs to attach great importance to the economic and trade impact brought by the NSR, and actively promote the scientific and rational strategic layout of the new route, to gain new momentum for development. Specifically, the government can provide technical and equipment support for the development of the Arctic shipping in terms of software technology and hardware facilities. Also, the government should actively promote policy communication with other countries under the framework of multilateral mechanisms to jointly promote the sustainable development and utilization of the NSR.

For future research, this paper only considers the average year-round conditions for the NSR navigation and neglects the specific navigation conditions for each season. The results may change as the shipping cost varies from season to season under different scenarios. This issue needs further research.

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Delivery without Bills of Lading under Chinese Law: Possible Solution Suggested

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Abstract

Purpose – Bill of lading is an important document both in the sale contract and the sea carriage contract. The two areas of laws separately cannot solve the problems on wrongful deliveries. This paper suggests two solutions to these problems.

Design/methodology/approach – The causes of the wrongful deliveries in China are stated. How the wrongful deliveries are handled under the Chinese law are discussed. Thus, the current situations of wrongful deliveries are understood.

Findings – There should be a fundamental change in the two areas of laws to solve the problems of wrongful deliveries. There should be a new concept of FOB sea carriage contract. The carrier should be given more duties by the issuing of FOB bill of lading.

Originality/value – The paper is suggesting a totally new concept, FOB bill of lading, as the solution of the problems of wrongful deliveries.

Keywords: Bill of lading   Delivery without bill   FOB contract

1. Introduction

In international sea carriage law, bill of lading is an important shipping document symbolizing the title of the goods being carried on board a cargo ship. It is also an important credit document controlling the payment of goods in an international sale contract.

The unique characteristic of the bill of lading is that delivery of the goods must be made against surrender of the original bill of lading (OBL). This rule has a twofold purpose. It is to protect the holder of the bill who is usually the seller of the international sale contract. On the other hand, it is to identify the lawful owner of the goods in the sea carriage contract.

However, by breaching the said rule, there are many cases that the carrier will take the risk to deliver the goods without the presentation of the OBL. This happens more often in relation to chartered ships than liners because of the problems of storage of the bulk cargoes, the liability of demurrage or damages for detention. (Wilson, 2010).

These wrongful deliveries are quite commonly happened every day. In China, the courts are handling many cases of this nature, i.e., delivery without the surrender of the OBL. In 2009, the Supreme People's Court announced that the number of cases dealt with by the Chinese courts were more than the total number of cases dealt with by all other countries. (Supreme People's Court, 2009b).

2. Identity function of bills of lading

After the delivery of goods from the shipper to the carrier at the port of loading, it is the right of the shipper to demand for the issue of bill of lading as evidence of the receipt of the goods by the carrier. It is good evidence of the external condition and quantity of the goods at the time of such delivery.

The OBL is not only to be used as a receipt of the goods. It is also a document of title. It is the duty of the carrier to return the same condition and quantity of goods to the lawful owner (or consignee) at the port of discharge in accordance with the sea carriage contract formed between the shipper and the carrier. If the consignee is not the same person as the shipper, the OBL will be used to identify who has the right to take delivery of the goods stated in the bills. It is the duty of the carrier to return the goods to the lawful owner. Thus, anyone who can present the properly endorsed OBL can prove to be the lawful owner of the goods.

3. Circumstances of deliveries without bills of lading

One of the purposes that the bills of lading must be surrendered is to protect the seller of the goods. Usually, the shipper who is also the seller will be issued by the carrier a set of bills of lading. By holding the OBL without releasing them to the consignee, the seller has the control of the goods and can make sure the collection of the payment of the goods from the buyer before delivery.

However, under the "free on board" (FOB) term of an international sale contract, the seller will lose such control of the goods and may suffer a loss in the payment of the goods by the buyer. In a typical FOB sale contract, the seller will be paid the price of the goods by the buyer before the former transfers the title of the goods to the latter by loading the goods on board the ship sent by the buyer. After the goods have been loaded on board the ship, the seller will have transferred the title of the goods to the buyer. In this typical FOB sale arrangement, since the seller has been paid for the goods by the buyer, it can be one of the arrangements of the international sale contracts.

Fraudulent FOB contracts

FOB contract can be used by a dishonest buyer as a tool to cheat for the goods without payment. This fraudulent act is not unknown to Chinese sellers. In fact, many Chinese sellers do not have the same bargaining power as the foreign buyers. Many manufacturers or traders in China are of small and medium enterprises (SMEs). In practice, by forming a sale contract on FOB terms, the Chinese seller will be paid a deposit first, say, 30% of the price upon or before shipment. The foreign buyer will usually appoint its own freight forwarder to make a sea carriage contract with the carrier. The parties of this sea carriage contract are the carrier and the buyer.

After the seller has loaded the goods on board the ship, the buyer's freight forwarder will be issued the bills of lading by the actual carrier. In many cases, the seller will be issued by the buyer's freight forwarder a document known as the Forwarder's Cargo Receipt (FCR) which is only a receipt in nature. Thus, the seller who is not the holder of the OBL will have lost the control of the goods loaded onboard the ship. Under such circumstances, the buyer can take delivery of the goods at the port of discharge, with or without the OBL, and, after taken delivery, the buyer will not pay for the price of the goods to the seller.

In other cases, although the seller has been issued a set of OBL, they have been issued by the contract carrier, i.e., the buyer's freight forwarder as carrier. Again, this OBL cannot really control the goods not to be delivered to the unpaid buyer. It is because the buyer's freight forwarder is the shipper in another sea carriage contract with the actual carrier. Under such conditions, it is very easy for the buyer to take delivery of the goods without the presentation of the OBL to the carrier.

In some other cases, the seller may take delivery of the goods by using forged bill of lading. Although the seller is still holding the OBL, the carrier has already released the goods to the buyer against the forged bill. As a result, the seller will not be paid for the price of the goods.

4. Laws governing the wrongful deliveries

In China, there are special provisions in the *Chinese Maritime Law* (CML) to deal with delivery without OBL. The Chinese courts are commonly applying Articles 71 to 80 concerning the use of shipping documents in their judgements in wrongful delivery cases. The number of provisions in this area, of course, is far less than enough to deal with different circumstances of the wrong delivery incidents.

Article 71 of the CML provides that:

> A bill of lading is a document which serves as evidence of the contract of carriage of goods by sea and the taking over or loading of the goods by the carrier and based on which the carrier undertakes to deliver the goods against surrendering the same. A provision in the document stating the goods is to be delivered to the order of a named person, or to order, or to bearer, constitute such an undertaking.

Only the OBL has such function to identify who the lawful owner of the goods is. A copy of the bill of lading cannot serve the same purpose.

To reach better judgements in dealing with wrongful deliveries, the Supreme People's Court (SPC) announced some rules by way of judicial interpretations in 2009 which were revised in 2020 due to the new statute of the Chinese Civil Code. These rules are known as "*Provisions of the Supreme People's Court on Several Issues concerning the Application of Law during the Trial of Cases about Delivery of Goods without an Original Bill of Lading*" (SPC-DWoB 2020). There are 15 rules in this statutory instrument. They are mainly governing the contractual or tortious liabilities of the carrier or the unlawful receiver of the goods.

5. People who should be liable

According to the contract of carriage between the shipper (or the seller) and the carrier, the latter should return the goods to the lawful owner of the goods (or the paid buyer). The way for the carrier to identify the lawful owner is by the presentation of the OBL at the port of discharge.
It is a breach of contract if the carrier has delivered the goods to a person without the presentation of the OBL. It is, thus, logical, and straightforward for the seller to claim against the carrier for damages for the loss of the price of the goods. However, it is not always so clear that who should be liable as the carrier of the contract of carriage.

Who is the carrier?

According to Article 42 of the CML, there are two types of carriers, i.e., the actual carrier and the contractual carrier. The actual carrier is the person who actually perform the sea carriage for the shipper in accordance with the contract of carriage and that is the normal case in the shipping industry. The contractual carrier is usually a non-vessel operating common carrier (NVOCC) or a freight forwarder who does not have its own ship to carry the goods. The NVOCC must form another sea carriage contract with an actual carrier to carry the goods. It will issue a house bill which is a document different from the bill of lading issued by the actual carrier to the shipper. Many wrongful delivery cases are carried out by a contractual carrier. Rule 2 of the SPC-DWoB 2020 provides that the carrier should be liable for causing the loss of the holder of the OBL. The carrier is including the actual and the contractual carriers.

In Case 7 of the National Cases of Classical Maritime Trial 2018, the seller sold goods to a US buyer who appointed a logistic company to handle the carriage of the goods. (Supreme People's Court, 2018a) After receiving the goods from the seller, the logistic company instructed its agent to issue a set of bills of lading to the seller and stated it as the shipper. Although the seller was holding the whole set of the OBL, the logistic company released the goods to the buyer at the port of discharge. At first, the seller sued the agent of the logistics company for the loss of the price of the goods. The case was lost because the Guangzhou Maritime Court held that that agent was not the carrier of the goods.

The seller started another action to sue the logistic company. This time, the Guangzhou Maritime Court decided that the logistic company should be liable for the wrongful delivery as the carrier, i.e., the contractual carrier.
If a carrier delivers the goods against a forged bill of lading, it is treated as delivery without the presentation of the OBL. Under Rule 5 of the SPC-DWoB 2020, the carrier is liable for the loss of the seller when the carrier has delivered the goods to a person who has used a forged bill of lading. The reason is simple. It is because a forged bill of lading is not the same as the OBL. Thus, the carrier cannot escape liability on delivery of the goods based on a forged bill of lading.

A forged bill is described by an English case that "a forged bill of lading is in the eyes of the law a nullity; it is simply a piece of paper with writing on it, which has no effect whatever." (Motis Exports v Dampskibsselskabet, 2000, p 216)

Tortious liability

Other than the carrier, the person who has taken delivery of the goods without the OBL (the wrongful receiver) is also liable to the lawful owner or the holder of the OBL. The legal reason for the liability of the wrongful receiver is different from the carrier. Since the wrongful receiver of the goods does not have any contractual relationship with the holder of the OBL, the former is liable under tort law. In other words, the wrongful receiver has infringed the property right of the seller.

According to Rule 11 of the SPC-DWoB 2020, both the carrier and the wrongful receiver should be liable to the holder of the OBL jointly and severally. In practice, the holder of the OBL usually claims against the carrier, rather than the wrongful receiver since the burden of proof of contractual breach is easier.

Forwarder's cargo receipt

Under a FOB contract, when the freight forwarder has been nominated by the foreign buyer to handle the transportation of the goods at the port of loading, the sea carriage contract formed between the carrier and the buyer's freight forwarder who acts as an agent of the foreign buyer. After the seller has handed over the goods to the buyer's freight forwarder or arranged the goods to be loaded on board the ship assigned by the buyer's freight forwarder, the seller will be issued a FCR by the latter.

In the sea carriage contract, the seller is known as the actual shipper. However, the actual shipper is not a party of the sea carriage contract. Although the FCR looks very similar to a bill of lading, the nature of the FCR is mere a receipt, not a document of title. Thus, when the actual carrier has delivered the goods without the presentation of the OBL, the seller who is the holder of the FCR has not the right to claim against the carrier for the loss of the goods.

In the case of *Junrong Underwears v Hongying International Forwarder and the American President Line*, after the seller had handed over the goods to the buyer's freight forwarder, the latter issued a FCR to the seller. After finding out that the actual carrier had delivered the goods without the presentation of the OBL, the seller sued the carrier for damages. (SPC Appeal 1604 of 2016)

The SPC held that the seller was only the holder of the FCR. The seller did not have the control of the goods because the FCR was not the same as the bill of lading. Since the seller had not formed the contract of carriage with the carrier, the latter did not owe a duty to the seller to deliver the goods against the presentation of the OBL. Thus, the seller had no right to claim against the carrier for wrongful delivery.

6. Limitation and exemption of the liability

Rule 6 of the SPC-DWoB 2020 provides that the measure of damages of the goods should be the value of the goods at the time of shipment plus freight and insurance premium, i.e., the CIF value of the goods. In other words, the carrier is liable for the full damages of the goods.

Under a wrongful delivery case, the carrier is not entitled to the benefit of the limitation clause in the contract of carriage or Article 56 of the CML. Thus, the unit limitation of 666.67 Special Drawing Right (SDR) per shipping unit is not allowed.

The reason of limitation of liability of the carrier is a distribution of maritime risks during the voyage between the carrier and the owner of the goods. Since wrongful delivery is not a maritime risk, the carrier should not be allowed to enjoy the limitation of liability. Moreover, it is the carrier's own decision to release the goods without the presentation of the OBL. It is not a risk covered by the marine insurers or any shipowners' protection and indemnity clubs. (Wang, 2011)

Rule 13 of the SPC-DWoB 2020 provides that if the wrongful receiver has agreed to compensate the lawful owner of the goods and the amount of the compensation is not enough, the carrier is still liable for the balance between the actual damages and the agreed compensation.

Exemption of liability

Rule 7 of the SPC-DWoB 2020 provides that where the carrier has to deliver the goods to the customs authority or the port authority and let them to make formal delivery to the receiver in accordance with the local law of the unloading port stated in the bill of lading, the carrier shall not be liable for the wrongful delivery made. The background of this provision has considered the compulsory laws in delivery of goods and allowing delivery without the presentation of the OBL found in the Central and South America, such as Brazil, Nicaragua, Guatemala, Honduras, El Salvador, Costa Rica, Dominica, Venezuela and in Africa, such as Angola, Congo. (Sofreight.com, 2019) (Wang, 2011)

In practice, the ports in Brazil are good examples of the application of Rule 7. The Brazilian law requires the carriers to hand over the goods to the unloading ports, no matter the goods are taxable or not. After the handing over, the carriers will have no more control of the goods on whom to be delivered. The port authorities will be responsible for the formal deliveries of the goods to the "lawful owners". Thus, many wrongful deliveries have occurred in the ports of Brazil. The Chinese courts are of the view that the port authorities in Brazil are not the agents for the carriers. Under such situations, the carriers will not be held liable for delivery of the goods without the OBL. (Shanghai Maritime Court, 2021)

However, the application of Rule 7 is not so straight forward as it is read. Even if the goods had been delivered in Brazilian ports, some carriers were held by the Chinese courts that they were liable for wrongful deliveries. In fact, the Chinese courts have set several conditions on the application of Rule 7 to exempt the liability of the carriers: (Supreme People's Court, 2020)

(1) The carrier should prove that the local law does force the carrier to hand over the possession of the goods to the port authority or the customs. For such evidence, a legal opinion which is written by a local lawyer is accepted as a personal opinion only and thus it is not sufficient. It is better to provide an official document issued by the Chinese embassy or the foreign trade authority located in that country.

(2) The carrier has to prove that he has lost the control of the goods and the release of the goods is decided by the port authority or the customs.

Rule 8 of the SPC-DWoB 2020 provides that, due to no one making declaration to the customs within the statutory time limit to claim for the goods, if the customs sell off the goods or the court makes a ruling to auction the goods retained by the carrier, the carrier should be exempted from the liability to deliver the goods personally. Rule 9 of the SPC-DWoB 2020 provides that where a carrier, on the request of the shipper of a straight bill of lading, suspends the transportation, returns the goods to the shipper, changes the place of destination, or delivers the goods to another consignee, the carrier shall not be liable to the holder of the straight bill for delivery without the OBL.

Rule 10 of the SPC-DWoB 2020 provides that when there is a set of bills of lading with several copies of original bills, the duty of the carrier is to deliver the goods against the first person who presents a part of the OBL. The carrier shall not be liable to other holders of the OBL for delivery without the OBL. In practice, there is frequently a provision in the bill that "one being accomplished, the others to stand void".

7. Limitation of action

The limitation of action in relation to the claims made by the holder of the OBL against the carrier who has delivered the goods without the OBL is provided in Rules 14 and 15 of the SPC-DWoB 2020, i.e., the limitation period in Article 257 of the CML should be applied. The limitation period is one year from the day when the goods should have been delivered. Interruption of the limitation period is the same as Article 267 of the CML.

The limitation period will be interrupted because of bringing a legal action or submitting the case for arbitration or admitting by the respondent to perform the obligation.

In Case 7 of the National Cases of Classical Maritime Trial 2018, the seller was issued a set of bills of lading by the agent of the contract carrier. (Supreme People's Court, 2018a) On 16 January 2015, the contract carrier delivered the goods at the port of discharge without the presentation of the OBL. On 21 October 2015, the holder of the OBL sued the wrong party, i.e., the agent of the contract carrier, for the loss of the price of the goods. The case was lost because the Guangzhou Maritime Court held that that agent was not the carrier of the goods. On 24 February 2016, the seller started another action against the contract carrier. The issue was whether the second action had taken after the 1-year limitation period had expired.

By applying Article 267 of the CML, the Guangzhou Maritime Court decided that the limitation period was interrupted by the first action on 21 October 2015. The 1-year limitation period counted again from 21 October 2015. Thus, the second action was taken within the 1-year limitation period.

8. Prevention of wrong deliveries

Many victims of wrong delivery cases are Chinese sellers in international trade selling goods to foreign buyers. Moreover, many wrong delivery cases are happened because of FOB term in the sale contracts. As early as in 2000, the Ministry of Commerce had already issued a document to remind Chinese sellers how to get rid of the risk of delivery of goods without the presentation of bills of lading. (Ministry of Commerce, 2000)

The suggestions made by the Ministry of Commerce are:

(1) Chinese sellers should not agree with the foreign buyers on the FOB term.

(2) If the FOB term has been agreed, Chinese sellers should not accept the freight forwarders nominated by the buyers. The reason is that it is unlawful for foreign freight forwarders who have not been approved by Chinese authority to issue bills of lading.

(3) If a foreign buyer insists to use a foreign freight forwarder, the Chinese seller should insist a Chinese approved freight forwarder to issue the bills of lading. Moreover, such freight forwarder has to provide a letter of indemnity to admit liability for any wrongful delivery at the port of discharge.

Possible solution to get rid of wrongful deliveries

The suggestions made by the Ministry of Commerce are not practical since it is unrealistic for a Chinese seller who is usually only a SME to protect itself by refusing to accept FOB term in the sale contract.

Bearing in mind that the unequal bargaining power and the fraudulent FOB contracts are the sources of wrongful deliveries, the Chinese sellers who are the weaker party in forming the international sale contracts have to be protected by the Chinese government by making new statutory and compulsory law to protect their interests.

Although there are several common reasons for wrongful deliveries, many of these cases are in close connection with the use of FOB sale contract between the seller and the buyer. However, the rule that a carrier has a duty to deliver the goods carried against the presentation of the OBL is a rule of the sea carriage contract between the shipper and the carrier. Thus, the nature of wrongful delivery is involving two different areas of laws.

Another special feature of wrongful delivery is that the seller has lost the control of the goods because of not holding the OBL. As a result of wrongful delivery, the seller is usually suffered the loss of the price of the goods. Since wrongful delivery is involving both areas of the international sale contract law and the sea carriage law, it has become a difficult problem which cannot be resolved easily. The solution of wrongful delivery must change the rules in both areas of laws.

When there is a sale contract on FOB term and the seller has not collected the price upon handing over the goods to the buyer's freight forwarder. Under such circumstances, the new statutory law will presume that a special sea carriage contract is created which is known as "FOB sea carriage contract".

Under a FOB sea carriage contract, the carrier should be given an additional duty to protect the interests of the FOB seller. The carrier should have a duty to make enquiry to find out whether the carriage is based on a FOB sale. If it is, the carrier has to find out whether the seller has been paid the price of the goods in full. If it is not, the carrier, both the contract and the actual carriers, should issue the bills of lading to the seller and state the seller as the shipper. This is known as a "FOB bill". Thus, the seller will not loss his control of the goods and wrongful deliveries will not happen easily.

Before the new law has been enacted, another possible solution is to insert a provision in the sale contract. The effect of such provision is that, before the seller has been fully paid the price of the goods under FOB terms upon handing over the goods to the buyer's freight forwarder, the seller should be issued the set of OBL by the carrier, both the contract and the actual carriers, and stating the seller as the shipper. This provision should be classified as a condition of the sale contract.

9. Conclusions

Wrongful deliveries have a long history, and this problem is not easy to resolve. The traditional protection of the seller under FOB terms is by way of holding the OBL. It has proved that this protection is ineffective. After the wrongful delivery has occurred, the period of limitation of action is short, i.e., one year. When the court has made a judgement to allow damages to the seller, it may be too late that financial difficulties have been caused to the seller, or the seller has to face with another problem in enforcing the judgement, especially in foreign countries.

It is much better if the wrongful delivery can be prevented. It is submitted that such prevention can be achieved if the rules of the international sale contract law and the sea carriage law can be changed. The new concept of "FOB sea carriage contract" plus the use of "FOB bill" will prevent the problem of wrongful delivery. Alternatively, the seller should insert this new concept into a FOB sale contract by way of contract terms.

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Resilience and Growth Strategy of International Aviation with Sustainability Concepts of Green and Social Responsibility

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Abstract

Aviation Industry was among the worst affected sector during the Covid-19 pandemic and despite the ongoing crisis, we begin discussions about various strategies to be applied as sustainability initiatives. While the resilience of the aviation market amid Covid 19 pandemic is underway, the exponential growth and high fuel use shall contribute to the increase of CO_2 emissions. This study aims to analyze the severity of global warming contributed by aviation industry and to estimate the cost of achieving CO_2 emission reduction targets. In the process of sustainable growth, it becomes necessary to sacrifice either sustainability or profits where the governments and the aviation industry must strike a balance in national interest and recovery plan for the airlines in achieving its carbon emission reduction targets with optimum utilization of resources, policy incentives and financing for technology adoption. The findings are based on systematic review and data derived from published articles related to IATA, ICAO, ICCT and from recognized academic publications to extract the research-based information presented in literature review. Also, citation index and review of the paper noted to ensure credibility of the data. A close evaluation of analytical data in reference to aircraft types, fuel consumption, route and distance based on primary data of 2 years from market peers was assessed to calculate GHG emission and to propose the GHG reduction trajectory shall be the core objective with suggested profitable network and intermodal transport connectivity. The study concluded with the inadequacies of ESG factors and sustainability reporting calling upon the need for individual participation in tackling climate change and to demonstrate industry leadership and management incentives designed to encourage in delivering a low carbon transition plan, carbon disclosures, carbon credit and green finances. Hence, the emphasis laid upon the international aviation's efforts in collective leadership towards reducing carbon emissions and comply with their global responsibility.

Keywords: Resilience, Sustainability, Green Finance, Innovation, Collective Leadership.

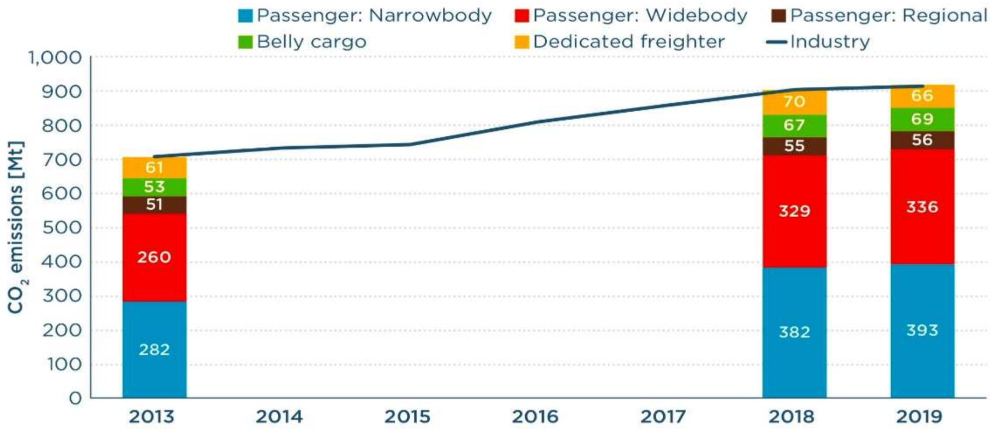
Introduction

This study aims to develop a framework that can be used to evaluate, explore and implement sustainable mitigation approach to reduce GHG emissions and to decarbonize aviation sector. Apart from the reduction of GHG from the atmosphere, there are policies implemented towards carbon offset scheme, whereby the carbon footprints shall be neutralized by abatement activities in other sectors. The Covid 19 impact has helped to develop a sustainable growth plan consisting of green initiatives using fuel efficient aircrafts, alternative fuels, advanced technology to build up the digital capabilities and effectively manage the surge in demand and maximized fleet utilization with minimum carbon footprint. The policy support and improvement in infrastructure has been explained using various sustainability strategy concepts and models. The findings suggest that the green initiatives in achieving transformational changes and GHG emission reductions at scale while maintaining competitiveness and economic growth. The study concluded with a detailed sustainability strategy designed to demonstrate collaborative leadership towards achieving carbon emission reduction goals by achieving carbon neutral by 2030 and carbon negative by 2050 . Although the multilateral treaties signed in the past have proved the commitment from Governments and Environmental Agencies, the inadequacies of the policy in achieving climate goals still remains a debatable concern because of the rapid changing social, economical, political and climatic factors. The key focus towards achieving the sustainable goals is the use of quantitative tools merged with qualitative strategies to find the right balance between the abatement cost and reducing CO_2 emissions.

1. Overview of Aviation Sustainability and its Impact on Environment

Environmentally conscious aviation and sustainable policies have become quite prevalent on the global level. As per the recently published data on the environmental portals, the contribution of aviation industry towards

CO_2 emissions has exceeded 2.5% which amounts to 920 million metric tons of CO_2 emissions in 2019. Below is a Global Aviation Carbon Assessment (GACA) model analysed data for 3 years showing CO_2 emissions of different aircraft class.



CO_2 emissions by operations and aircraft class in the three analyzed years.

Picture – 1

The analysed years 2013, 2018 and 2019 shows the contribution of passenger flights CO_2 emissions upto 85% of the commercial aviation amounts to 785(Mt) CO_2 which is an increase of 33% from 2013 figures. Also, the impact of freight is upto 15% of the total emissions which amounts to 135(Mt) of CO_2 emissions consists of cargo movement on dedicated freighters and belly capacity of passenger flights. Most commercial airlines are using Jet-A and Jet-A1 fuels which are fossil fuel emitting more than just CO_2.that includes water vapour, methane, nitrous gases and aerosol particles that affects the air quality impact on climate change. Also the combusion of Jet fuels forms contrails contributing to anthropogenic contrail cirrus with radiative response to the climate system. Although, there are several operators who have made a gradual shift from conventional jet fuels by introducing alternative bio fuels but the ratio is too less to make a significant impact on decarbonization considering the active commercial fleet in service.

2. Emerging Concept of Sustainable Strategies in Aviation

World's population is almost nearing to eight billion and estimated to reach 9 billion by 2050. Sustainability quite often being associated with the global warming and climate change as a result of increase in carbon dioxide (CO_2). Although CO_2 not harmful to our life but its increase causes earth to retain the heat thereby making it warmer. This temperature increase has contributed to melting glaciers and rising sealevels causing adverse conditions including natural disasters caused as a result of human induced emissions. Not only does it affect the survival on the land but also cause coral degradation from CO_2 absorbed by the ocean increasing acidity of the ocean. Strategies have been suggested towards reducing the carbon footprint of the aviation industry, however the most popular and accepted strategies around the world in connection with the airline industry is the newer aircraft types like the Airbus A320neo(narrow body) and Boeing 787-9(widebody), or replacing Jet Fuel with Sustainable Aviation Fuel(SAF) processed from renewable sources like plants and used cooking oil which is considered to have signficant reduction in CO_2 emissions. Although, SAF is yet to gain momentum in the aviation sector due to high cost, availability issues, logistics challenges and inadequacies in terms of government support and industry commitments, the future of replacing jet fuel is still a potential step towards reducing CO_2 emissions by 80% while the rest of the decarbonization achieved through offset measures that includes carbon credits and other green initiatives used for carbon offset.

3. Resilience of Aviation Industry Post Pandemic Era

While the pandemic has affected the aviation industry causing serious financial losses due to decline in demand for air travel and quarantine regulations, it can also be seen as a good opportunity mainly with the airlines response to the crisis and restore their business sustainably. Resilience of aviation industry depends on the long term contingency plan and it requires commitments at all levels to coordinate and implement policies aimed at achieving carbon emission reductions and enhanced operational efficiency. In the recovery phase of the aviation industry, the airlines need to carefully evaluate on the abatement measures to determine carbon footprint at the lowest cost.

During the covid-19 the demand for cargo movements has been on the rise due to the decline of passenger flights where more than 50% of cargo moved on the passenger flight belly and major volumes related to the e-commerce goods, medical and health kits, pharma products, vaccines and electronic products. The overbookings on freighter capacities had to be moved on the belly of passenger aircrafts and cabin space converted for freighter operations to fill the gap and was a relief to many airlines to have utilized the opportunity and prevented airline from bankruptcies and protecting the debt providers while on the other hand the equity owners weighted average cost of capital (WACC) remained low due to lower margins. However, as per the latest reports from IATA, the global revenue passenger kilometre (RPK) has improved by 18% and this is due to the increase in demand for passenger movement as a result of vaccine roll out , removal of travel restriction and quarantine regulations in most of the countries. The domestic market also continues to indicate strong fundamentals while the tough competition among the airline to regain the business shall be a boon to the passengers to enjoy low fares and also improved connectivity will make it more convenient for domestic trips.

The impact of aviation industry on the global warming has been addressed in the international forum for climate change and published with supported evidence indicating that the targets set by the global organizations has been given less priority or even ignored by majority of the industry leaders. Paris Agreements on decarbonization, the KYOTO Protocol for reducing emissions and CORSIA as the carbon offset and reduction scheme are few of the several policies and schemes to enhance the participation from the aircraft manufacturers, industry leaders, airline companies and other stakeholders showing their commitment towards reducing carbon footprint. However, as per the latest reports of IPCC, GISS indicates strong warming trend for last four decades likely reflecting a shift from balanced aerosol & GHG effect on the atmosphere to a predominance of GHG effect after the aerosols were curbed by pollution control.

4. Efforts to Address GHG Emissions from International Aviation

The main objective of signing the Chicago convention in 1944 was to achieve uniformity in the standard of civil aviation policies and procedures globally and has lead to the formation of ICAO as a global regulatory framework. For the past seven decades, aviation industry has grown rapidly as an essential part of the economy by facilitating international trade and tourism and becoming an indispensable means of transport. It is also important to note the role of affiliated bodies and independent international organizations also to join the aviation community with individual goals and collaborative leadership. Several reports are published from reliable sources ACI (Airports Council International), CANSO (Civil Aviation Navigation Service Organization), IATA(International Air Transport Association), ICCAIA (International Coordinating Council of Aerospace Industries Association) , (ATAG) Air Transport Action Group , ICCT(The International Council on Clean Transportation) provides up to date information about the global trends in aviation and providing assistance to all industry stakeholders at all levels to benefit from the data.

Aviation industry currently with over 33,299 aircrafts registered over 1478 airlines has been serving approximately 3780 airports globally and managed by 162 air navigation service providers (ATAG Figures) As per the forecast reports, the growth of aviation sector shall be very rapid in the next 2 decades and most likely to double in terms of air traffic volumes. The allied divisions and support frames of aviation shall also grow in proportion thereby creating a positive impact on job creation, efficiency and technology upgrade. However, the exponential growth of aviation will lead to increase of CO_2 emissions that needs sustainable planning and investments in green aviation.
The impact of aviation on the environment has contributed to the global warming and responsible for 2.4% of global emissions of CO_2 as per 2018 statistics of IATA and is expected to grow significantly with the traffic growth. The global aviation industry has demonstrated its commitment and devised various strategies to reduce global emissions of CO_2 through technological, operational and infrastructural improvements towards achieving carbon neutral goals from 2020.

5. Proposed Solutions by adopting the standard methodology and framework

With the growing impact of climate change the governments, international organizations and institutions being more engaged in the estimation and reporting of carbon footprint and policies amended towards achieving the targets more effectively. Several carbon calculating methodologies have been scrutinized to match with the required standards set forth by government departments, environmental agencies, international trade bodies and carbon offset companies. Also introduced in this report is new methodologies like those developed by Sabre holdings which is more sophisticated and improved method to make it an international standard for use by carbon offset companies and supports business CSR reporting.

The methodology to calculate the CO_2 emissions may vary from the method of estimating the emissions of CH4 and N2O. CO_2 can be calculated by using the emission factors multiplied with quantity of fuel consumed. But the CH4 and N2O emissions depend on the emission control equipment installed, efficiency and vintage of the combustion technology, maintenance and operational practices. Hence, CO_2 estimation is more simplified compared to other gases CH4 and N2O but in practice the calculation of CO_2 is most important to estimate the organization GHG inventory. In the case of using biofuels, we must report in the GHG inventory to show Biomass CO_2 separately and inclusive of the other gases.

If blended fuels are used, the percentage of blend between gasoline and ethanol must be considered to split the CO_2 emissions to show as Fossil and Biomass CO_2 emissions. If there is an uncertainity about the use of blend, the reporting must be based on Fossil CO_2 emissions. The GHG Protocol corporate standards are considering on isolating of the atmospheric carbon in the emission calculation.

For the aviation industry, the most preferred calculating method is as follows :

Primary data required for estimation of CO_2 emissions as listed below :

1. Fuel Type
2. Distance (using great circle)
3. Aircraft Type
4. Year of Manufacture (Also mention any fuel control technology installed)

Assumptions – Fuel consumption shall include the taxi fuel, and trip fuel, but exclude reserve fuel (contingency, alternative, final reserve fuel) this shall be considered based on special case if technical or emergency incidents. Also, it is assumed no fuel tankering performed on any flights.

If possible to record the fuel supplier data in units and the fuel prices should be considered based on regions where the fuel was procured either at origin, transit or destinations and based on the fuel index monthly average based on IATA Jet Fuel Price Monitor https://www.iata.org/publications/economics/fuel-monitor/Pages/index.aspx

Calculating CO_2 emissions by using default emission factors (EF) by metric tonnes. CH4 and N2 O emissions depends not only on the fuel type but also based on the combustion technology installed on the aircraft and the catalytic converter design.

Sources included in the GHG reporting shall include inventory reporting, environmental reporting and financial reporting and all other aspects of ESG reporting.

Documentary sources for fuel burn can be derived from

Fuel consumption data like fuel supplier bills with quanity specified in metric tonnes

Distance travelled data can be obtained from the great circle mapper

Fuel economy data can be obtained from the maintenance manual of the aircraft

Activity data and emission data can be verified from different approaches

If emission factors can be obtained from the fuel supplier and cross verified on US sites

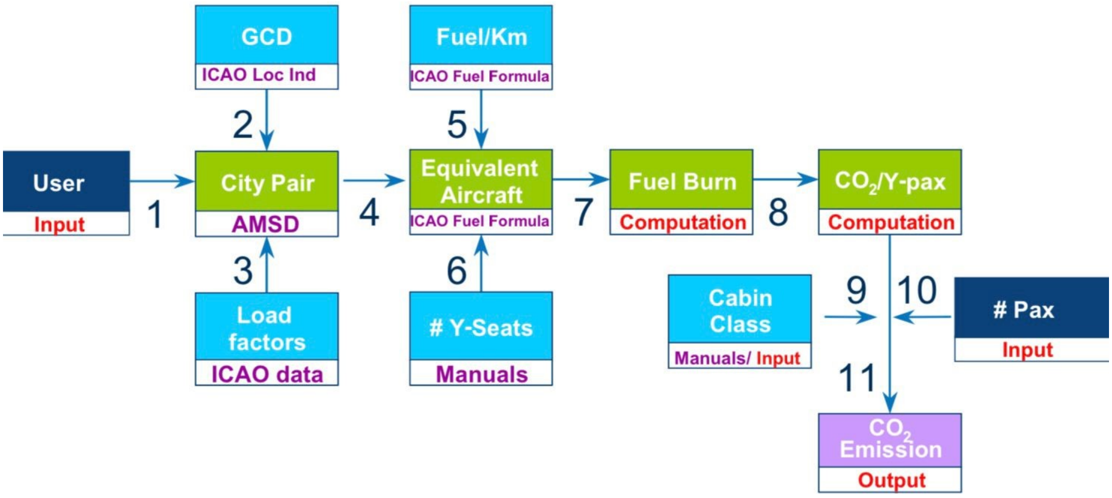
EF values used as basis for calculating GHG emissions :

To understand the calculation, we have tried to include two of the most commonly used methods as below :

Based on the distance derived from the great circles from origin airport to destination, below are few of the methods to calculate the CO_2 emissions:

i. ICAO Carbon Emission Calculating Method

The ICAO Methodology uses distance between origin and destination airport and uses the traffic and operational data published in the ICAO table to follow the below explained steps to obtain the CO_2 footprint attributed to each passenger travelling between two airports. The City Pairs data obtained from airline multilateral schedules database (AMSD), great circle distance obtained from coordinates from ICAO location database, load factors of the city pair data obtained from traffic by flight stage (TFS) and domestic traffic and operational data from the ICAO and flights schedule published by the airlines. Fuel per kilometre obtained from fuel consumption ICAO Fuel Consumption Formula. The seating information based on cabin layout with economy, business and first class information obtained from the aircraft manuals of the aircraft manufacturers.



Picture – 2

Step – 1

From the great circle mapper, enter the origin and destination. If city pair or code share is considered as one flight. If use different carrier will calculate distance separately. The GCD correction factor is included in excess of the actual distance flown to adjust the stacking, traffic and weather-driven corrections.

Step – 2

Passenger load factor and passenger freight factor with reference ICAO data base Appendix A : Load factor by route group (2015)

Step – 3

The fuel burn related to flight distance is extracted from ICAO Fuel consumption theory. Variables are known , the amount of fuel consumes is based on weighted average on the routes multiplied with total departures for the year.

Step – 4

Comparison of the maximum seats on aircraft and occupancy rate.

Step – 5

CO_2 emissions per economy passenger derived using the below formula

CO_2 per pax = 3.16 * (total fuel * pax-to-freight factor)/(number of y-seats * pax load factor)

For further improvement in the methodology, the variable factors are updated by ICAO and available for the carriers offseting programmes with more accuracy in estimating carbon footprint and enhance the efficiency to achieve the carbon reducing goals.

ii. DEFRA Methodology.

The UK department of energy food and rural affairs (DEFRA) in the United Kingdom responsble for environmental protection, food production standards, agricultural and fisheries and rural communities in the United Kingdom. As part of the CO_2 emissions reporting has developed their own calculating methodology which was later adopted by other institutions and international organizations.

The UK government produces new set of conversion factors every year along with the methodology on how the conversion factors has been derived. The emission factors are intended to represent the average emissions per passenger kilometer from different range of aircrafts (Domestic, Medium Haul and Long Haul Aircrafts)

DEFRA factor depends on per range and flight type as below

FLIGHT RANGE	**% CONTRIBUTION**	**GHG EMISSIONS IN CO_2e**
DOMESTIC FLIGHT SHORT	<500 KM	2.70488 $KgCO_2$
MEDIUM HAUL FLIGHT	500 – 600 KM	1.05849 $KgCO_2$
LONG HAUL	>1600 KM	0.770081 $KgCO_2$

Table: 1

The following methodology helps in calculations of carbon emission for air freight to multiple export routes.

Total CO_2 emissions per route:

CO_2 emissions = (Distance flown directly between two airports in km * total weight of consignment * defra factor)

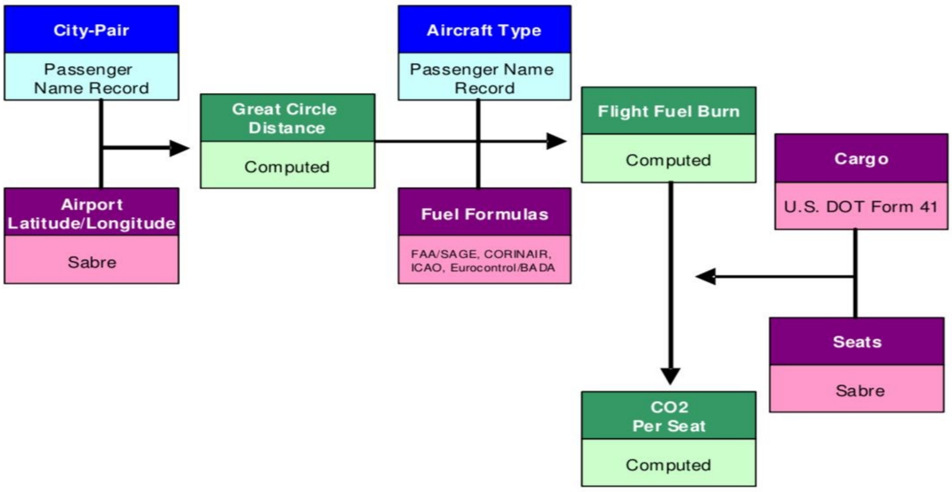
The collection of data is mostly from the annual reports, sustainability reports and corporate social responsibility reports published by the carriers. The actual emissions can differe significantly by aircraft type in terms of domestic, medium and long haul and also with the load, cabin level, flight route etc. The emission factors refers only to the direct emissions of CO_2, CH4, N2O. Due to the ambiguity about non-CO_2 emissions and it impact including water vapour, N2O, contrails has been taken into consideration by adding a specific factor.

This method can used to evaluate the emissions from transhipment cargo and intermodal transportation via gateway hubs. Intermodal connectivity must be evaluated and planned to ensure CO_2 emissions can be lowered while planning the routes. In addition to the inventory of the current CO_2 emissions, the department also plays an important role in various sustainable initiatives aimed at achieving the CO_2 reduction targets.

iii. The SABRE Holding Model

SABRE is the reservation system with database of the passengers travel information, aircraft and seat configuration details and consists of two high quality of data source namely The System for assessing Aviation's Global Emissions SAGE and Passenger Name Record. The CO_2 emissions calculated are more accurate from the data retrieved from SAGE which is a system developed by the US Federal Avition Administration's office of Environment and Energy. The model is available to the international aviation community as a tool to calculate the global emissions. The passenger name record (PNR) contains individual flight details used for passenger flight booking and the information obtained from PNR system enables accurate calculations of CO_2 emissions per flight basis.

The Methodology of SABRE Holdings Model as in below illustrated flow chart can be explained in four steps:



<u>Picture – 3</u>

Schematic methodology used in SABRE Holding Model

Step – 1

From the PNR, can obtain the passenger travel information, distance from great distance mapper calculated. The extra fuel burn for stacking or deviations accounted for and do not need to consider additional factor. The PNR also contains the aircraft type and Sabre Model has developed fuel burn formula in its feature for easy reference tool to calculate the fuel burn for the flight.

Step – 2

The fuel burn for the flight calculated after removing cargo factor using data US Form 41 traffic data after which the fuel burn per seat using aircraft configuration and seat plan based on data available in the database of Sabre Holding Reservation System.

Step – 3

CO_2 emission per seat obtained by multiplying with the emission factor of 3.16 $KgCO_2/Kg$ fuel and for calculation must consider only the CO_2 portion and not any other non- CO_2 towards additional climate impact at altitude.

6. Collaborative Efforts of Government, International Organizations, Airlines, NGO's and Policy Makers as part of the reporting initiatives.

Effective polices are very important to implement and achieve net-zero emissions. Although several International Treaties have been adopted to address climate change, the GHG-A emissions from global aviation have increased on average 3.3% per year since 1990 due to rapid growth in Air Volumes of 5.2% per year(IATA, 2015,2017) As reflected in the Paris Agreement, limiting the air temperature rising and maintain its levels below the 2°C by reducing the carbon emissions, increase the ability to adapt Climate Change policies and to mobilize adequate finance to invest in sustainability initiatives. Hence, it is extremely important for understanding about the reporting protocols and the approach to accounting for the CO_2 emissions as below:

a. The Green House Gas Protocol Initiatives

One of the most widely used reporting tool is Green House Gas Protocol(GHG Protocol) to enable the government and industry leaders in understanding, measuring and reporting the green house gas emissions. The GHG Protocol is a long term collaboration between the World Research Institute and the World Business Council in working closely with the government, international organizations, environmental boards and business groups in building an advanced platform to address the climate issues and to develop and implement sustainability programmes.

Providing with accounting framework designed to meet every GHG standards and to support every individual companies to comply with the International Standard Organization and providing assistance in preparing and reporting GHG inventories. GHG Protocol support to aviation industry by providing with the emission factors and is prepared on the distance based methodology. The GHG Protocol uses DEFRA's emission factors to calculate the CO_2 emission and can be classified into three type of trip short, medium and long haul with the emission factors 0.180, 0.126 and 0.11. as the GHG Protocol is based on DEBRA methodology, they are suitable for reporting per seat basis. However, Sabre Holdings has more accuracy to measure CO_2 emission on flight by flight basis becos it can differentiate betwen different carriers and aircraft type to calculate emissions while GHG protocol is per passenger based methodology.

b. World Resources Institue (WRI)

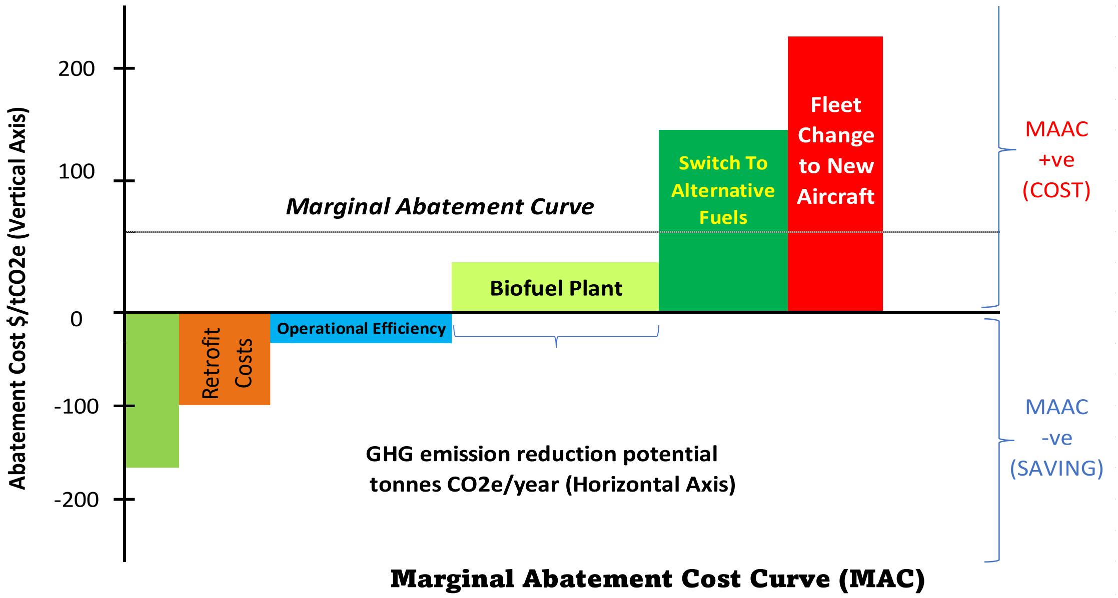
Once of the main focus of the institute is to to motivate more and more industry leaders about the sustainable policies and provide guidance to foster environmental and social developments in achieving the climate goals. It has developed a calculator tools named Safe Climate for calculating the carbon footprint using a flat conversion factor 0.18 $KgCO_2/Km$ and is applied for all flights but the basis of the emission factor is on short haul and derived from the DEBRA methodology.

c. Global Reporting Initiative (GRI)

GRI as an organisation aiming towards uplifting the sustainable reports to world standard and most commonly used for the reporting and has been the choice of most of the leading organization from all over the world including international organizations, aviation community, NGOs working towards sustainable developments and CSR Programmes. The framework for reporting is based on sustainability reporting guidelines and includes participants from business, civil society and environmental organizations. The tools are updated from time to time to enhance the reporting framework to meet the industry standards for continuous development and allows performance comparison with industry piers for voluntary initiatives. The updated version GRI-3 guidelines includes six categories for reporting economic, social, environmental, human rights, labour, product responsibility. There are 30 environmental protocols included among which 17 are mandatory and 13 protocols are voluntary in nature.

7. Marginal Abatement Cost Curve for Achieving Carbon Emission Reducing Targets

In order to reduce the carbon footprint, the airlines must implement strategies which comes with a certain cost. The major challenges for the available options shall be the lead time, efficiency levels and the cost implications. The levelized cost of carbon abatement, LCCA is an improved methodology to compare the available technologies and policies based on cost of carbon abatement. These costs can depend on the geographical, infrastructural and other factors and the LCCA measures how much CO_2 emission can be reduced by a specific investment on the basis of dollar per ton of emissions reduced. The analysts and modellers over the years have attempted to evaluate the associated costs of CO_2 emission reduction on a $/Ton basis using high level macro-economic analysis commonly represented by general equilibrium model (GEM) based on market specific conditions like demand, supply, inflation etc and underlie estimates of social carbon cost (SCC) which estimate future economic cost associated with the climate change. Marginal abatement cost cuve(MAC) is a different approach to estimate a general cost curve to estimate the marginal abatement cost with its key findings that some of the measures generated negative costs benefits the airline to save cost at the same time reduce carbon footprint.



Picture – 4

Global GHG abatement cost curve to related the emission reduction potential in tonnes CO_2e on the horizontal axis and cost of emissions on the vertical axis to show the marginal abatement measures in dotted horizontal line. Marginal abatement cost curves are useful for comparing and prioritizing the most beneficial project project in carbon management perspective are those with highest carbon reductions in tonne CO_2e at the lowest cost. MAC Curve methodology has limitations as it does not provide any information about the lead time at which the abatement is possible and this will draw to inconsistency on the final cost associated with the implementation and likely to underestimate required investments. Beyond these approaches, many analysts have attempted to estimate abatement cost based on technology advancement, introducing fuel efficient aircrafts, airport efficiency, infrastructure developments, improving air traffic control and estimated abatement costs $/tons which shall generate revenue despite substancial up-front costs.As part of new initiatives, new technology Direct Air Capture (DAC) Technology which has claimed to absorb surplus carbon using high turbo plants and store underground in tanks, However this concept had lot of criticism from the environment activists and international organizations and not gained importance also due to the high abatement cost.

SUSTAINABLE AVIATION FUEL AS A CARBON MANAGEMENT FACTOR

Sustainable Aviations Fuels Aviation sector has been an integral part of the economy and the need to reduce the carbon footprint with available options of battery powered, hydrogen powered is not an immediate availability. Technology and infrastrure, air traffic improvements can reduce some emission but not dramatic changes as required to meet. Based on the available resources and the ICAO standards, the primary focus shall be on the use of alternative fuels towards decarbonizing the aviation sector. The carbon offsetting and reduction scheme is also aiming towards carbon offsetting and creating demand for low carbon alternative fuels by implementing various voluntary and mandatory targets.

ASTM International has approved six pathways to develop sustainable aviation fuels(SAF) and these are low carbon fossil fuel or bio-fuel which are blended with the conventional jet fuel to develop these blendstocks as listed below:

1. Biomass Fischer-Tropsch Synthesis (FT)
2. Hydrotreated Esters and Fatty Acids (HEFA)
3. Alcohol to Jet (ATJ)
4. Direct Sugar to Hydrocarbon (DSHC)
5. Co-processing
6. Catalytic Hydrothermolysis Jet (CJJ)

Specific carbon reduction depends on feedstock type, availability, associated land-use changes, carbon intensity and blend ratio. Fuel carbon intensity for each type may depend on feedstock harvest, transportation, processing method, logistics to end user and combustion. Among the above six pathways, most preferred for price advantage and carbon intensity compared to the jet fuel A baseline are FT, HEFA, ATJ and DSHC.

Limitations:

Although this approach is robust and valid, there is still an uncertainity on the performance to fully decarbonize of total air miles travelled. Due to the limitations with allowable operating standards, SAF can only be considered as partially substitutable and fully decarbonizing using SAF shall be a very costly and difficult aspect due to both availablity and affordability. SAF option do not substantially reduce fuel carbon intensity and the processing cost is higher compared to the biofuel processed from used cooking oil or through Fischer-Tropsch for lignocellulosic biomass residue and muncipal solid waste which has relatively low abatement cost. While the policy makers and international organizations aims at reducing the carbon footprint of aviation, the SAF suppliers are aiming at increasing the demand so production cost can be lowered and the airlines looking at switching to alternative fuels when the availablility and affordability is improved. The aviation fraternity has to team up for collaborative leadership and strike a balance between all stakeholders in achieving the sustainable goals.

Conclusion

The key areas on the continuous improvement shall be on the service quality, cost, safety, city pair and interlines, technology advancement, consistency and sustainability. Close evaluation of all the available abatement options, use of sustainable fuels and fleet upgrade to replace fuel efficient aircraft seems most potential for reducing the carbon footprint. A critical step in achieving a competitive advantage is to focus on the cost and the cost drivers and in this scenario the airlines consider cost that included financial cost and non-financial cost. Non financial cost can be the carbon pricing and social cost of carbon (SCC) and this shall be provision for abatement cost. Also, the profit does not mean just the difference of revenue and cost and it must also apply the same as non-financial profits in the form of intangible values of the company earned due to competitive advantage that comes from the sustainability initiatives, the brand recognition and credit ratings, share value increased due to the CSR programmes. Regional collaborations to influence the industry piers to participate in the sustainability projects like bulk purchase and negotiations with SAF suppliers to enjoy the economies of large scale thereby reducing the buying cost. Green initiatives to invest in massive plantation projects and accumulate carbon credits at cheaper cost compared to individual buying. Participate in joint investments to set up bio diesel plants nearby to the sea port locations where there could be a regular supply of certified SAF or alternative fuel using napier grass, bagasse, used cooking oil or solid municipal waste as the feedstock.

Collective participation in developing own block chain technology based application integrated with sourcing, planning, logistics, payment gateway, marketing surplus to regional partners and overseas trade of SAF and biofuels. Spearheading local and regional level GHG reporting initiatives and providing technical and academic support to investors, customers, aviation partners and connecting with the international associations. Volunteers participation, low cost leaders, inviting experts to award functions to recognize potential members to felicitate in the events conducted in the interest of stakeholders and regional sponsors. Brand promotion using advance digital technology and conducting similar kind of events regionally.

Carbon emission calculating methodology supported with scientific methods and case analysis using fuel management experts to evaluate fuel consumption and emission factors based on aircraft type, payload and closely monitor the GHG reporting data to match with the global standards will enable aviation industry to achieve the carbon neutral followed by carbon negative economy before 2050.

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Abbreviations

CO_2	Carbon dioxide
IATA	International air transport association
ICAO	International Civil Aviation Organization
GHG	Greenhouse Gas
ESG	Environmental, Social and Governance
ICCT	International council on clean transportation
GACA	Global aviation cargo assessment
Mt	Million Tonnes
Mt	Million Tonnes
SAF	Sustainable Aviation Fuel
R&D	Research and development
WACC	Weighted Average Cost of Capital
RPK	Revenue Passenger Kilometre
KYOTO	KYOTO Protocol was international treaty adopted in Kyoto Japan
CORSIA	Carbon offsetting and reduction scheme for international aviation
GISS	Goddard Institute of Space Administration
CANSO	Civil aviation navigation service organization
ICCAIA	International council of aerospace industries association
ATAG	Air transport action group
NDC	Nationally determined contributions

CH4	Methane
N2O	Nitrogen dioxide
CSR	Corporate social responsibility
EF	Emission Factor
GWP	Global warming potential
AMSD	Airline multilateral schedules database
TFS	Traffic by flight stage
GCD	Great circle distance
DEFRA	Department of energy, food and rural affairs
$KgCO_2e$	Kilogramme Carbon dioxide equivalent
PNR	Passenger name record
WRI	World resource institute
GRI	Global report initiative
LCCA	Levelized cost of carbon abatement
GEM	General equilibrium model
SCC	Social cost of carbon
MAC	Marginal abatement cost

Airport Cargo Loader Rollers from Aluminium to Composite: Environmental, Sustainability and Social Benefits

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Abstract

The Hong Kong Airport Authority published the "Substantiality Report 2020/21" (HKIA, 2022) which set its environmental targets and a range of environmental footprint reduction measures in key environmental aspects such as carbon management and climate resilience. This paper is inspired by these targets and measures. The performance of two major types of rollers made of aluminium alloy and composite used in airport air cargo loaders is compared. It is noticed that the number of rollers used in the loaders is huge and they might be a hazard to the environment. Due to the developments in material technologies, the materials used in the making of the rollers may have impacts on the sustainability, environment and social responsibility. For the reduction of carbon footprint, one possible way is to reduce the weight of airport air cargo loaders. Thus, the energy for driving the loaders is reduced which results in the reduction of carbon footprint. The weights of an aluminium alloy roller and a composite roller are 275 and 130 g, respectively. With appropriate assumptions made, the total weight of rollers in loaders at the Hong Kong International Airport is reduced by 47.2 tonnes if all the aluminium alloy rollers are replaced by composite rollers. This results in significant reduction in the energy (~ 86.3 tonnes diesel per year) of moving such heavy load around the airport and hence carbon footprint reduction. The carbon footprint differs by 4.4 times for the refining the aluminium and nylon. The equivalent difference is 561.5 tonnes carbon footprint reduction which is even more significant. For the manufacture of rollers from the materials, preliminary finding is that as aluminium melts at 660 ºC and nylon melts at 264 ºC, so the energy needed is also significantly different. Last but not least, in terms of social responsibility, a detailed comparison on toxicity of the materials is presented in this paper. It is proposed to replace the aluminium alloy rollers by composite rollers for the sake of sustainability, environment and social responsibility.

Keywords: Air cargo loaders; Rollers; Aluminium alloy; Nylon composite; Environmental footprint

1. Introduction

Hong Kong International Airport (HKIA) has been one of the world's busiest international airports since 1996, in terms of both total passengers and cargos (Lo et al., 2015; Tsui et al., 2014). In 2020, HKIA handled 4.5 million tonnes of total cargo throughput, which accounted for about 43% or HK$3,500 billion of the total value of Hong Kong's external trade. Currently, HKIA provides 43 parking stands for cargo aircraft and is recognized as a competitive advantageous air cargo hub in the world. Air cargo loaders are the key ground equipment for air cargo loading and are spread all around the ramp areas at HKIA. In recent years, operators are in great concern about the environmental impacts of ground equipment operating at the airport which include noise, dust, smell and toxic material.

Loaders engage quite a big number of ground equipment at the airport. It was noticed that the number of rollers used on the loaders was huge and it might be a hazard to the environment. In addition to the conventional aluminium alloy rollers, composite rollers had been used for about 10 years at airports and air cargo handling depots in the region for reasons of lighter, quieter and probably cheaper. While on the development of electric cargo loaders, weight is a big concern for cargo loader OEMs. As electrification is a must for airport operation in the coming decade, composite rollers are being seriously considered by loader manufacturers. This study compares these two categories of rollers on environmental, technical and operational aspects and analyzes the effectiveness of their utilization.

2. Methodology

The study focuses on two types of rollers, namely aluminium alloy and composite rollers. They are chosen because they are commonly used in the industry but are made of very different materials. Aluminium alloy rollers are usually made of aluminium alloys 6061-T6 (with >95% aluminium) and 7075-T6 (with >87% aluminium). Composite rollers are made of composite by a patented process (Hon, 2014) using nylon, glass beads, glass fiber powder, lubricating anti-wear agent; graft type toughening modifying agent; antioxidant; lubricating dispersant and nucleating agent. The highest percentage of material used in making the composite rollers is nylon-66 (also known as nylon 6-6, 6/6, 6,6 or 6:6).

This study is based on several types of information available. The first one is the theses, as well as information available from the Internet. The second type of information is results obtained from independent testing laboratories. In Internet, Wikipedia forms an important basis of this study. Although we are aware that Wikipedia cannot capture all the information needed, it does provide a consistent basis for comparison and it is updating regularly by an independent community in the field.

The remaining of this paper will be divided into the following three main parts:

Section 3 compares the environmental footprints of aluminium and composite rollers, including their weights and the energy consumption for moving and making them.

Section 4 focuses on the toxicity properties of aluminium and composite materials. The toxicity of aluminium is raised in two theses of the Technological and Higher Education Institute of Hong Kong (THEi) under the theme of "*Investigation of Occupational Safety impacts of Operating Air Cargo Loaders at the Airport*". The research work was supported by the Hong Kong Airport Authority. The acute oral toxicity of the composite was inspired by the work of the discussion about toxicity of aluminium to humans. As there is not much similar information about harmful effects of the component materials making the composite rollers available from the Internet, an acute oral toxicity study of the composite was carried out by an independent testing laboratory.

Section 5 is about the comparison of other properties of these two types of rollers. Some of these are technical in nature such as the composition of material for making the rollers and adhesive wear. One interesting and useful comparison is on the trend of the material cost. Engineers are very mindful on the production cost. When the economy comes back, it might be difficult to get the necessary material in a reasonable cost.

3. Environmental footprints of Aluminium and Composite Rollers

As we have found a main deck loader with approximately 1464 rollers and a lower deck loader with approximately 960 rollers. It is estimated to have around 300 loaders in the HKIA, among which 25% are main deck loaders and 75% are lower deck loaders. Therefore, the total number of rollers is:

$$1464 \times 75 + 960 \times 225 = 325{,}800$$

3.1 Carbon footprint comparison in moving aluminium and nylon rollers

With the above assumptions made, the total weight of rollers in loaders at the HKIA is reduced by 89.6 - 42.4 = 47.2 tonnes if all the aluminium alloy rollers are replaced by composite rollers (see Table 1). This will result in significant reduction in the energy consumption of moving such heavy load around the airport. Such benefit could be estimated based on assuming a kinetic friction coefficient of 0.9 between the tractor and the ground. Assuming the rollers were moved 10 km per day in the airport, the saved energy due to weight reduction from aluminium to composite rollers can be calculation as:

$$47.2 \text{ tonnes} \times 9.8 \text{ N/kg} \times 0.9 \times 10 \text{ km/day} \times 365 \text{ day/year} = 1.52 \times 10^{12} \text{ J/year}$$

The heat value of diesel is typically around 44 MJ/kg. Assuming a thermal efficiency of 40% for the diesel engine of the tractor, the above energy reduction is equivalent to saving the following amount of diesel fuel:

$$1.52 \times 10^{12} \text{ J/year} \div 44 \text{ MJ/(kg diesel)} \div 40\% = 8.63 \times 10^{4} \text{ (kg diesel)/year}$$

Table 1: Weight and carbon footprint data.

	Aluminium alloy roller	Composite roller
Weight of a roller (w)	0.275 kg	0.130 kg
Total weight of rollers (w×325,800)	89.6 tonnes	42.4 tonnes
Emission factor (f) of refining aluminium/nylon*	8.14** kg CO_2 per kg	7.9 kg CO_2 per kg
Carbon Footprint (w×1250×300×f)	729 tonnes CO_2	335 tonnes CO_2

Notes: * https://www.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_Appendix_H-WSTP_South_End_Plant_Process_Selection_Report/Appendix%207.pdf
** It is between 11.89 and 8.14 kg CO_2 per kg

3.2 Carbon footprint comparison in refining aluminium and nylon

The carbon footprint for refining the aluminium and nylon for making the rollers can be found quite easily. The result is also shown in Table 1. For all the rollers at the airport, such carbon footprint for refining the major material aluminium and nylon are 729 and 335 tonnes CO_2, respectively. The ratio of carbon footprint is 2.2 (=729/335) and the difference is 394 tonnes (=729 – 335) CO_2 which is very significant. In the letter from GSEL, it states that "the operating life of a smart composite roller is close to double that of an equivalent aluminium roller. Thus the ratio of carbon footprint is 4.4 (=2*2.2). The equivalent difference is 561.5 (=729 – 335/2) tonnes CO_2 which is even more significant.

For the manufacture of rollers from the materials, as data are not readily available, this study will continue upon such availability. Preliminary finding is that as aluminium melts at 660 ºC and nylon melts at 264 ºC, the energy needed is significantly different.

4. Toxicity of Aluminium and Composite

4.1 Toxicity of Aluminium to Humans

Aluminium alloy is a neurotoxic rich material which gives side effects on the function of the brain (associated with Alzheimer's disease) such as loss of balance, memory issues, lack of coordination, loss of bodily control, mental decline (Cheng, 2021). Long-term inhalation of aluminium dust will accumulate in the lungs and will not be discharged (Mak, 2021). It has been suggested that the inhaled aluminium accumulates in the brain through absorption via the olfactory system (Roberts, 1986; Exley et al., 1996) or systemized (a) through the lung epithelial (Gitelman et al., 1995) and (b) via the gastrointestinal tract as particulates are swallowed.

4.2 Acute Oral Toxicity of the Composite Rollers

There are two main ways to study the toxicity of the composite rollers. One way is to get the composition of the roller and see if any of the component is toxic in nature. The results will be presented in Section 5. A testing laboratory has advised and adopted the National Standard "GB/T 21603-2008 Chemicals-Test Method of Acute Oral Toxicity" for such purpose (Nanjing Medical University, 2021). 20 clean-grade Institute of Cancer Research (ICR) mice were specially prepared for this purpose, fed with the stipulated quantity in a controlled environment for 14 days following GB/T 21603-2008. The key findings of the tests are presented as follows.

Animals showed a trend towards increased body weight after dosing, and animals showed no abnormal signs. None of the animals died during the course of the experiment. All animals had been subjected to gross necropsy at the end of test. No obvious abnormality was found.

Acute oral toxicity test LD_{50} of both female and male mice of smart composite roller are more than 20000 mg/kg-bw. According to the acute toxicity (hazard) classification, smart composite roller acute toxicity (hazard) toxicity category is IV. Toxicity category IV is practically non-toxic and not an irritant. That is to say, the composite is rather safe as substantiated by the Conclusion of the Test.

4.3 Comparison on the compositions of rollers

Compositions of the rollers are obtained from two reports done by an independent testing laboratory. The results on the compositions of a typical aluminium alloy roller (STS Testing Services, 2021a) and a typical composite roller (STS Testing Services, 2021b) are presented in **Tables 2** and **3**, respectively. Wikipedia is used to extract the relevant information. Two key terms, "toxicity" and "poisoning" were used in searching. Such findings are also presented in Tables 2 and 3. Relevant pages of the component/element were reviewed as well.

For the elements found in the aluminium alloy roller, 99.9% (except from Silicon and Titanium) have been classified as toxic and/or poisoning in nature. Toxicity of aluminium to human is of serious concern because aluminium contributes for around 95% of the composition of the aluminium alloy roller. There is a potential hazard caused by the aluminium powders generated during the operation which might be inhaled by workers nearby. The seriousness of the hazard depends on a number of factors such as quantity and size of aluminium powder inhaled. This hazard results in the safety and health concerns that is major accountability of the employer to address.

Table 2: Compositions of aluminium alloy rollers.

Element	Mass content (%)
Silicon (Si)	0.077
Iron (Fe)	0.20
Copper (Cu)	4.02
Manganese (Mn)	1.01
Magnesium (Mg)	1.48
Zinc (Zn)	0.015
Titanium (Ti)	0.023
Beryllium (Be)	0.023
Aluminium (Al)	Remainder

Table 3: Compositions of composite rollers.

Component	Mass content (%)
Polyamide 6 (PA6)	82
Polytetrafluoroethylene (PTFE)	3
Silicate	14
Ethylene bis stearamide and Pigment	1

For the composite, according to the manufacturer, both PA66 and PA6 are used for the manufacturing of rollers. However, because of very similar molecular structure, the equipment used for testing could not explicitly tell the difference between them. This explains why PA66 is not mentioned in the report.

There may be an issue of Safety of Polytetrafluoroethylene (PTFE) that needs further discussion. Pyrolysis of PTFE is detectable at 200 °C. The degradation by-products can be lethal to birds, and cause flu-like symptoms in humans. The load sticks tightly with the roller. Thus, the chance of generating frictional heat is low. The operating environment also cannot provide the high temperature 200 °C.

It is quite clear that information presented in Table 3 shows that the Composite is not toxic in nature. This is further reconfirmed with the "Acute Oral Toxicity Study".

5. Other Properties of the Rollers

5.1 Noise pollution

Aluminium is much harder than the nylon and thus the aluminium alloy rollers produce much higher noise than that of composite rollers. The effect of absorption of noise by composite roller is an interesting topic. Unfortunately, data is not available and this may be an area of exploration subject to funding available.

5.2 Adhesive wear

According to Ludema (1996), severe adhesion is at least as an initiator of damage. This is explained further in (Theo et al., 2010) that many polymers (e.g., PTFE, Telfon) possess excellent adhesion resistance. As polymers are more adhesion resistance, the composite roller has an interesting and useful high frictional characteristics.

Fugro Technical Services Limited (2022) provides the comparison of the frictional characteristics for the two types of rollers. The results are presented in Table 4. The composite roller has a much higher coefficient of dynamic friction (as reflected by higher pull-out force). That is to say, the chance of skidding is much lower. It is also interesting to note that this coefficient increases under a wet condition. This results in further reduction in the chance of skidding. Such characteristic is a very desirable feature to avoid accident due to the skidding of the load.

Table 4: Comparison of pull out forces.

	Dry condition	Wet condition
Aluminium roller	10.33 N	8 N
Composite roller	16.66 N	The 18.33 N

5.3 Comparison of material cost trends

The two types of rollers are made from very different materials. Therefore, it is not that useful to compare the cost of the material directly. Instead, the comparison of the trend of material cost is more important. Figures 1 and 2 show the trend in the material cost in terms of US$/t for aluminium and RMB thousands/t for nylon 66. It is quite obvious that the cost of aluminium goes up rapidly in the recent months while the cost of nylon 66 is quite steady in China where the material is sourced to support the manufacturing of composite rollers.

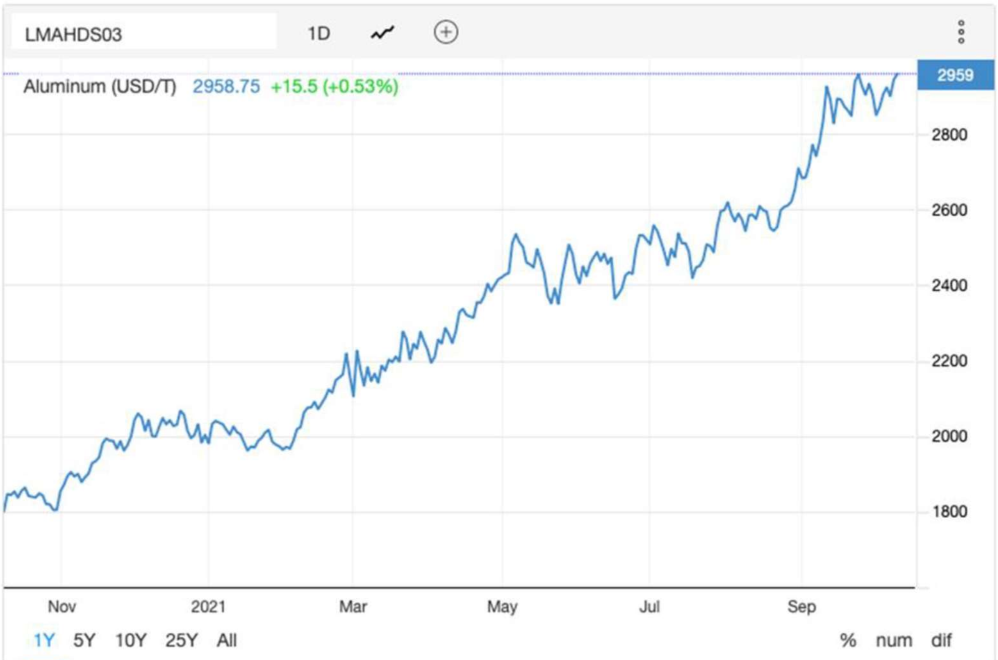

Figure 1. Material cost of aluminium (in US$/t).
Source: https://tradingeconomics.com/commodity/aluminum

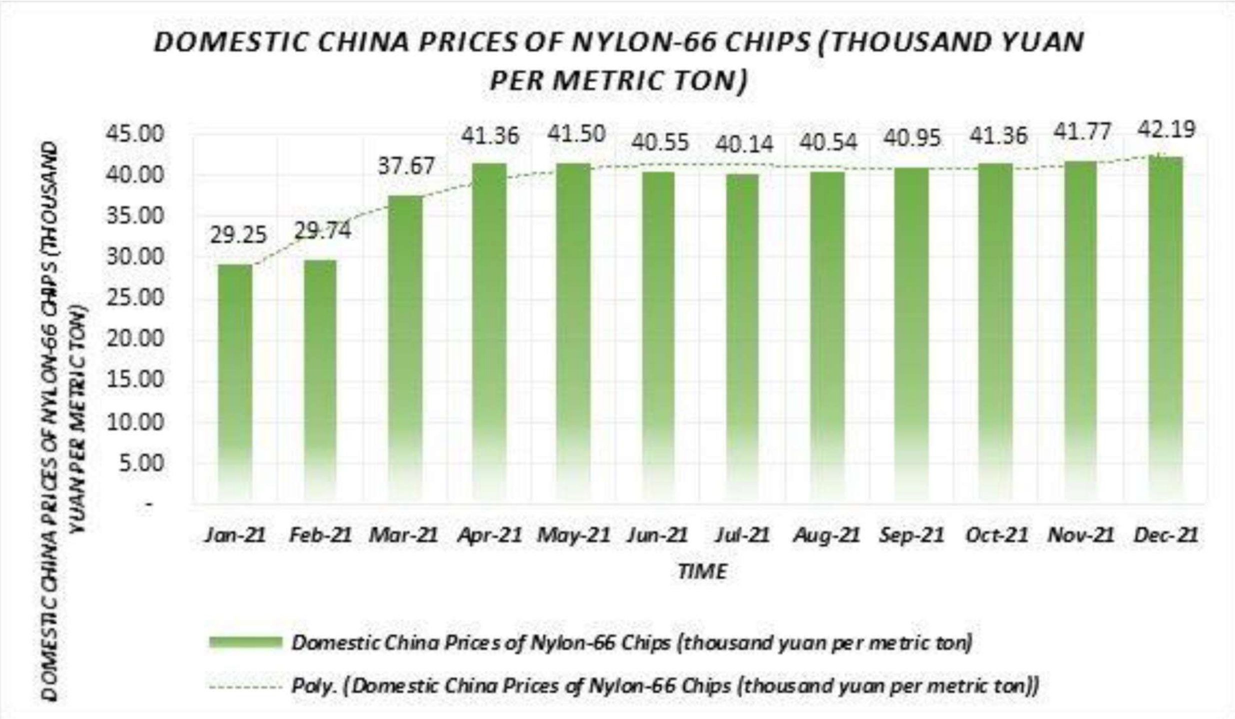

Figure 2. Material cost of nylon 66 (in RMB thousand/t).
Source: https://www.fibre2fashion.com/news/textile-news/nylon-66-chips-price-in-china-may-recover-by-end-of-q3-2021-texpro-275026-newsdetails.htm

6. Conclusion

Two types of rollers commonly used in air cargo loader applications were studied. The methodology is based on information from theses and Internet plus results from independent testing laboratories. The conclusions of this study are summarized as follows:

1) The two types of rollers differ in environmentally friendliness. The composite roller weights lighter and thus a lot of energy is saved in moving it. Assuming moving the loaders 10 km per day, a total of 86.3 tonnes of diesel fuel could be saved from the tractors every year. The carbon footprint differs by 4.4 times for the refining the aluminium and nylon.

2) Toxicity of aluminium to humans was a major concern. The comparison on roller composition demonstrates that aluminium alloy roller has 99% of its material being toxic in nature in different degrees, while the composite is not toxic at all. An independent test laboratory found that the toxicity of the composite was in Category IV which is practically non-toxic and not an irritant.

3) The composite roller is adhesion resistant. Thus it has the preferred characteristics of non-skidding and in particular when the roller is operating under rainy condition.

4) The cost of aluminium has gone up very rapidly in the recent months but the cost of nylon in making the composite is quite steady.

5) Composite rollers, due to its various positive characteristics, might be one of the alternate choices to replace aluminium rollers in future environmentally friendly, sustainable, and economic operation. This further addresses the social responsibility of achieving a safety and health environment for people working at the airport where air cargo loaders are in operation.

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Investigating the Impact of COVID-19 Pandemic on Financial Risks and Credit Risks of Shipping and Logistics Industry –Taiwan and Hong Kong

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Abstract

To explore the impact of the COVID-19 outbreak on the financial and credit risks of the shipping and logistics industries in Taiwan and Hong Kong, this study collected TEJ Taiwan-Hong Kong financial data from 2016 to 2020. Including the stock returns of shipping and logistics companies, the composition of cash flow and accrual items, company size, debt ratio, etc., and the C-Score method of Khan and Watts (2009) is used to explore the differences in accounting earnings stability between the two places.

The results show that after the outbreak, regardless of whether their accounting is conservative or not, Taiwanese companies have improved their earnings quality. While Hong Kong accounting conservative shipping companies have deteriorated, but non-accounting conservative companies have improved their earnings quality. This may be because Taiwanese companies actively used earnings stabilization and adopted aggressive accounting policies, allowing them to weather the crisis and grow against the trend. The earnings quality of accounting conservative companies in Hong Kong may be affected by the pre-pandemic endogenous problems that could worsen their earnings quality.

Based on the above research results, this study proposes that if manage the company's management accounting policies and financial decisions properly, reduce operational risks, improve credit risk levels, and ease financing constraints, then it will enable them to tide over adversity in the early stage of the epidemic and drive them to prosperity in the middle and late stages of the epidemic, otherwise it will not able for them to tide over the difficulties.

Keywords: Conservatism accounting, Accrual component of earnings, Cash flow, Component of earnings, financial risks, Credit risks
[1]

1. Introduction

Since the global spread of the COVID-19 epidemic in December 2019, different economies and industries around the world have had a huge impact, and even experienced a contraction in real economic activity.

Especially, the economies of Taiwan and Hong Kong are both exogenous and cannot be avoided. All industries are affected in two places, in particular, on import and export trade, tourism and entertainment, catering and retail, transportation and other service industries.

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Following the outbreak of COVID-19 in early 2020, most governments' implements on anti-epidemic measures, such as, work shutdowns, traffic blockades, crowd and logistics controls, have resulted in severe port congestion, shortages of containers, ships and labour shortage, as well as delays due to shipping schedules and supply chain disruptions. With the economic downturn and weak demand, it is not uncommon for some small and established companies with huge accounts receivable and poor financial and risk management to undergo mergers, reorganizations and even bankruptcy.

With the easing of the epidemic at the end of 2020 and the resumption of production in the manufacturing industry, the economy has recovered significantly and trade volume has soared. Due to insufficient capacity, freight rates have risen instead. Large companies in Taiwan (including Evergreen, Yang Ming, Wan Hai) and even established companies have benefited from this situation.

Since then, with the resurgence of the epidemic, various countries have resorted measures to work from home and study at home, which has greatly reduced the number of people going out and led to the outbreak of the "home economy", and 3C (*ie* computers, communication equipment and consumer electronics) and peripheral products grew significantly.

Port congestion and container shortages have not eased, and freight rates have risen further. The Shanghai Export Containerized Freight Index (SCFI), one of the main indicators of global freight rates, also soared from a low of 816 points in April 2020 to 2,783 points in December of the same year, and even soared to 5,094 points in 2018. January 2022. Port congestion and container shortages have not eased, and freight rates have risen further.

The Shanghai Export Container Freight Index (SCFI), one of the main indicators of global freight rates, also surged from a low of 816 points in April 2020 to 2,783 points in December of the same year, and soared to 5,094 points in January 2022.

As countries conduct large-scale vaccination campaigns to control the epidemic and adopt a "coexist with the coronavirus" strategy, there has been retaliatory consumption, retailers scrambled to restock, online shopping and more. Changes in consumer spending habits have resulted in a further shortage of market capacity.

Transfer prices therefore must also be adjusted as contracts are exchanged, and generations of high freight rates are the new norm. Since the implementation of the International Carbon Reduction Convention in 2023, when most ships must sail at a reduced speed, the actual supply of market capacity will drop significantly, and the supply shortage situation will become more serious until new ships are launched and launched one after another. Therefore, the outlook for the shipping and logistics industry remains very positive.

Has the accounting conservatism of the shipping and logistics industry in Taiwan and Hong Kong under different legal systems also been affected before and after the epidemic? How big is the impact? However, the responsiveness of the shipping and logistics industries in the two places to financial credit risks, the management accounting policies and financial decisions of stable and unstable enterprises are all affected by the epidemic, resulting in the deterioration of the quality of enterprises and the benefits? Or is it because proper and correct earnings stability and aggressive accounting policies have weathered adversity in the early stages of the pandemic and pushed them forward in the middle and late stages of the pandemic? It is well worth exploring all of these issues in depth.

Therefore, in order to explore the impact of the novel coronavirus pneumonia on the financial and credit risks of the shipping and logistics industries in Taiwan and Hong Kong, this study collected data from the TEJ financial database for a total of 5 years from 2016 to 2020. This paper includes the stock returns, cash flow composition and accrual item composition, company size, debt ratio, etc. of shipping and logistics companies in the two places, and uses the C-Score method (Khan and Watts, 2009) to discuss the accounting of the shipping industry in the two places. Differences in earnings stability. At the same time, this study shows consistency with the findings of C. Gabriel and C.B. Baker (1980) (ie, "higher returns, lower financial risk") and Dichev et al. Through the above method analysis results, it is verified that the shipping and logistics industries in Taiwan and Hong Kong are governed by different legal institutional environments.

As Hong Kong is one of the world's important shipping and logistics hubs, Hong Kong has experienced several unprecedented internal problems of varying scale between 2016 and 2020. While Taiwan and Hong Kong share similar cultural and geographic features, but adopt a statutory legal system, this similarity and difference makes Taiwan the ideal antithesis of Hong Kong, and it is worth examining the impact of these issues on the industry. Therefore, Taiwan and Hong Kong were selected as the research objects.

2. Research Background

Due to the impact of the epidemic, production lines in many parts of the world have been shut down, the flow of people and logistics cannot be smooth, and the supply chain is disconnected. Many companies are therefore forced to change their sales behavior. They began to obtain sales through online trading platforms and use the shipping logistics industry to deliver products to consumers. During the epidemic period, many different phenomena occurred in all walks of life, especially the supply and demand of the shipping market has also undergone great changes. Therefore, the shipping and logistics markets have experienced a period of "oversupply". Today, under the constant impact of the epidemic, along with the strong recovery of European and American countries, there has been a phenomenon of "supply exceeding demand". Therefore, the most important examination of this study is to focus on the cash flow and profit of the company due to the substantial increase in the revenue of the shipping and logistics industry.

Extrapolating from the performance of earnings growth, profit, and cash flow between the two locations, there may be considerable differences. What are the reasons for the differences between the shipping and logistics industries of the two places? This research will investigate whether the impact of hypothetical robust and unsound accounting on the company's financial risk and credit risk will have a certain impact after the epidemic.

3. Accounting Conservatism and Data Description

3.1 Accounting Conservatism

The definition of the principle of accounting conservatism：

Conservatism in the traditional sense means "to foresee all possible losses, but not to anticipate any uncertain earnings (Bliss, 1924)". Only in the legal sense there exists evidence that can confirm the existence of earnings, convicted earnings or expected earnings are permitted. The American Accounting Principles Board (APB, 1970) defines conservatism as "historically, managers, investors, and accountants tend to underestimate assets and profits. It can also be said that accountants require good news to be better than bad news. There is a tendency for higher verifiability".

In the whole corporate life cycle, no matter which accounting method is used, the total amount of income should be identical, so the conservatism of an accounting period may lead to the non-conservatism of the next accounting period. Wolk, Tearnye and Dood (2001) argue that, from an accounting reporting perspective, conservatism will result in: (1) slower revenue recognition, (2) faster expense recognition, and (3) lower asset values, (4) a higher amount of debt. A number of scholars have successively published journals regarding the conservatism of corporate financial statements. Basu (1997) found that there is asymmetry in the recognition of bad news and good news in the market, and therefore deduced that accounting earnings have characteristics of conservatism. Ball et al. (2003) used Basu's (1997) measurement basis to examine common law countries, such as Canada, the United Kingdom, the United States, Australia, as well as statutory law countries, such as France, Germany, and Japan, and conduct a comparative analysis of accounting conservatism. The results indicate that in countries with different legal systems, enterprises are subject to different legislations, and will choose accounting methods that are beneficial to the company, and even have earnings management behaviors to maximize the interests of the company itself or the management itself. For this reason, this study not only focuses on Hong Kong, which is closely related to Taiwan, but also focuses on the public offering companies in the shipping and logistics industries to explore whether they have accounting earnings conservatism and their resilience under the COVID-19 shock.

4. The academic method of measuring accounting conservatism

Basu's robust formula for the development of equations, β_0 represents the conservatism of the good news, And β_1 represents bad news robustness, That is bad news for the degree of conservatism is $\beta_0 + \beta_1$ 。 Khan and Watts (2009) argue that the degree of conservatism of the G-Score and the bad news of the bad news will vary from year to year, and the model is as follows:

$$G\_Score_{i,t} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev$$

$$C\_Score_{i,t} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev$$

Assume that G_Score and C_Score are influenced by firm size (SIZE), market value and book value ratio (MB), and debt ratio (Lev). Givoly and Hysan (2000), based on US listed companies from 1950 to 1998, found that US companies' profitability (ROA) was declining over the past four decades, and the authors learned more about the causes and found that the accrued earnings were decreasing year by year. The ratio is about 16% of the surplus, but the cash flow has not decreased year by year. Further analysis shows that the main reason for the decrease in accrued surplus is due to the decrease in no performable accrued earnings, Accounting for 16% of the profit and loss; as the business accrued surplus showed a trend of rising year by year, which shows the growth characteristics of the sample company consistent. Second, they found that the ratio of loss companies from the early 2% to 3% increasing to 35%. Therefore, is there a growing trend of steady accounting or not for the company is to be scrutinized.

For the capability of C-SCORE has the robustness of predicting 3-year accounting policies, the study adopts the C-SCORE method, hopes to explore the shipping logistics industry in the further 3 years (2021~2023).

5. Data Description

Data for this study was taken from the "Consolidated Financial Information of Listed (Counter) Companies (General)" database in the "TEJ Finance Database" of Taiwan Economic News Agency, and the stock price information was obtained from the "Adjusted Price Database" in the "TEJ Equity Database".The study period is from 1st January 2016 to 31st December 2020.

The sample companies selected by this research must meet the following criteria:

1. Except for those with missing data, samples with insufficient disclosure of financial statement information, missing variables and abnormal data will be excluded.

2. Use the WINSORIZE statistical method to delete 1% of the upper and lower portions for removing the extreme values.

The sample selected in this study is 30 companies from Taiwan and 37 companies from Hong Kong, a total of 67 companies from the total of 187.

6. Methodology and Design

This paper deduces the following three hypotheses based on the research motivation and purpose as stated previously.

This study adopts the C-Score method of Khan and Watts (2009). Khan and Watts' C-Score is based on the Basu's theory to form an index gauging corporate conservatism by increasing the company size, market capitalization to book value ratio and leverage ratio. Since Khan and Watts (2009) believe that the Basu (1997) model mainly uses cross-sectional industries or time series of individual companies for estimation, which implies that under the same industry, the financial statements of individual companies are homogeneous; or for individual companies, it is assumed that if the long-term operating conditions of the company exhibit a stable trend, the conservatism of financial statements also displays the characteristics of stability, which is not the case indeed. In order to solve the inability of Basu (1997) model to measure the degree of conditional conservatism of individual companies across years, Khan & Watts (2009) developed a firm-year accounting conservatism measure, known as C-Score, to examine the effectiveness of C-Score in assessing accounting conservatism from a time-series and cross-sectional perspective. Results show that C-Score can evaluate the soundness of the company's accounting policies in the next three years, from a cross-sectional point of view, the shorter the establishment period of a company, the greater the uncertainty of its operating risks and the higher the degree of information asymmetry, the higher the C-Score. Grounded on the above theoretical basis, the following hypotheses are proposed for this study:

H1: In the shipping and logistics industry, companies with higher earnings stability can, in a timely manner, respond speedily and differently when confirming "bad news" and "good news".

Basu (1997) used the speed at which earnings reflect good news and bad news to measure accounting conservatism, since the principle of accounting conservatism is that the expected loss can be recognized immediately, on the contrary, the expected gain can be recognized only when it is realized, using the earnings asymmetry model to test whether the earnings are robust.

Ball and Shivakumar (2005, 2006A, 2006B) believe that in terms of earnings stability, economic losses are caused by accruals (ACCRUALS), which are less likely to be realized immediately, and accruals can reduce the disturbance caused by cash flow, both are negatively correlated. Therefore, earnings conservatism means that accruals have an asymmetric relationship with cash flows. Therefore, the conservatism of accounting policies is mainly through the adjustment of accruals, that is to say, the increase in the conservatism of the composition of accruals would reduce the responsiveness to the bad news. On the contrary, the higher the conservatism of the cash flow composition, the greater responsiveness to the good news. This paper proposes the following two sub-hypotheses:

PLANT A: The greater the conservatism of the composition of accruals of shipping and logistics companies, the less responsiveness they are to bad news.

PLANT B: The greater the conservatism of the cash flow composition of shipping and logistics companies, the greater responsiveness they are to good news.

H2: The pre-COVID-19 accounting earnings conservatism of the shipping logistics industry is more robust than its post-COVID-19 accounting earnings conservatism.

Regarding whether there have been changes of conservatism between the two places over time, the method of Penman and Zhang (2002) are used with time factor T added to examine whether the conservatism of shipping and logistics companies before and after COVID-19 lead to the change of over time. Then, the comprehensive indicators of earnings management are discussed through the stabilization of earnings in the two places. Leuz et al. (2003) are used to measure the earnings management of the two places to conduct a cross-regional comparison method, and compare the earnings management between the two places before COVID-19 and its level of earnings management after COVID-19.

H3: Post-COVID-19 in the shipping logistics industry; the higher the earnings robustness, the more robust the responsiveness of financial risk and credit risk.

It is expected that online sales may still be the lord even when COVID-19 has dissipated, as consumers are more accustomed to online shopping and their respective logistics systems should have already been well established. This is the first new norm we could foresee, identifying many research questions related to operational risks in the shipping logistics industry. There will also be some “new norms” for companies in the logistics industry. Key members are shipping companies as we expect to see many changes. The shipping industry, in particular, has continued to grow during COVID-19 (Cui, Qiu and Chen 2016). COVID-19, as an influential societal issue, is also being studied in TRE's ongoing special issue, nurturing advances in risk analysis optimization methods. In addition, in order to save operating expenses, shipping companies will conduct business process reengineering. Airlines are expected to widely apply data analysis tools and employ business automation to improve efficiency. How these behaviours affect business risk should also be studied in the future researches.

7. Research Design

Earnings are more sensitive to bad news because the accounting conservatism principle is to recognize the expected possible losses immediately, while the expected possible gains cannot be recognized until they are realized.

According to earnings conservatism, it is discussed from two directions, accruals and changes in the two components of cash flow. Using the theory of C-Score developed by Khan and Watts (2009) to evaluate accounting conservatism and its benefits. Basically, C-Score can evaluate the soundness of a company's accounting policies for the next three years, mainly based on Basu (1997), and extended to include company size (SIZE), market capitalization to book value (MB) and debt ratio (LEV) A measure of the robustness of the formed company.

The model proposed by Basu (1997) to measure the conditional robustness is as follows:

$$EARN_{i,t} = \beta_{1,} + \beta_{2,t} \times NEG_{i,t} + \beta_{3,t} \times RET + \beta_{4,t} \times NEG_{i,t} \times RET + \varepsilon_{i,t} \quad (1)$$

$EARN_{i,t}$: The first company's extraordinary profit before and after-tax net profit and opening market value deflator

$NEG_{i,t}$: Is defined as 1. Otherwise 0.

RET_{it} : Represents the company and the stock return in year T.

λ_{1t}...... λ_{4t} : Parameter value to measure accounting conservatism.

$\varepsilon_{i,t}$: Residuals of the i-th company and the t-th year, assuming normal distribution

Since the β_3 coefficient represents the sensitivity of accounting earnings to good news, and the $\beta_3 + \beta_4$ coefficient represents the sensitivity of accounting earnings to bad news, it represents the β_4 incremental response of earnings to bad news, and it can measure the speed of timely response of good news and bad news. , which is also a measure of robustness. If β_4 > 0, it means that the accounting surplus is robust, and the larger the value, the greater the degree of robustness of the condition. In addition, $(\beta_3 + \beta_4)/\beta_3$ represents the sensitivity of earnings to good news and bad news. If $(\beta_3 + \beta_4)/\beta_3 > 1$, it means that bad news is reflected in earnings faster than good news; in terms of explanatory power, since the robust principle responds more timely to bad news, the explanatory power of earnings for bad news should be better than that of earnings. Ability to interpret good news, so expect bad news R^2/good news $R^2 > 1$.

8. Research Method

8.1 Conservatism measure (C-Score)

According to the inference of khan and watts (2009), in order to compensate β_3 and β_4 for the individual companies in different years the market value ratio (mb), enterprise size (size) and debt ratio (lev) linear number, ie:

$$\beta_{3i,} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev \quad (2)$$

$$\beta_{4i,t} = u_{1,t} + u_{2,t} size + u_{3,t} MB + u_{4,t} Lev \quad (3)$$

$size_{it}$ = The size of the company, the market value of the interests of log

MB_{it} = For the market value of the book value ratio

Lev_{it} = Debt ratio

Khan and Watts (2009) substitutes the formulas (2) and (3) into the formula (1) and additionally controls the possible influence of SIZE, MB and LEV, and becomes the following equation (4):

$$EARN_{i,t} = \beta_{1,t} + \beta_{2,t} NEG_{i,t} + RET_{i,t}(\mu_{1,t} + \mu_{2,t} Size_{i,t} + \mu_{3,t} MB_{i,t} + \mu_{4,t} Lev_{i,t}) \quad (4)$$
$$+ NEG_{i,t} RET_{i,t}(\lambda_{1,t} + \lambda_{2,t} size + \lambda_{3,t} MB + \lambda_{4,t} Lev)$$
$$+ (\sigma_{1,t} size + \sigma_{2,t} MB_{i,t} + \sigma_{3,t} Lev_{i,t} + \sigma_{4,t} NEG_{i,t} Size^{i,t} + \sigma_{5,t} NEG_{i,t} MB_{i,t} + \sigma_{6,t} NEG_{i,t} Lev_{i,t}) + \varepsilon_{i,t}$$

The $\lambda_{1t}.\lambda_{2t}.\lambda_{3t}.\lambda_{4t}$ and $\mu_{1t}.....\mu_{4t}$ estimated by the annual (4) type are replaced by the formula (2) and (3), And the calculated β_3 and β_4 are referred to as the T-year G-Score and C-Score of the i-th company. In other words, the original β_3 of the formula (1) represents the surplus of the [overall average] Sex, recalculated G-SCORE represents the sensitivity of a particular company to good news for a particular year. Similarly, CSCORE represents the company in the year, its accounting earnings on the bad news of the increase in sensitivity. And calculate the company's annual surplus stability coefficient (CSCORE), to obtain the company's annual surplus stability coefficient. The higher the CSCORE value, the more robust the company's financial reporting.

$$Cscore_{i,t} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev \quad (5)$$

Verification of accruals and cash flow conservatism

(1) Verification of statistical accounting accrual project robustness

ACC (ACCScore) for the total accrual items, net profit after tax net profit from operating activities and then to the beginning of the total assets of the reduction. As in the formula (2), the (1) type is estimated by the different strain numbers,

$$ACCScore_{i,t} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev \quad (6)$$

(2) Verification of statistical cash flow robustness

CF is the net cash flow of operating activities, with a view to the beginning of the total assets of the reduction, cash flow stability coefficient, CF score value higher, on behalf of the company's financial reporting more robust .As in (3):

$$CFscore_{i,t} = \hat{\lambda}_{1,t} + \hat{\lambda}_{2,t} size + \hat{\lambda}_{3,t} MB + \hat{\lambda}_{4,t} Lev \quad (7)$$

Due to the different composition of the surplus, the cash flow and accruals are different for the content of the information (Dechow1994; Sloan 1996; Xie 2001). Basu (1997) had proofed that empirical accruals are instruments that account for the asymmetry of gains and losses. Therefore, in reporting the unfavourable situation of the company, the financial stability of the debt basis is timelier than the cash flow. Based on the empirical method of Pac et al. And Pae (2007), this study is divided into accruals (Accscore (6)) and cash flow robustness (CFscore (7)) to establish different accounting conservatism indicators, Therefore, the following equation (8) is extended:

$$EARN_{i,t} = \beta_{1,t} + \beta_{2,t} \times NEG_{i,t} + RET_{i,t} \times (\mu_{1,t} + \mu_{2,t} Size_{i,t} + \mu_{3,t} MB_{i,t} + \mu_{4,t} Lev_{i,t})$$
$$+ NEG_{i,t} \times RET_{i,t}(\lambda_{1,t} + \lambda_{2,t} size + \lambda_{3,t} MB + \lambda_{4,t} Lev) \quad (8)$$
$$+ (\sigma_{1,t} size + \sigma_{2,t} MB_{i,t} + \sigma_{3,t} Lev_{i,t} + \sigma_{4,t} NEG_{i,t} Size_{i,t} + \sigma_{5,t} NEG_{i,t} MB_{i,t} + \sigma_{6,t} NEG_{i,t} Lev_{i,t}) + \varepsilon_{i,t}$$

$EARN_{it}$ = The i-th company is profitable.

$NEG_{i,t} = RET_{it} < 0$ Defined as 1, otherwise 0.

RET_{it} = Represents i and t Year stock returns.

$\lambda_{1t} ...... \lambda_{4t}$ = The value of the measure of accounting robustness.

Here, the study examines all the companies in the shipping logistics industry have experienced changes in robustness over time before and after COVID-19. The C-Score, CF Score, Acc Score values calculated by Khan and watts (2009) are added with the time T factor by Penman and Zhang (2002) to judge whether the IPO has led to a change in the degree of robustness over time or not.

$$C_t = \beta_0 + \beta_1 t + \varepsilon_t \qquad (9)$$

Here, in the regression equation,

C_t: The average conservatism of all sample companies in year t, with the original data and the sorted data, were analysed to see if there was a significant change in the conservatism of the covid-19 before and after the covid-19.

t: 1 before covid-19; 0 after covid-19: 1.

β_1: Is positive, on behalf of the degree of robustness over time is showing an incremental situation; negative, on behalf of the degree of robustness over time to show a decreasing situation.

8.2 The pre-COVID-19 accounting earnings conservatism of the shipping logistics industry is more robust than its post-COVID-19 accounting earnings conservatism.

With the method of Basu (1997), we will further examine the level of accounting conservatism of the initial listing cabinet companies and investigate whether the feature has hypothesis 1 and hypothesis 2 correlation exists or not. Through the corporate characteristics of factors: very profitable before and after tax net profit. Before the implementation of covid-19 and after covid-19, the number of samples were captured from an interval of 2 years (*i.e.* 2016 ~ 2017, 2017~2018, 2018~2019, and 2019~2020).

$$\Delta X_{i,t} = \beta_0 + \beta_{1,t} DUMi\ (1,2,3,4) + \beta_{2,t}\Delta X_{i,t\text{-}1} + \beta_{3,t} DR + \beta_{4,t}\Delta X_{i,t\text{-}1} DR + \varepsilon_{i,t} \qquad (10)$$

Table 1 Variable definition of shipping company accounting conservatism before and after covid-19

VARIABLE SYMBOL	VARIABLE	DEFINITION	EXPECTED DIRECTION
$\Delta X_{i,t}$	Dependent Variable	Net profit before tax is b/f market value from (8) $EARN_{i,t}$	+
$DR_{i,t}$	Independent Variable	$\Delta X_{i,t} < 0 = 1$， Other=0	+
$DUMi(1,2,3,4)$	Independent Variable	DUMI 1=2016,2017 2016=1 2017=0	+
		DUMI 2=2017,2018 2017=1 2018=0	-
		DUMI 3=2018,2019 2018=1 2019=0	+
		DUMI 4=2019,2020 2019=1 2020=0	+

8.3 Post-COVID-19 in the shipping logistics industry; the higher the earnings robustness, the more robust the responsiveness of financial risk and credit risk.

Since Lara and Mora(2002) and Balle et al.(2000) add CSCORE,ACCSCORE,CFSCORE to FR,TCRI and Covid-19 variables, as the higher the earning conservatism, the more robust the degree of financial risk and credit risk response

$$\begin{aligned} EARN_{i,t} = \beta_0 + \beta_{1,t} CSCORE + \beta_{2,t} ACCSCORE + \beta_{3,t} CFSCORE + \beta_{4,t} FR \\ + \beta_{5,t} TCRI + \beta_{6,t} COVID\ 19 + EARN_{i,t-1} + \varepsilon_{i,t} \end{aligned} \qquad (11)$$

Financial Risk (FR)

From Concepts of Business and Financial Risk Stephen C.Gabriel and C.B Banker 1980.
Financial risk is defined to be the added variability of the net cash flows of the owners of equity that results from the fixed financial obligation associated with debt financing and cash leasing, also as mentioned by Van Arsdell

$$FR = \frac{\delta_2}{\overline{C}X - I} - \frac{\delta_1}{\overline{C}X}$$

δ_1: Standard deviation of net cash flows without debt financing

δ_2: Standard deviation of net cash flow with debt financing but before the deduction of debt servicing payment

$\overline{C}X$: expected net cash flows without debt financing

I : fixed debt servicing obligations

Credit Risk (TCRI)

From the Taiwan TEJ database credit risk observation and evaluation, the evaluation method firstly obtains the basic level from financial data then obtains the threshold level according to the risk and scale, and finally determines the TCRI based on non-quantitative factors.
It is divided into 1 to 9 grades. Those with a comprehensive score below 165 are ranked 9th, those with a score above 760 are ranked 1st, and 85 points are divided into one grade. Those who are classified into the 9th class have the highest credit risk; and those classified into the first class have almost no credit risk, and the risks decrease in sequence.

9. The responsiveness when confirming bad and good news

According to Khan and Watts (2009) regression formula, the C-score value can used for the company as to be the increase sensitivity for accounting surplus on the bad news on the year.

According to the definition[1] of Basu (1997) regression, β_3 represents the sensitivity of the overall average surplus to good news, and β_4 represents the sensitivity of the surplus to the bad news. The company in the year, the accounting surplus on the bad news of the increase in the degree of sensitivity, the overall average return to the results of the following table.

9.1. Taiwan: good news reported faster than bad news (Table 2)

Since the coefficient of NEGxRET = -1.72E-5 is negative, it means that the reflection of accounting earnings on bad news is time-delayed (*i.e.* accounting earnings are not robust). The estimated coefficient RETxSIZE =-0.7526E-6 is also negative, indicating that large scale companies are not intend to report good news immediately. The estimated coefficient NEGxRETxSIZE=2.655E-5 is positive, indicating that earnings conservatism increases with company size. The timeliness of high-growth companies (measured in MB) to report good news is high since RETxMB=0.000265 is positive, but the estimated coefficient of NEGxRETxMB =-0.00137 is negative, indicating that the reporting of good news is more timely, which may due to the fact that the companies are freshly listed.

9.2 Hong Kong: bad news reported faster than good news (Table 2)

Since the coefficient of NEGxRET=-0.016 is a significantly negative value, so the reflection of accounting

[1] Since the coefficient β_3 represents the sensitivity of accounting earnings (EARN) to good news, and the coefficient $\beta_3 + \beta_4$ represents the sensitivity of accounting earnings (EARN) to bad news, β_4 represents the incremental responsiveness of earnings to bad news, which can gauge the speed of timely responsiveness of good news and bad news as well as conservatism. If $\beta_4 > 0$, the accounting earnings is robust, and the larger the value of β_4, the greater the degree of conditional conservatism. In addition, $(\beta_3 + \beta_4)/\beta_3$ represents the sensitivity of earnings to good news and bad news. If $(\beta_3 + \beta_4)/\beta_3 > 1$, bad news is reflected in earnings faster than good news; in terms of explanatory power, since the conservatism principle responds more timely to bad news, the explanatory power of earnings for bad news should be better than that of good news, so the R^2 of expected bad news/ R^2 of good news > 1.

earnings on bad news is time-sensitive (*i.e.* accounting earnings are robust). The estimated coefficient RETxSIZE = -0.012 is negative, indicating that small-scale companies tend to report good news in a timely manner. The estimated coefficient NEGxRETxSIZE=0.002 is positive, indicating that earnings conservatism increases with company size. The timeliness of high-growth companies (measured in MB) to report good news is low since RETxMB=-0.002 is negative but the estimated coefficient of NEGxRET xMB =0.002 is positive, indicating that the reporting bad news is more timely. Noted that the estimated coefficient RETxLEV=-0.026 is significantly negative. Although the debt ratio does not affect the timeliness of reporting of good news, it will improve the timeliness of reporting of bad news, since the estimated coefficient NEGxRETxLEV=0.026 is positive.

Table 2 Results of estimated C-Score

	Coefficient		t- value		p- value	
	Taiwan	Hong Kong	Taiwan	Hong Kong	Taiwan	Hong Kong
β_1, Intercept	0.001	0.593	3.171**	16.728***	0.002	0.000
β_2 NEG	0.00169	-0.068	1.852	-14.760***	0.067	0.000
β_3 RET	4.955E-5	-0.016	2.614*	-21.342***	0.010	0.000
β_3 SIZExRET	-7.526E-6	-0.012	-.248	-12.687***	0.805	0.000
β_3 MBxRET	0.000265	-0.002	2.066**	-1.230	0.041	0.221
β_3 LevxRET	0.000154	-0.026	1.723	-7.753***	0.088	0.000
β_4 NEGxRET	-1.720E-5	-0.016	-.550	-8.905***	0.583	0.000
β_4 SIZExNEGxRET	2.655E-5	0.012	.563	-5.767***	0.574	0.000
β_4 MBxNEGxRET	-0.000137	0.002	-1.099	.767	0.274	0.445
β_4 LevxNEGxRET	-0.000127	0.026	-.626	2.726*	0.533	0.007
SIZE	8.868E-5	-0.055	1.159	-12.381***	0.249	0.000
LEV	-0.001	-0.103	-2.212**	-6.488***	0.029	0.000
MB	-0.000459	-0.003	-2.668***	-.401	0.009	0.689
SIZExNEG	-6.434E-5	0.055	-.468	9.571***	0.641	0.000
MBxNEG	0.000405	0.002	1.080	.313	0.282	0.755
LevxNEG	0.001	0.103	1.791*	4.272***	0.076	0.000
N	131	133				
R^2	0.501	0.897				
adj. R^2	0.154	0.884				
F	2.595	68.63				

*p<0.1,**p<0.05,***p<0.01

This table reports the annual average of the annual cross-sectional fama-Macbeth surplus and the regression of the listed variables from the year 2016 to the beginning of 2020. NEG is a virtual variable with a value of 1 indicating that the stock returns (RET) are negative, otherwise 0; size is the natural logarithm of the equity market; MB is the net value ratio; the LEV is the short term liabilities plus the long term liabilities.

10. Whether the conservatism of a company will be changed by time of COVID-19

Table 3 shows that the change of magnitude of conservatism of the shipping and logistics companies prior and subsequent to COVID-19, using the C-SCORE value as a measurement of conservatism, and the COVID-19 dummy variable as a measurement of the impact of the COVID-19 epidemic. Results show that the COVID-19 (T) value of samples of Taiwan has a very significant impact on conservatism (C-Score) (coefficient = -

3.039E-5, T-value = -3.111, p-value = 0.002); significant below 1% level. For Hong Kong, the COVID-19 (T) value is not significant impact on conservatism (C-Score) (coefficient = 0.011, T-value = 1.574, p-value = 0.118); only samples of Taiwan show greater earnings conservatism prior to COVID-19. Especially, the F (=9.680) value of Taiwan, which indicates that the variable has a remarkably high explanatory power, and it is also the best portrait to this phenomenon.

Table3 Logistics and shipping company at COVID-19 period time accounting conservation to effector

		coefficient	T Value	P Value
Taiwan	Intercept	-4.625E-6	-1.010	0.314
	COVID19	-3.039E-5	-3.111	0.002***
	N		131	
	R^2		0.069	
	adj. R^2		0.062	
	F		9.680	
Hong Kong		Coefficient	T Value	P Vale
	Intercept	-0.007	-1.688	0.094*
	COVID19	0.011	1.574	0.118
	N		134	
	R^2		0.018	
	adj. R^2		0.011	
	F		2.477	

p-values in parentheses * $p < 0.1$， ** $p < 0.05$， *** $p < 0.01$

11. Accounting Conservatism of Shipping and Logistics Companies in Hong Kong Prior and Subsequent to COVID-19

In this study, it is observed from the change of magnitude of conservatism prior and subsequent to COVID-19 that Taiwan is affected by COIVD-19 but not for Hong Kong. In order to verify the validity of this phenomenon, the method of BASU (1997) is used. Table 4 indicates that in 2017 to 2018, they were significant at 0.193, but non-significant in other years. Obviously, Hong Kong's shipping and logistics industries were not affected greatly during the prevalence of COVID-19 but their accounting earnings conservatism in 2017 to 2018 was largely affected. As affirmed by this research, this is the consequence of economic shocks caused by the political instability arising from the social movement in Hong Kong.

Table4 Accounting Conservatism in Hong Kong Prior and Subsequent to COVID-19

	(1) 2016，2017	(2) 2017，2018	(3)2018，2019	(4)2019，2020
	deltax	deltax	deltax	deltax
Intercept	0.352**	0.059	0.061	0.035***
	2.530	1.123	1.665	5.645
	(0.039)	(0.272)	(0.102)	(0.000)
deltaxt1	0.188	0.080	0.033	0.069
	0.792	0.555	0.914	0.533
	(0.466)	(0.584)	(0.365)	(0.599)
DR	0.22	-0.002	-0.069	-0.030
	0.11	0.019	-1.346	-0.002
	(0.916)	(0.985)	(0.184)	(-0.985)
DRdeltaxt1	-0.376*	3.061	1.206	0.975
	-1.987	1.865	1.354	2.428

	(0.087)	(0.073)	(0.182)	(0.023)
DUMi	0.808	0.193^{**}	0.033	-0.008
	1.764	2.369	0.914	-1.018
	(0.599)	(0.026)	(0.365)	(0.318)
N	12	31	57	30
R^2	0.742	0.339	0.205	0.740
adj. R^2	0.595	0.238	0.144	0.699
F	5.039^{*}	3.337	3.350	0.000

p-values in parentheses * $p < 0.1$， ** $p < 0.05$， *** $p < 0.01$

12. Due to the Increase in Freight Prices and the Change of Consumption Patterns by Consumers During the Prevalence of COVID-19, the Higher the Earnings Conservatism, the Greater the Responsiveness of Financial Risks and credit risks.

The study calculated the impact of COVID-19 on accounting conservative companies and non-accounting conservative companies based on C-SCORE. From the following, it can be inferred that the larger the coefficient of earnings conservatism for Taiwan and Hong Kong, the greater the magnitude of conservatism. The coefficient of earnings conservatism of accounting conservative companies in Taiwan's shipping and logistics industries is very significant at 0.0805, which means that they were not affected by the absence of accounting conservatism prior and subsequent to COVID-19, and yet they exhibited growth in conservatism. The earnings conservatism coefficient of non-accounting conservative companies is significant at 0.353, the earnings conservatism also exhibited remarkable growth, though slightly lower than that of accounting conservative companies, but their credit risk is also significant at -2.801E-5***, indicating that on-accounting conservative companies possess credit risks.

For Hong Kong's accounting conservative companies, their coefficients of earnings conservatism exhibited negative growth and is non-significant at -0.047, while the cash flow is very significant at -0.065. During the period from 2016 to 2020, accounting conservative companies were seriously disturbed by cash flow.

The earnings conservatism coefficient of non-accounting conservative companies in Hong Kong is very significant at 0.554, indicating that their earnings conservatism prior and subsequent to the epidemic have grown remarkably.

Table5 Financial Risk and Credit Risk At accounting conservatism effector

	Taiwan		Hong Kong	
	Accounting Conservatism	Non Accounting Conservatism	Accounting Conservatism	Non Accounting Conservatism
Intercept	$-4.300E-5^{**}$	0.000	0.005	0.018
	-0.055	-0.205	0.206	0.274
	(0.957)	(0.838)	(0.838)	(0.785)
$EARN_{i,t-1}$	0.805^{***}	0.353^{***}	-0.047	0.554^{***}
	14.887	5.623	-0.610	5.218
	(0.000)	(0.000)	(0.546)	(0.000)
CSCORE	-0.1086	-2.880	-0.098	3.343
	-0.271	-0.691	-0.852	2.145
	(0.787)	(0.492)	(0.400)	(0.181)
ACCSCORE	0.003	0.007	-0.235	0.432
	0.519	0.500	-1.308	0.898

	(0.606)	(0.619)	(0.200)	(0.373)
CFSCORE	-0.003	0.014	-0.065***	0.098
	0.007	1.126	-3.076	1.368
	(0.734)	(0.264)	(0.004)	(0.176)
FR	-1.874E-5	1.202E6	0.000	3.708E-5
	-0.467	-0.226	0.471	0.044
	(0.643)	(0.822)	(0.641)	(0.965)
TCRI	6.619E-5	-2.801E-5***	-	-
	0.944	-0.226	-	-
	(0.350)	(0.000)	-	-
COVID-19	5.709E-6	0.000	0.006	-0.004
	0.023	-0.423	0.448	-0.091
	(0.981)	(0.674)	(0.657)	(0.928)
N	58	74	40	74
R^2	0.822	0.392	0.267	0.308
adj. R^2	0.798	0.328	0.159	0.246
F	33.082	6.084	2.471	4.963

p-values in parentheses * $p < 0.1$， ** $p < 0.05$， *** $p < 0.01$

13. Conclusion

According to the empirical results of this research, both Taiwan and Hong Kong, after the conservative changes in accounting earnings before and after COVID-19, can act as a reference when making investment decisions and conducting business for the investors and legal entities in the shipping and logistics industries of the two places. The main findings are summarized as follows:

(1) By comparing the accounting conservatism of the two places before and after COVID-19, the results (Table5) are consistent with the findings of Gabriel and C.B. Baker (1982), Dichev (1998) and others. That is, the higher the return stability, the lower the financial and credit risk, and vice versa.

(2) The higher the profitability of Taiwan and Hong Kong, the greater the ability to respond to good news in a timely manner. This paper estimates that Taiwan's CSCORE value is more conservative than Hong Kong's and shows a stronger timeliness in confirming bad news based on the method proposed by Khan and Watts (2009). Since large companies often report good news in a timely manner, earnings conservatism does not increase with company size. High-growth companies, measured in megabytes, are less likely to report good news in a timely manner.

(3) There is a high difference in the timeliness of the disclosure of good news between Taiwan and Hong Kong, which may be due to the difference in the rules and regulations between statutory and non-statutory laws. And lead to conservatism (balance sheet conservatism), especially the unconditional conservative claim of the autonomous accounting choices of multinational corporations themselves.

(4) The results of this study show that there are some differences in the existence of unconditional conservatism in different legal countries. For statutory law countries, differences in institutional and regulatory environments make their assets undervalued. And because of their accounting choices, their assets are further undervalued, which means their unconditional conservatism is higher than in non-statutory countries. Unconditional conservatism in China and Taiwan (statutory law countries) is higher than Hong Kong (non-statutory law countries). It shows that the system and regulatory environment will have a certain degree of influence on accounting conservative. Therefore, due to the prudent control of accounting by the local system and tax system, the location of the operation centre of the shipping company will be different.

(5) Comparing the accounting conservatism results of the two places during the COVID-19 period shows that the company's earnings have become more conservative over time. At the same time, through the method

of Penman and Zhang (2002), the time T factor is embedded in the C-Score value, and the results show that the accounting conservatism in Taiwan is larger before COVID-19, while it is less significant in Hong Kong during this period. In addition, using Buse's (1997) econometric analysis results, it shows that the accounting conservatism of Hong Kong shipping and logistics companies shows significant differences in 2017-2018, but not in other years during the study period. This may be due to the political instability caused by social movements at the time, resulting in a deterioration in the quality of corporate earnings.

(6) Since the data in this study only covers 5 years at most, resulting in too few independent samples obtained within the study area, it is difficult to conduct more detailed verification of listed companies in the shipping and logistics industries in Hong Kong and Taiwan. In the future, medium and long-term research will be conducted, and the sample time series will be extended to 2021 or more in-depth research and discussion on COVID19 will be conducted.

Variable Definitions

$EARN_{i,t}$ ： The first company's extraordinary profit before and after-tax net profit and opening market value deflator

$NEG_{i,t}$ ： Is defined as 1. Otherwise 0.

RET_{it} ： Represents the company and the stock return in year T.

$\lambda_{1t} \ldots\ldots \lambda_{4t}$ Parameter value to measure accounting conservatism.

$\varepsilon_{i,t}$: Residuals of the i-th company and the t-th year, assuming normal distribution

$size_{it}$:The size of the company, the market value of the interests of log

MB_{it} :For the market value of the book value ratio

Lev_{it} : Debt ratio

C_t: The average conservatism of all sample companies in year t, with the original data and the sorted data, were analysed to see if there was a significant change in the conservatism of the covid-19 before and after the covid-19.

t: 1 before covid-19; 0 after covid-19: 1.

β_1: Is positive, on behalf of the degree of robustness over time is showing an incremental situation; negative, on behalf of the degree of robustness over time to show a decreasing situation.

$\Delta X_{i,t}$: Net profit before tax is b/f market value from (8) $EARN_{i,t}$

$DR_{i,t}$: $\Delta X_{i,t} < 0 = 1$ ， Other=0

$DUMi(1,2,3,4)$: Independent Variable DUMI 1=2016,2017 2016=1 2017=0、DUMI 2=2017,2018 2017=1 2018=0，DUMI 3=2018,2019 2018=1 2019=0, DUMI 4=2019,2020 2019=1 2020=0

δ_1: Standard deviation of net cash flows without debt financing

δ_2: standard deviation of net cash flow with debt financing but before the deduction of debt servicing payment

$\overline{CX}$: expected net cash flows without debt financing

I : fixed debt servicing obligations

FR: Financial Risk

TCRI : Credit Risk

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Effect of Emission Control Area (ECA) Regulations on the Cruise Shipping Network

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Abstract

Purpose – The rapid growth in cruise shipping coupled with increasing public awareness towards climate change has led to increasing concerns about the impact cruise shipping poses on the environment, especially regarding air emissions. This study aims to analyse the cruise shipping network in the Caribbean affected by ECA regulations to reflect the operations of cruise lines.

Design/methodology/approach – This study uses the data of 239 voyages serviced by 14 international cruise lines, visiting ports in the Caribbean Sea to construct the cruise shipping network covering 127 ports across 44 countries. The properties and connectivity of the network and ports are analysed using a complex network approach.

Findings – The network has a small-world property with a short average path length and high clustering coefficient. The ECA regulations affect connections among ports. Most ports in ECAs have lower connections than ports outside ECAs. Only a smaller number of ports in ECAs play important key roles, but many ports outside ECAs play a more important role in the network. This is because the regulations are barriers for cruise ships entering the ports. Royal Caribbean Cruises has the largest service network, and its important key ports are outside ECAs. In contrast, smaller service networks set ports in ECAs are key ports because the networks consist of voyages departing from other regions, and those ports are popular for cruise shipping.

Originality/value – This paper puts some constructive suggestions forward for cruise lines and port authorities to improve their operations according to ECA regulations. The paper also provides some suggestions for policymakers to consider their regulations in order to adjudge to be reasonable or attract more cruise shipping to travel in ECAs.

Keywords: Emission control area; Cruise shipping; ECA regulations; Complex network approach; Network analysis

1. Introduction

Cruise shipping is a form of shipping service used primarily for pleasure and leisure purposes where the voyage itself, the ship's amenities, and stops along the way all form a part of passenger experiences. Cruise shipping is one of the fastest-growing sectors in the transport industry. In 2019, global cruise passengers increased by more than 29.7 million and were expected to reach 32 million in 2020 (CLIA, 2021). The annual growth rate of the global cruise passenger volume grows at 6.63% (Sun et al., 2021). The average ocean-going cruise ship is 222,900 tonnes and can carry 5,400 passengers (Lau and Yip, 2020). Pollutants and waste from cruise ships include wastewater, solid waste, and air emissions. On a one-week voyage, the average cruise ship generates 210,000 gallons of sewage, 1 million gallons of sewage, and eight tons of solid waste (Transportation, 2002). Especially, each passenger generates an average of 30 litres of sewage, 120-300 litres of greywater and 3.5 kilograms of solid waste onboard a cruise ship in a day (Lau and Not, 2020). The rapid growth in cruise shipping coupled with increasing public awareness towards climate change has led to increasing concerns about the negative impact cruise shipping poses on the environment, especially regarding air emissions (Tichavska et al., 2019), which is the most apparent from a visual perspective. The emissions from cruise ships are typically most evident when berthing, where large hotel loads combined with their proximity to port cities result in bad air quality for city residents. This adversely influences city residents' physical conditions, such as asthma, lung cancer, and respiratory diseases.

The negative health impacts of the two main ship emission pollutants: nitrogen oxides (NOx) and sulphur oxides (SOx), have been well established. This has to lead to the introduction of Emission Control Areas (ECAs) in order to curb excessive emissions. According to the International Maritime Organisation (IMO), ECAs are maritime areas in which stricter environmental controls were established to minimise emissions from ships, mainly NOx and SOx (IMO, 2016). Such emission regulations of emissions and thus fuel type stems from the growing concerns of air pollution and environmental impacts of the shipping industry (Chen et al., 2018). Annex VI contains provisions for two sets of emission and fuel quality requirements, a global requirement, and the more stringent controls in ECAs. ECAs current encompasses the Baltic Sea, the North Sea and the English Channel, the North American area, and the United States Caribbean coasts, as shown in Figure 1.

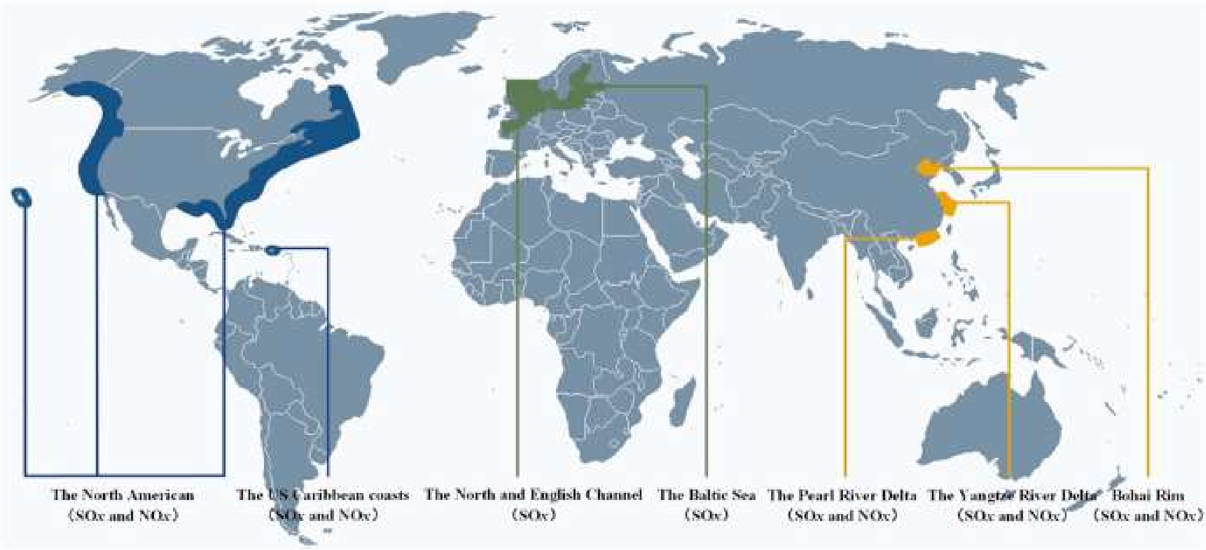


Figure 1: Global map of ECAs
Source: Zhen et al. (2018)

From

Table 1, the threshold for sulphur limits in fuels both globally and within ECAs has been gradually lowered. The introduction and subsequent enforcement of ECAs have remarkably successfully controlled marine pollution but have impacted the shipping industry as with any restrictive measure. In terms of operations, fuel costs are a major total cost factor (Zhen et al., 2018). For example, the *Harmony of the Seas* by Royal Caribbean has two four-storey high 16-cylinder engines, which at maximum power could burn through approximately 66,000 gallons a day. Cost-wise, this would mean that about two to three dollars per gallon could cost upwards of 200,000 dollars per day in fuel costs alone (Cullinane and Bergqvist, 2014). This expense is further magnified as cruising in ECAs requires the use of low-sulphur fuel compared to relatively cheap bunker fuel (Cullinane and Bergqvist, 2014).

Table 1: MARPOL Annex VI fuel sulphur limits

<table>
<tr><th rowspan="2">Year</th><th colspan="2">Sulphur limit (% m/m)</th></tr>
<tr><th>ECAs</th><th>Global</th></tr>
<tr><td>2000</td><td>1.5</td><td rowspan="2">4.5</td></tr>
<tr><td>2010</td><td>1.0</td></tr>
</table>

2012		3.5
2015	0.1	
2020		0.5

Source: Diesel Net (2020)

ECA regulations also affect cruising speed and routing, in turn affecting itinerary planning and port selection. Three main alternatives are commonly used in addressing the sulphur standards as regulated in ECAs (Fagerholt et al., 2015). The first is scrubber systems that remove sulphur from ship exhaust, allowing cruise ships to continue using bunker fuel or heavy fuel oil in ECAs. The second is to use liquefied natural gas (LNG) and onshore powering when berthed. Thus, ports with LNG bunkering and are capable of supplying power to cruise ships have become important drivers of port attractiveness to cruise lines. Also important is the public perception of cruise lines as a clean, wellness, and environmentally friendly tourism sector. Equally important is a ports' status as a hub, where its attractiveness lies in its location and facilities, which can be essential factors in cruise lines adding or removing them from the cruise itinerary. The third is fuel switching which allows cruise ships to switch between burning heavy fuel oil outside ECAs and marine gas oil with low sulphur content inside ECAs (Gu and Wallace, 2017)

Recently in July 2021, Venice, a major hub for cruise ships, decided to ban cruise ships from entering its canals (Asero and Skonieczny, 2018). This is due to the canals now being listed as a UNESCO cultural heritage site. This is also due to increasing concerns about the emissions that these cruise ships bring to the city. Venice is the largest European cruise port, representing 1.7 million cruise passenger movements. With its landmark move to ban cruise ships, perhaps other ports might also follow suit in order to promote an environmentally friendly image. As can be seen from the landmark move in Venice, without countermeasures, the emissions of cruise ships would result in worsening air qualities in ports due to their large hotelling loads even when berthed. Additionally, being green and sustainable has also been increasingly part of cruise and port authority agendas due to the cruise industry's heavy reliance on a positive public perception (Gonzalez-Aregall and Bergqvist, 2020). From a tourist perspective, the inclusion of ports in ECAs could be an important decision-making factor if the cruise itineraries are being marketed as being more environmentally friendly. The Florida-Caribbean Cruise Association (FCCA) has made several predictions for 2019 cruise travel, of which "Conscious Travel" is the most relevant to this study (FCCA, 2021). Travellers want to travel the world in a more conscious way and are paying more attention to the environmental impacts of cruising. This line of thinking also extends to cruise lines themselves are implementing innovations that decrease the environmental footprint of cruise travel. Florida leads the US market share with its 2.4 million passengers (17% of all US-sourced cruise passengers), with Miami being a significant destination for many cruises with Caribbean itineraries, as will be shown in the results. In March 2010, the IMO officially designated the waters off North American coats as an area where stringent international emissions standards will apply, known as ECAs (EPA, 2010).

The ECAs extend 200 nautical miles away from the coast. As a result of this regulation, ships travelling within these coasts will be required to burn cleaner fuel or seek other alternatives such as scrubbers to clean exhaust fumes. These standards seek to lower emissions from ships and help safeguard port communities. In response, cruise lines can either increase cruise fair, thus passing the increased fuel cost onto customers, minimise an itinerary's route inside ECAs, or simply eliminate certain itineraries (CLIA, 2020). As cruise ships do most of their cruising within ECA bounds to offer views of the shoreline to cruisers, it might be a case where they are disproportionately affected compared to other forms of maritime traffic such as container ships. Following the 1% sulphur limit on fuels, Carnival Cruise Lines (CCL) announced an agreement with the United States and Canadian environmental agencies to invest US$180 million in emission-reducing technology on its cruise ships to comply with ECA standards (Carnival, 2014). Under this agreement, CCL will install scrubbers and diesel particulate filters on its ships to reduce SOx and particulate matter, both of which are pollutants that damage human health and contribute to smog. A similar deal between the US Environment Protection Agency and Royal Caribbean Cruises (RCC) was also agreed upon, which called for the installation of pollution controls instead of using low-sulphur fuels to meet the emission standards (EPA, 2010).

The Caribbean is the leading market for cruise ship fleet deployment, accounting for 34.4% of global deployment capacity market share in 2018, is thus the focus area of this study. The FCCA has also forecasted a

6.4% increase in passengers for 2019, approximately 30 million passengers. Specific to the Caribbean and Latin American destinations, the cruise industry's economic impact cannot be discounted. From 2015 to 2018, direct expenditures generated by cruise tourism increased 6.3%, totalling US$3.36 billion. Destinations also welcomed 25.2 million onshore visits from cruise passengers, with an average spend of US$2.56 billion. On average, a single transit cruise call with approximately 4,000 passengers and 1,640 crew generates almost US$400,000 in spending alone. Additionally, cruise line expenditures generated US$534 million, including port fees and taxes, repair and maintenance, payments to tour operators, and payments to local businesses for supplies and services. From this, it is clear that the cruise industry's economic impact in the Caribbean and Latin America is significant and is projected to continue to grow (FCCA, 2019).

Many studies on cruise shipping mainly focus on the global service supply chain (Soriani et al., 2009, Véronneau and Roy, 2009, Véronneau et al., 2015), capacity deployment and itineraries (Rodrigue and Notteboom, 2013), itineraries design (Wang et al., 2017b, Wang et al., 2017a). Cruise ship emission has begun getting attention in estimating and analysing ship exhaust emissions (Dragović et al., 2018, Maragkogianni and Papaefthimiou, 2015).

In terms of maritime studies in ECAs, most works concentrated on speed optimisation of ships, sailing paths, ship routing and scheduling based on ECAs regulations in order to minimise the total costs (Fagerholt et al., 2015, Fagerholt and Psaraftis, 2015, Gu and Wallace, 2017, Chen et al., 2018). In cruise shipping, only Zhen et al. (2018) conducted the study of rescheduling voyage plans by optimising speeds, sailing patterns and ports-of-call sequences to reduce fuel cost in ECAs.

The above studies show that existing works do not consider the effect of ECA regulations on the maritime network and port connectivity, especially the cruise shipping network. Therefore, this study aims to analyse the effect of ECAs on cruise shipping and how cruise lines design the cruise shipping network based on ECA regulations. Therefore, this study seeks to answer the research question: *How do ECA regulations affect the cruise shipping network?* This is analysed in terms of network structure, characteristics and connectivity using a complex network approach. The findings are drawn the implications for the cruise sector, ports authorities, industrial practitioners, and policymakers. The rest of this paper is structured as follow. Section 2 describes the analytical methods. Section 3 presents the findings and discussion. Section 4 presents managerial implications. Conclusion and the implication for future research are shown in the last section.

2. Methodology

This study aims to analyse the effect of ECA regulations on the cruise shipping network. A complex network approach is applied to achieve our research purpose. This approach is used to create the network studied based on nodes that are connected by edges or links. In this study, nodes refer to cruise ports, and links refer to cruise shipping routes that connect between ports indirect ways. That is, the network studied is a directed network. Many scholars have applied a complex network approach to analyse port networks (Tsiotas et al., 2018, Kanrak and Nguyen, 2022, Ducruet and Notteboom, 2012, Kanrak and Nguyen, 2021, Ducruet and Zaidi, 2012).

This study wishes to interpret network structure and properties and the roles of ports in ECAs. The study gives prominent importance to network visualisation as a whole. The study is based on data from cruise itineraries offered by cruise lines to passengers. Network analysis is conducted at the network and port levels to reflect the effect of ECA regulations on the network and ports in the Caribbean Sea.

2.1 Network level

The structure and properties of the cruise shipping network in the Caribbean are analysed using various network measures, including network density, average path length, clustering coefficient, assortativity, and rich-club coefficient. Each measure reflects the different network properties, as detailed following.

2.1.1 Network density

Network density indicates the connectivity of the network by determining the ratio of links to nodes. A network with high network density reflects the efficiency of its connections. The network density of node *i* is the fraction of the number of links and the possible number of links in a network, as show in (1) (Scott, 1988). Where *m(G)* stands for the number of links that a network has, and *n* is the total number of nodes in a network.

$$\rho(G) = \frac{m(G)}{n(n-1)} \quad (1)$$

2.1.2 Average path length

Average path length measures the mean shortest path between two nodes in a network, defined as the average number of steps along the shortest paths for all possible pairs of nodes. A network with a short average path length has the efficiency of information or mass transport between nodes. Average path length is calculated as the proportion of the sum of the shortest distance (step) between nodes *i* and *j* and the total number of the possible number of links in a network (Watts and Strogatz, 1998):

$$L = \frac{1}{n(n-1)} \sum_{i \neq j}^{n} d_{ij} \quad (2)$$

2.1.3 Clustering coefficient

Clustering coefficient reflects the degree to which nodes tend to cluster together, indicating the level of cluster or group of a network. This metric describes the probability of a new pair of nodes to the third node in a network. The clustering coefficient of node *i* can be written as:

$$C_i = \frac{2E_i}{k_i(k_i - 1)} \quad (3)$$

Where E_i is the number of existing links between the neighbour of node *i*, and k_i is the number of links of node *i*. Therefore, the clustering coefficients of a network is the average clustering coefficient of all nodes:

$$C = \frac{1}{n}\sum_{i=1}^{n} C_i \quad (4)$$

2.1.4 Assortativity

Assortativity indicates the preference of nodes in a network to connect to others with the same properties. The assortativity of a network is usually examined in terms of a node's degree to present the tendency of a high degree node being connected by other high degree nodes. The assortativity of a network can be written as (5). Where a_i and b_i represent the ratio of each type of a link attached to nodes of type *i*, *e* is the matrix elements, e_{ij} is the fraction of links connection nodes of type *i*, to the nodes of *j*, and $\|x\|$ is the sum of all elements of the matrix *x* (Newman, 2002):

$$r = \frac{\sum_i e_{ii} - \sum_i a_i b_i}{1 - \sum_i a_i b_i} = \frac{Tre - \|e^2\|}{1 - \|e^2\|} \quad (5)$$

2.1.5 Rich-club coefficient

Rich-club coefficient measures the extent to which well-connected nodes also connect to each other. A network with a relatively high rich-club coefficient indicates *the rich-club effect* or *the rich-club phenomenon* and will have many connections between nodes of a high degree. The rich-club coefficient of a network is the proportion of the number of links among nodes of degree greater than or equal to *k* to the total possible number of links if nodes are fully connected (Zhou and Mondragón, 2004), presented as (6). Where $E_{>k}$ stands for the number of edges between nodes and degree greater than or equal to *k*, $n_{>k}$ is the number of nodes with degree greater than or equal to *k*.

$$\phi(k) = \frac{2E_{>k}}{n_{>k}(n_{>k}-1)} \quad (6)$$

In this study, network density is used to analyse network connectivity and the potential connections among ports. The average path length is used to analyse the efficiency of network connectivity. The clustering coefficient is used to analyse the level of intra-connection among ports within the network, explaining the level of meeting cruise connections among a port's neighbours. Assortativity is used to analyse the tendency of ports with a similar degree to connect to each other. The rich-club coefficient is used to examine *the rich-club phenomenon* that exists in the cruise shipping network in ECAs.

2.2 Port level

To identify the important key ports and their roles in ECAs, three centrality measures are used to analyse the network at the port level, including degree, betweenness and closeness centralities.

2.2.1 Degree centrality

Degree centrality reflects the number of edges that a node has. A port has a high degree centrality if it is connected to many other ports. Degree centrality of node i is defined as the sum of the number of nodes connected to a given node in the network, as shown in (7). Where a_{ij} is 1 if a link connects ports i and j; 0 if otherwise. A node with a high degree is an important node that plays as a hub, thus controlling network connectivity.

$$C_D = \sum_{j=1}^{n} a_{ij} \quad (7)$$

2.2.2 Betweenness centrality

Betweenness centrality presents the degree to which two nodes stand between each other. The betweenness centrality of node i is the ratio of the shortest paths passing through it and the number of the shortest paths, as shown in (8). Where $\sigma_{st}(i)$ is the number of the shortest paths passing through node i, and σ_{st} is the total number of the shortest paths in the network.

$$C_B = \sum_{s \neq i \neq t} \frac{\sigma_{st}(i)}{\sigma_{st}} \quad (8)$$

2.2.3 Closeness centrality

Closeness centrality measures the average shortest paths from a node to all other nodes in a network. It reflects the ability of a node that is able the spread information and transport very effectively through a network. A node with high closeness centrality has the shortest distance to other nodes. The closeness centrality of node i is presented in (9) as:

$$C_C(i) = \frac{n-1}{\sum_{j \neq i} d_{ij}} \quad (9)$$

This study uses degree centrality to find a hub port with high connectivity. Betweenness centrality is used to identify an intermediary port with high accessibility. Closeness centrality is used to identify a port with high reachability, reflecting their ability to reach all other ports with the average shortest path in the network in ECAs.

2.3 Data

This study utilises secondary data collected from the Australian cruise agent website (www.ecruising.travel/). The data covers 127 ports in 44 countries, mainly in the Caribbean, with 239 cruise voyages operated by 14 international cruise lines. For this study, note that different states in the United States of America (USA) are considered as separate countries. This study considers different voyages with durations of 1 to 15 nights in the peak season, visiting the Caribbean from November 2022 to April 2023. This is because short itineraries are very famous for passengers to cruise in this season, and cruise lines often design their itineraries to serve the increased need in cruise demand. At the same time, cruise lines also need to take into account emission control regulations due to the enforcement of ECAs. These combined factors can lead to network and port connectivity being affected. The analysis is conducted using the R statistical software.

3. Empirical analysis results and discussion

3.1 Network structure

Figure 2 illustrates the cruise shipping network in the Caribbean, consisting of 127 ports in 44 countries and 596 links. Among these, there are 41 ports in ECAs across 16 countries. The network is built based on voyages designed by the cruise lines, comprising of home ports, ports of call, cruise shipping routes (links) that connect between ports during voyages. Ports in the Caribbean are connected to ports in this and other regions because cruise lines design itineraries specifically to bring passengers to visit the Caribbean Sea in the peak season. Caribbean destinations are characterised by nice weather and attractive coastal areas providing various manmade and natural attractions (Sun et al., 2021). The network appears to have subnetworks consisting of ports mainly connected to others in the same areas, particularly ports in the Caribbean. This graph also shows that maritime traffic for cruise shipping is very crowded, indicating that ports in this region tend to connect to each other more than ports in other regions. However, some ports in other regions are still connected to the Caribbean ports because cruise lines want to bring people from other regions to experience Caribbean cruising. The network has a density of 0.0373, implying that cruise shipping covers only 4% of possible links between ports. This low network density also indicates that cruise lines efficiently design their itineraries by serving a large network with a small number of links. This is because cruise lines need to design voyages in line with ECA regulations in the Caribbean. Therefore, they try to optimise benefits by designing itineraries that cover the most cruise ports in this area using the smallest number of links. However, the relatively low density of the network reflects those ports in ECAs do not have a tight relationship.

The top three ports chosen as the departure ports of voyages are Miami, Fort Lauderdale, and Bridgetown. There are 48 voyages departing from Miami, 43 voyages departing from Fort Lauderdale, 21 voyages departing from Bridgetown, and the rest departing from other home ports. The three ports are chosen as the most popular departure because they are ranked the top 10 busiest ports globally, with large passenger numbers (Avoid-Crowds, 2020). This implies that these ports are popular for cruising, although some ports are in ECAs, especially Miami and Fort Lauderdale. This also signifies that some passengers do not consider ECA regulations when choosing their cruising. They primarily focus on cruise packages and destinations.

The most popular voyage from Miami is Miami→ Puerto Plata→ San Juan→ Gustavia→ Roseau→ St. John'S→ St. Maarten→ Miami (Figure 3a), which is a round trip with a total sailing distance of 2,715 nautical miles (nm). Miami and San Juan are in ECAs. For this itinerary, the cruise ship sails 320 nm within ECAs (marked as areas in green). The most popular voyage departing from Fort Lauderdale is a round trip: Fort Lauderdale→ Princess Cays→ San Juan→ Tortola→ Point-A-Pitre→ Martinique→ St. Maarten→ Fort Lauderdale (Figure 3b). The voyage has a total distance of 2,878 nm, and 298 nm in the ECAs are included. The most popular voyage departing from Bridgetown is a round trip: Bridgetown→ Scarborough→ Port of Spain→ St. George'S→ Kingstown→ Roseau→ Castries→ Bridgetown (Figure 3c). This voyage has a total sailing distance of 842 nm, and it does not pass through any ports in ECAs. Most voyages depart from Bridgetown visit ports outside ECAs because cruise lines probably do not want to bear more costs relevant to entering ECAs, such as extra fuel costs. Additionally, the average cruise price per day of the voyages departing from this port is lower than those departing from Miami and Fort Lauderdale. Therefore, this might not be profitable for cruise lines to design voyages departing from Bridgetown to visit ports in ECAs.

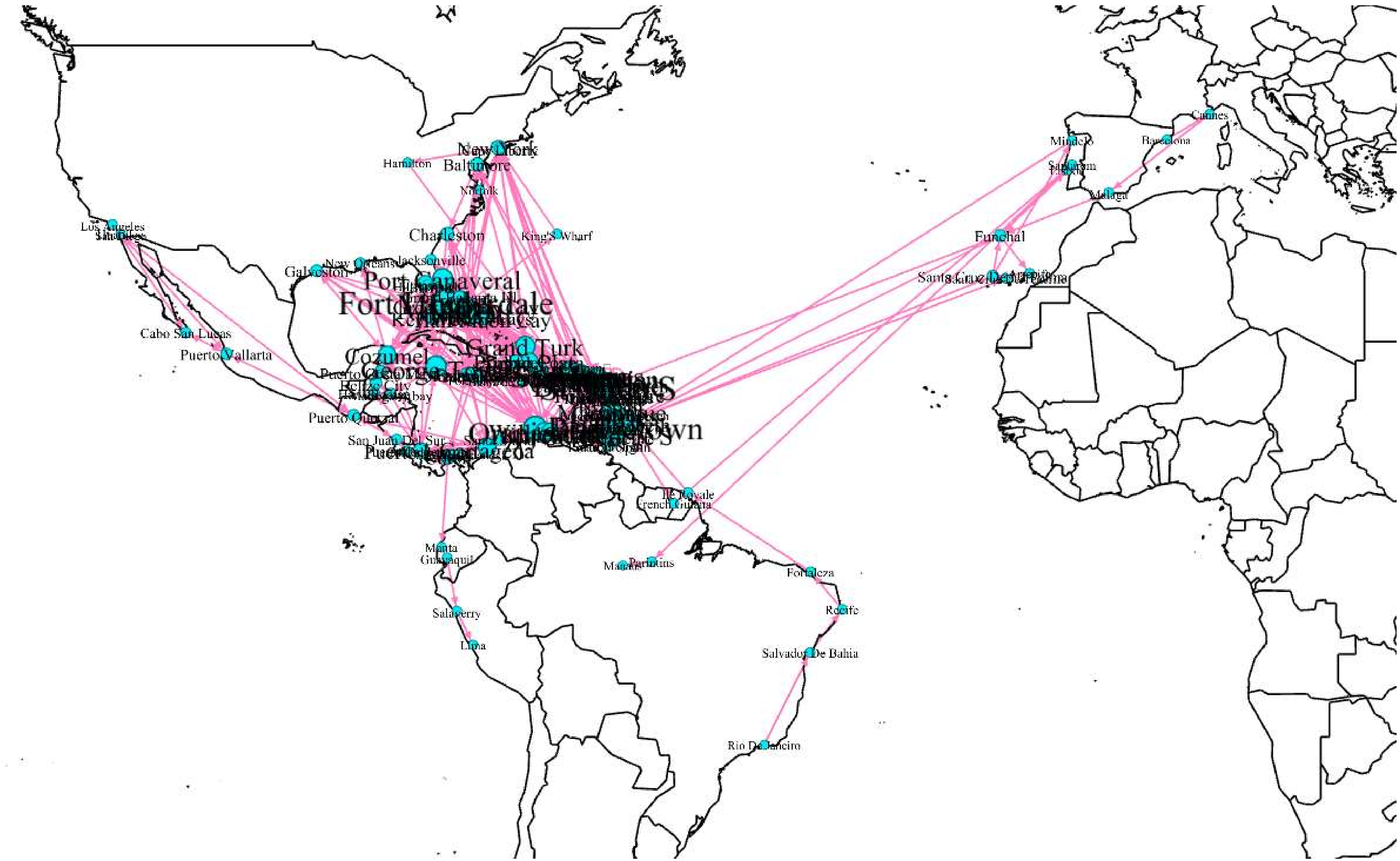
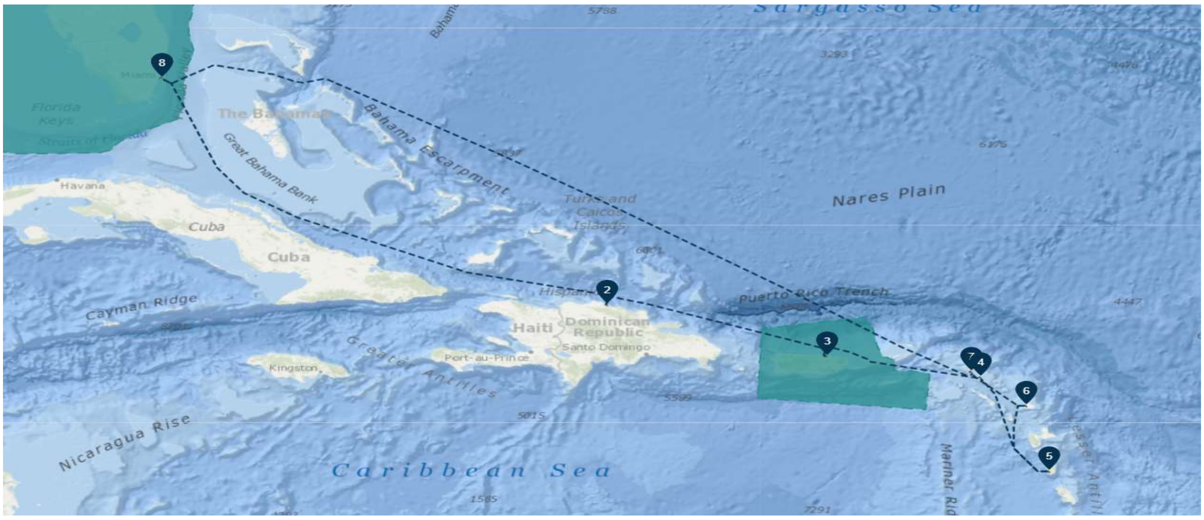
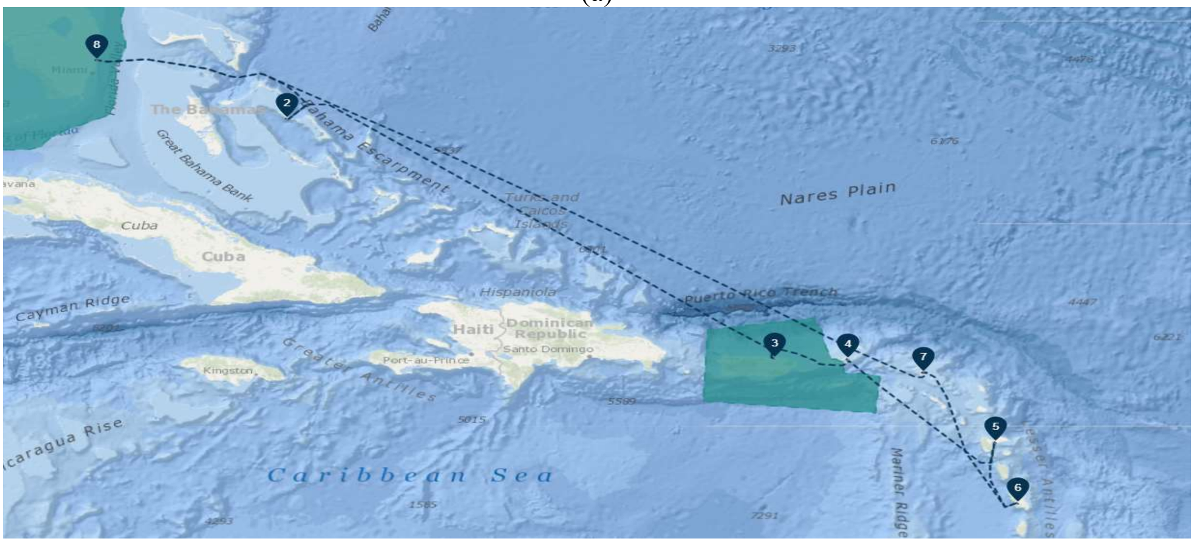


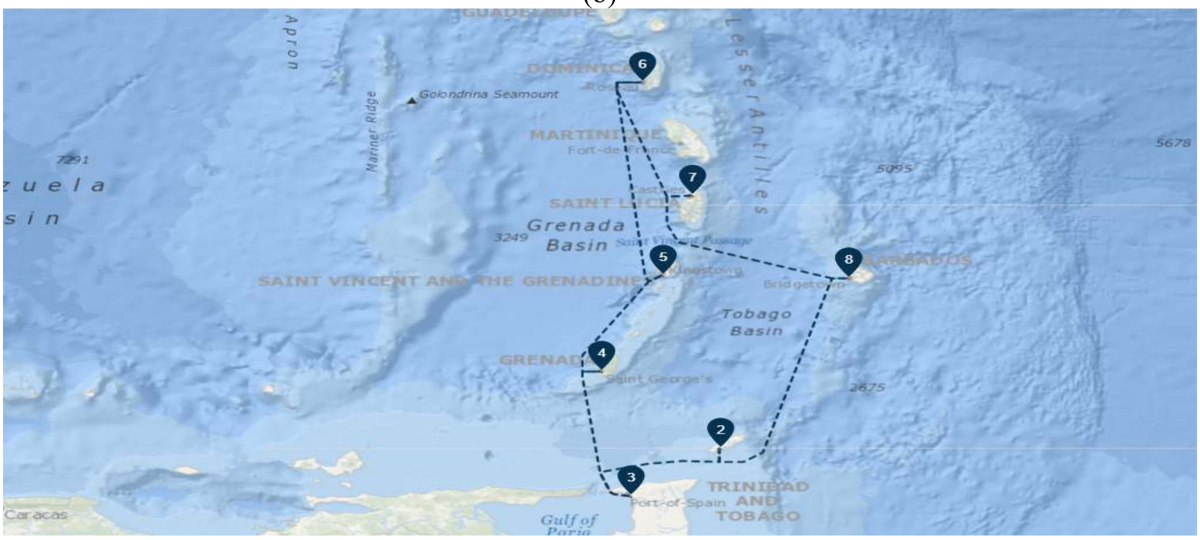
Figure 2: Graph of the cruise shipping network in the Mediterranean ECA area
Source: Authors' elaboration



(a)



(b)



(c)

Figure 3: Three most popular voyages departing from the three most popular departure ports, passing through ECAs (in green)
Source: Authors' elaboration.

In terms of network efficiency, the network has an average path length of 3.799 which is relatively low, indicating the high efficiency of mass cruising on the network with the short number of connection steps to another port. This also suggests that the network is efficient and easy to be navigated across. It is convenient for a cruise ship to sail from one port to another port in the ECAs since most ports are close to each other, as it is preferable for a ship to take the shortest distance to reach ports. In addition, the network has hubs facilitating short connections among ports. In other words, the neighbours of any port are likely to be neighbours of each other, and most ports can be reached from every other port by a small number of links (steps). This is confirmed by a high clustering coefficient of 0.321. The network has high intra-connectivity among ports, reflecting the tendency of meeting neighbours around a port are neighbour themselves (Carlini et al., 2021). The high clustering coefficient also reflects those ports heavily rely on the hubs connected to other ports.

Compared with a random network on the same number of ports and links, a random network has an average path length of 3.226 and a clustering coefficient of 0.080. The cruise shipping network has a short average path length similar to a random network, but its clustering coefficient is much higher than that of the random network. Thus, the cruise shipping network has a small-world network property, reflecting that although the network is of a large scale, the shortest path length between any two ports is small. That means all ports are closely connected, and cruise shipping efficiency is high (Zhang and Zeng, 2019).

The network has an assortativity coefficient of 0.085, indicating that high degree ports connect to each other. In other words, ports with similar degrees connect to each other, implying that cruise lines design voyages consisting of ports in the same areas based on ECA regulations. For example, ports inside ECAs tend to connect to each other. Likewise, ports outside ECAs most likely connect to each other. This leads to ports with a high degree tend to connect to other high degree ports, which are close to each other. It is also easy for cruise lines to organise services. For instance, ports outside ECAs are put in the same voyage with a longer duration than a voyage consisting of ports inside ECAs. The positive assortativity also implies the cruise network's tendency to have central ports with high interconnection (Mai et al., 2017). This is corroborated by the rich-club coefficient. The network has a rich-club coefficient of 0.063, indicating the level of the extent to which well-connected ports are connected to each other. Therefore, the positive assortativity and rich-club coefficient confirm that the cruise shipping network has *a rich-club phenomenon* (Ducruet and Notteboom, 2012).

3.2. Port properties

Cruise ports in the Caribbean play different roles based on the centrality measures. Ports with a higher degree are more important. A high degree means better serviceability for cruise shipping. Table 2 shows the 10 ports with the highest degree in the network. Miami ranks first with 42 degrees, followed by St. John'S, Fort Lauderdale, Bridgetown, San Juan, Basseterre, Oranjestad, Nassau, St. Thomas, Castries, Gustavia, George Town, and St. Maarten. This shows that these ports have more cruise shipping relationships with other cruise ports and are hubs controlling network connectivity. Six of these ports are in ECAs, including Miami, Fort Lauderdale, San Juan, Oranjestad, St. Thomas, and St. Maarten. Namely, these ports not only are hubs of the network but also are in the core position in ECAs. Therefore, the ports could be preliminarily thought to have a relatively strong demand for cruise shipping. They also have a wide scope of cruise shipping trade inside and outside ECAs.

St. John'S, Oranjestad and Miami are the ports ranked top three with 23, 22, and 20 for in-degrees, respectively. This indicates that they are directly connected to many incoming ports. Therefore, the ports are incoming hubs in the network. The incoming hubs ports will import cruise shipping from other ports to them. Miami, Fort Lauderdale, Bridgetown, and Basseterre have the highest out-degrees of 23, 19, 18, and 18 out-degrees. That is, these four ports directly connect to outgoing ports, so they are outgoing hubs of the network. The outgoing hub ports will export cruise shipping to other ports with a high connectivity level.

Figure 4 shows the degree distribution of ports, which describes how links are distributed across ports of the network. The network has a small number of ports with high degrees and many ports with low degrees. Ports with 20 degrees account for 14.96% of the total ports, while the remaining ports at 85% have degrees lower than 20 degrees. Among these, 5.51% of total ports have 16-20 degrees, 10.24% have 11-15 degrees, 17.32% have 6-10 degrees. Ports with 1-5 degrees account for the largest proportion, totalling 51.97% of the total ports.

Table 2: Top 10 ports with high degree centralities

Port	All degree	In-degree	Out-degree
Miami	42	19	23
St. John'S	39	23	16
Fort Lauderdale	37	18	19
Bridgetown	36	18	18
San Juan	36	20	16
Basseterre	34	16	18
Oranjestad	32	22	10
Nassau	30	13	17
St. Thomas	28	12	16
Castries	27	13	14
Gustavia	27	12	15
George Town	26	12	14
St. Maarten	26	11	15

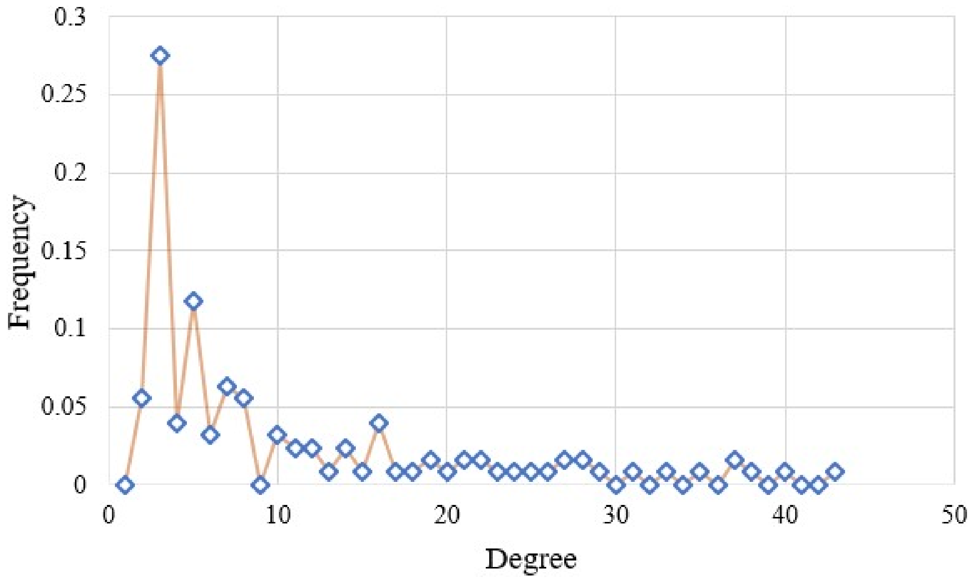


Figure 4: Degree distribution of the Mediterranean cruise shipping network in ECAs

Regarding the ports' betweenness centrality, Bridgetown ranks first with the highest betweenness centrality, followed by Fort Lauderdale, St. John'S, Cartagena, Gustavia, Oranjestad, Willemstad, Miami, San Juan, and Castries. Namely, the ports have the highest accessibility, so they are intermediate ports that play as transition ports for cruise shipping routes in the network. There are 20 peripheral ports with a betweenness centrality of zero since the ports have no shortest path between them to another port. 78% of ports have betweenness centrality of 1-500, while 16% have betweenness centrality of 1001-1500. Ports with a between centrality over than 1000 account for a small proportion of 4.72% for 1001-1500, 2.36% for 1501-2000 and 3.15% for over than 2000 (Figure 5). This betweenness distribution indicates that the network does not have a strong hub-and-spoke structure.

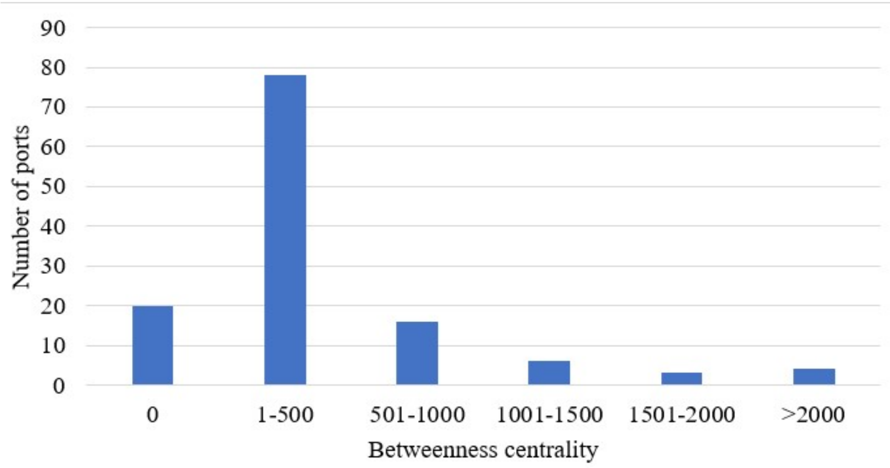


Figure 5: Betweenness centrality distribution of cruise ports

In terms of closeness centrality, ports have similar closeness centrality. However, Rio De Janeiro has the highest closeness centrality, followed by Salvador De Bahia, St. George'S, Recife, Castries, Gustavia, Fort Lauderdale, Fortaleza, Basseterre, Ile Royale, Miami, Bridgetown and Point-A-Pitre. This indicates that these ports have high reachability with the shortest path to other ports. As the table illustrates, many ports have closeness centrality between 0.00050 - 0.00059, accounting for 63.78% of ports. Ports with closeness centrality lower than 0.00040 accounted for 7.87% of ports, while 3.15% have the closeness centrality of 0.00040 - 0.00049. There are no ports with a closeness centrality of zero, indicating that all ports could connect to all others in the network. About 25% of ports have a high closeness centrality of at least 0.00060 (Figure 6).

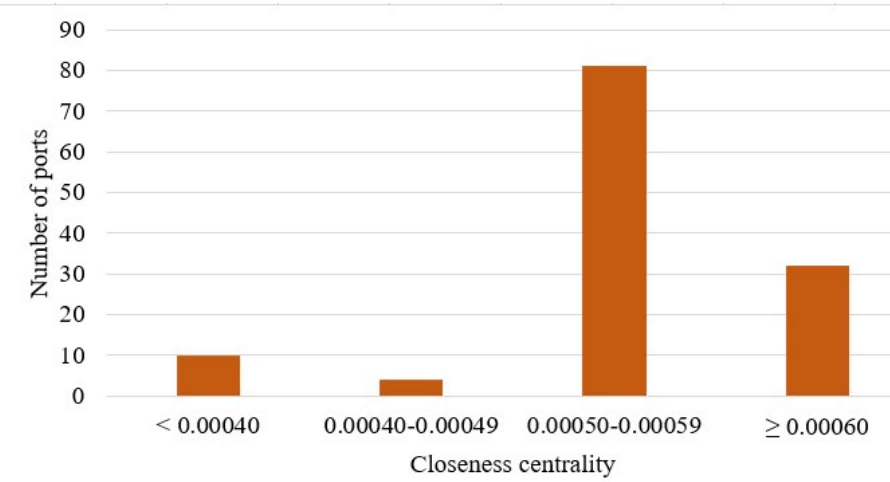


Figure 6: Closeness centrality distribution of ports

3.3 Service networks of cruise lines

Figure 7 represents the service network of 14 international cruise lines that provide cruise services for 1-15 nights in the Caribbean Sea. Most cruise lines design their itineraries departing and ending at ports in ECAs in the Caribbean. In contrast, few cruise lines design the itineraries that depart and end at ports from other areas. Among these, 63.60 % of total voyages in the network departing from four ports, i.e., 43 voyages depart from Fort Lauderdale, 21 from Bridgetown, 20 from Port Canaveral, and 20 from Tampa. The rest depart from the 20 other ports.

CCL provides the service network covering 33 ports in 19 countries through 93 cruise routes (links), as shown in Figure 7a. Among these, 16 ports are located inside ECAs. Nassau is connected by the largest number of ports. Therefore, it is a hub controlling network connections to others. Miami is an intermediary port with the highest accessibility to another port. This port also has high reachability to others with the shortest path. This reflects that the port outside ECAs is a cruise shipping hub, but a port inside ECAs has high accessibility and reachability.

Cruise shipping services of Celebrity Cruises covers 27 ports in 19 countries and 76 links (Figure 7b), with 44.44% of the total ports located in ECAs. Fort Lauderdale is a hub port since it is connected to 17 other ports, compared to other ports with a smaller number of connections. It is also an intermediary port that plays a transition role with high accessibility. Fort Lauderdale also has the shortest path to other ports, indicating its high reachability. This shows that although Fort Lauderdale is the ECA, the cruise line still set the port to play important roles in the network. This is because this port is popular for passengers, thus being more profitable for the cruise line.

Figure 7c shows the service network of Crystal Cruises designs, which covers 19 countries and 27 ports connected by 33 links. Only seven ports in four countries are in ECAs. Miami, which is located in the ECA, is a hub and intermediary port with a high connection and accessibility. Gustavia, where is located outside the ECA, has high reachability to other ports with the shortest path. Interestingly, Crystal Cruises provides cruise services covering the same number of countries and ports as Celebrity Cruises, but the number of links is 50% lower than that of Celebrity Cruises. This is because Crystal Cruises services a much smaller number of voyages (six voyages) than those of Celebrity Cruises (21 voyages).

The service network of Cunard Line covers only six ports in six counties connected by six links (Figure 7d). The network does not have a hub since all ports have the same number of connections. Additionally, there is no port with high accessibility and reachability, probably due to the shortness of the cruise line services. This implies that Cunard Line does not want to provide cruise services in the Caribbean and ECAs to avoid extra costs for sailing and operating.

Figure 7e shows the service network of Holland America Line (HAL), with 20 ports in 17 countries and 28 links. Seven ports are in ECAs. Fort Lauderdale and Half Moon Cay, inside and outside ECAs, are hub ports with the same number of connections, controlling network connectivity. Half Moon Cay also is an intermediary port with high accessibility. Fort Lauderdale also is a port with high reachability to all other ports.

Norwegian Cruise Line (NCL) provides the second-largest service network with 41 ports and 117 links. The cruise line services cruise shipping across 26 countries through 38 voyages (Figure 7f). Although the network has a large number of ports, only 36.59% (15 ports) of the total ports are in ECAs. Ports outside ECAs play key roles in the network. Puerto Plata is a hub with a large number of other ports connected to it, whilst Cartagena is an intermediary port with high accessibility. Great Stirrup Cay has the highest reachability to others with the shortest path.

Oceania Cruises has a service network of 30 ports in 23 countries connected by 68 links, as shown in Figure 7g. The cruise line designs voyages that visit 12 ports across seven countries in ECAs. Ports in ECAs play key roles in the network. Bridgetown is a hub controlling network connectivity and has high reachability to other ports with the shortest path. St. George'S is the intermediary port with high accessibility to another port.

Ponant’s service network covers 29 ports in 16 countries and 48 links (Figure 7h). Only five ports in France, the Netherlands and U.S. Virgin Islands are in ECAs. Les Saintes, which is located outside the ECA, has the highest number of connections and high accessibility. Therefore, it is a hub and intermediary port of the network. This port also has an average shortest path to others, indicating it has high reachability to other ports in the network.

The services of Princess Cruises cover 28 ports in 20 countries connected by 42 links, as shown in Figure 7i. There are eight ports in ECAs. Two of them are in ECAs and play important roles in the network. Fort Lauderdale is a hub port controlling network connectivity. Martinique is an intermediary port with high accessibility, and it can early reach other ports with the shortest path compared to others.

Figure 7j represents the service network of Regent Seven Seas Cruises (RSSC), covering 18 ports in 12 countries and 35 links. 50% of the total ports are in ECAs, but no ports in these areas play an important role in the network.

In contrast, Roseau in the Dominican Republic is a hub and intermediary port. The port also has high reachability to other ports. These results indicate that the cruise line designs the Dominican Republic as the central country for its cruise shipping.

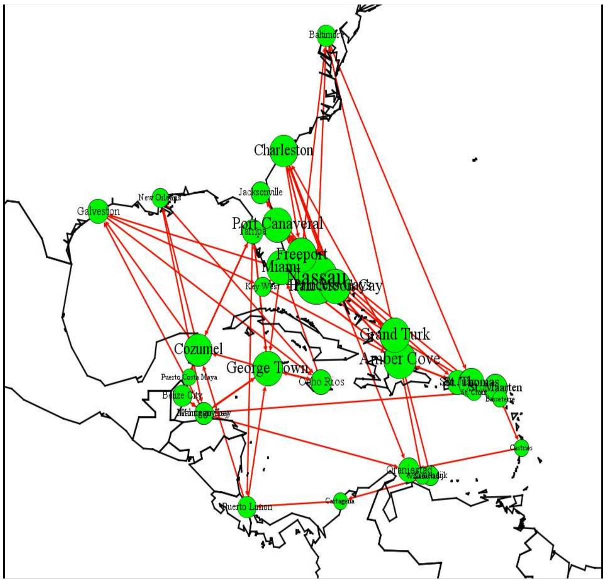
RCC has the biggest service network covering 45 ports in 27 counties connected by 143 links (Figure 7k). More than half (23 ports) of the total ports are in ECAs across 11 countries. However, ports in ECAs do not play key roles in the network. Cococay is a hub port controlling network connectivity. Bridgetown is an intermediary port, and Labadee has high reachability.

Figure 7l shows the service network of Seabourn Cruise Line (SCL), which covers 29 ports in 17 countries. Among those ports, 13 ports are in ECAs across six countries. Carambola Beach, which is not located in the ECA, has the highest number of ports that it is connected to. Therefore, it is a hub port of the network. This port is an intermediary and has high reachability to other ports in the network.

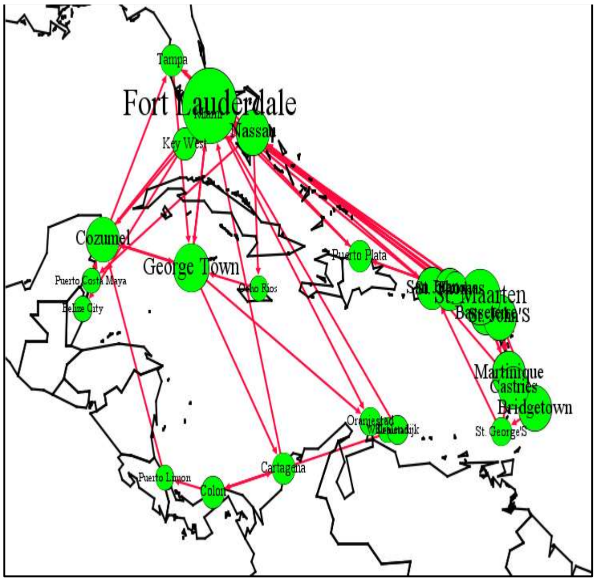
The service network of Silversea Cruises covers 34 ports in 22 countries and 67 links, as shown in Figure 7m. 16 ports are in ECAs, and do not play any important roles in the network. In contrast, ports outside ECAs play different key roles. Gustavia and St. John'S are hubs with a high number of connections. Bridgetown is an intermediary port with the shortest path connecting to one another, while Rio De Janeiro is a high reachability port with the shortest path to all other ports in the network.

Viking Cruises provides the service network covering 21 ports in 17 counties and 24 links (Figure 7n). Seven ports of these are located in ECAs across five counties. Ports outside ECAs play important key roles in the network. Ports in the network have a similar number of connections. However, Castries, St. John'S and Roseau have the highest connection of four degrees, and the ports are close to each other. This indicates that the cruise line intends to set up the hub ports being close to each other. Roseau is also an intermediary port and has high reachability.

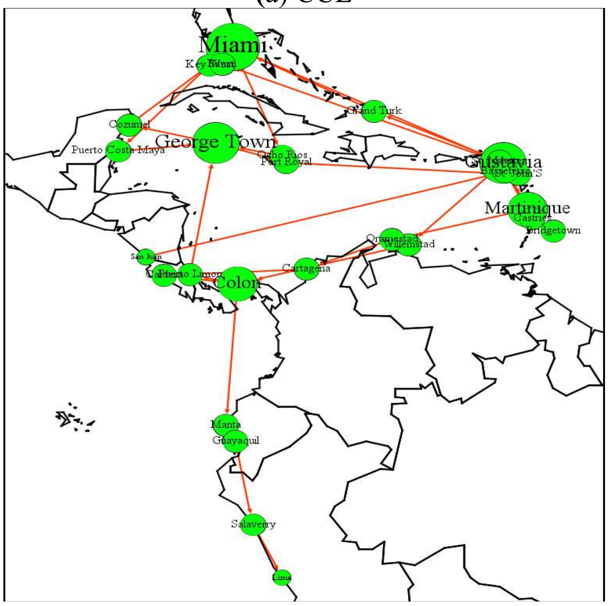
In conclusion, three ports in ECAs play key important roles in the networks of some cruise lines, including Miami (Florida), Fort Lauderdale (Florida), and Martinique (France). In contrast, some ports outside ECAs play key roles in some service networks. This result indicates that some ports play key roles in the service network of a cruise line but do not play essential roles in the overall cruise network. The result also reveals that key ports are mostly outside ECAs. Different centrality measures suggest different roles of ports can play in their service network. These require different conditions and strategies to promote themselves. Other ports in ECAs also may try to promote themselves to have more connections to other ports in the network. However, this would be difficult because they are subject to ECAs regulations that are barriers for cruise ships to visit.



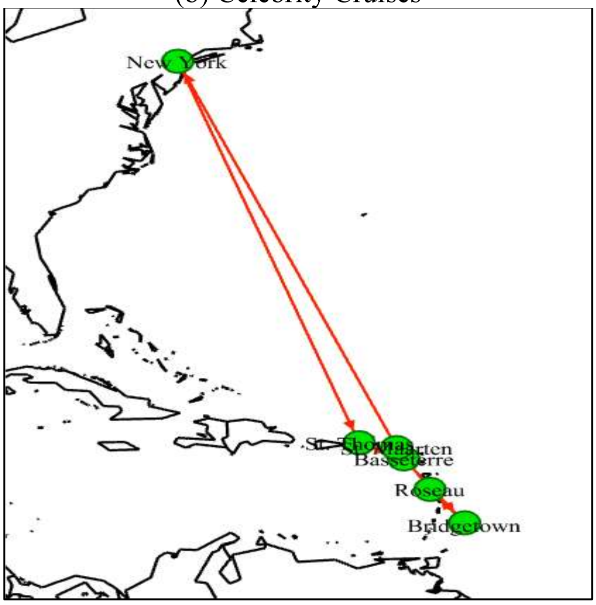
(a) CCL



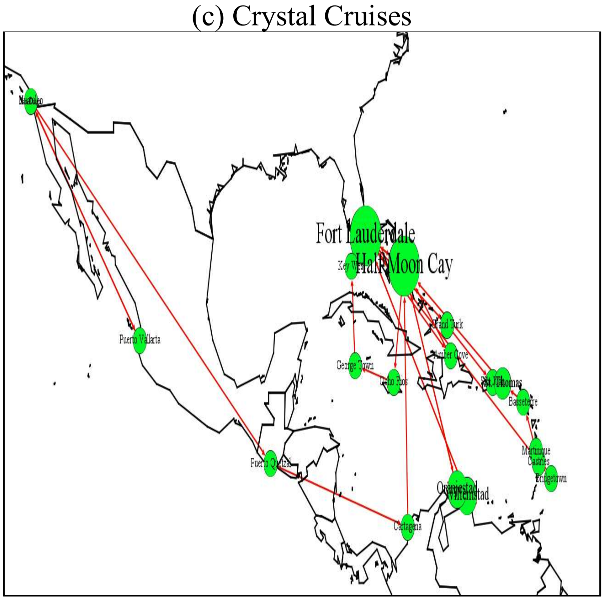
(b) Celebrity Cruises



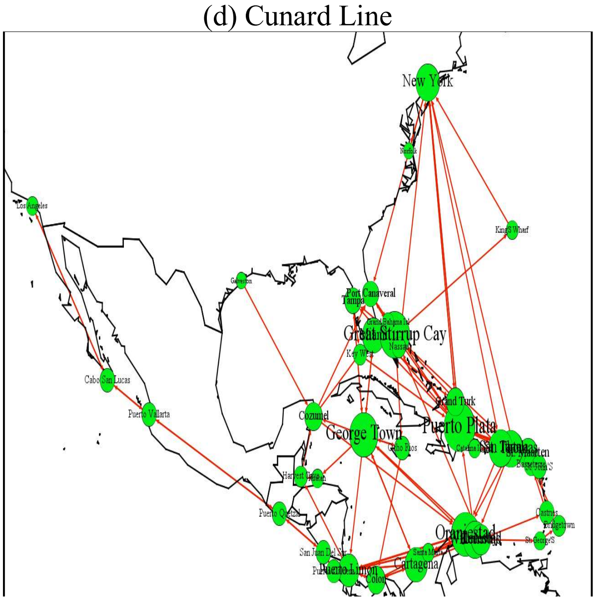
(c) Crystal Cruises



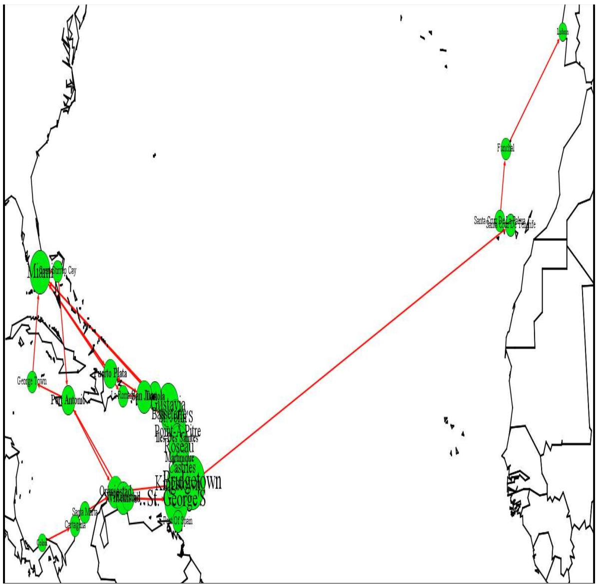
(d) Cunard Line



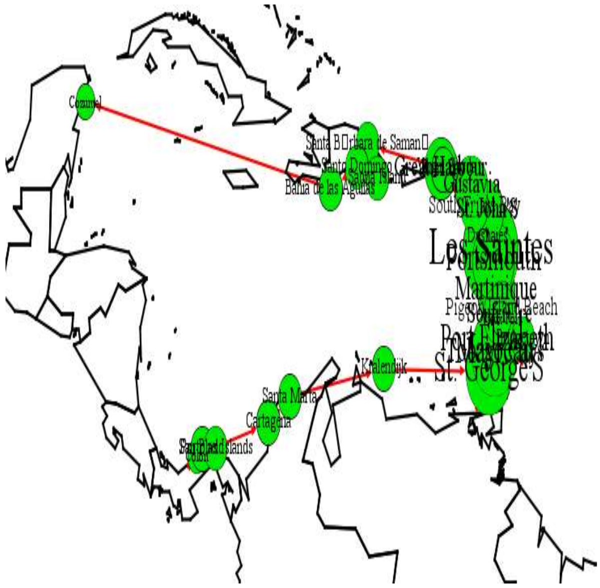
(e) HAL



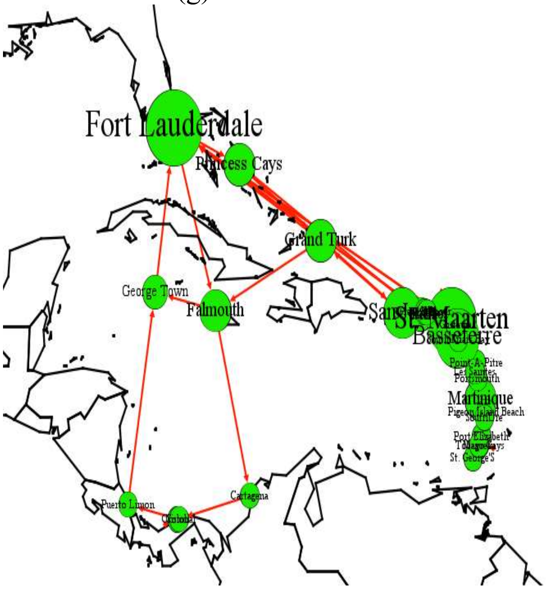
(f) NCL



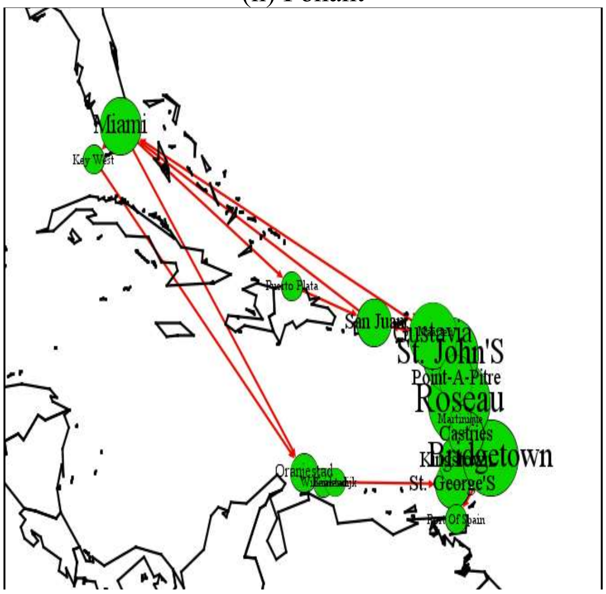
(g) Oceania Cruises



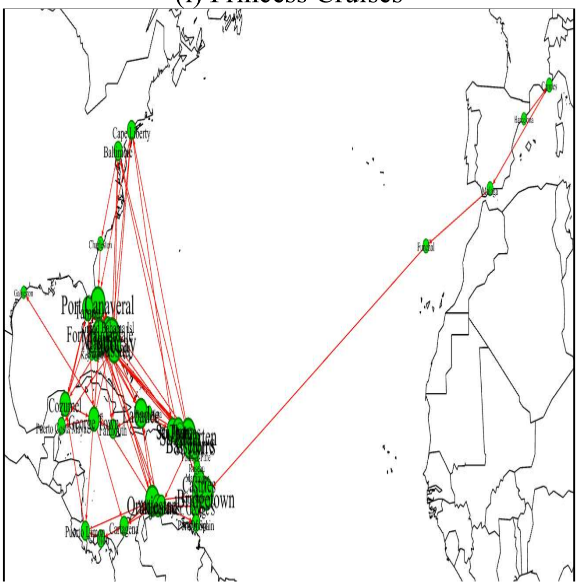
(h) Ponant



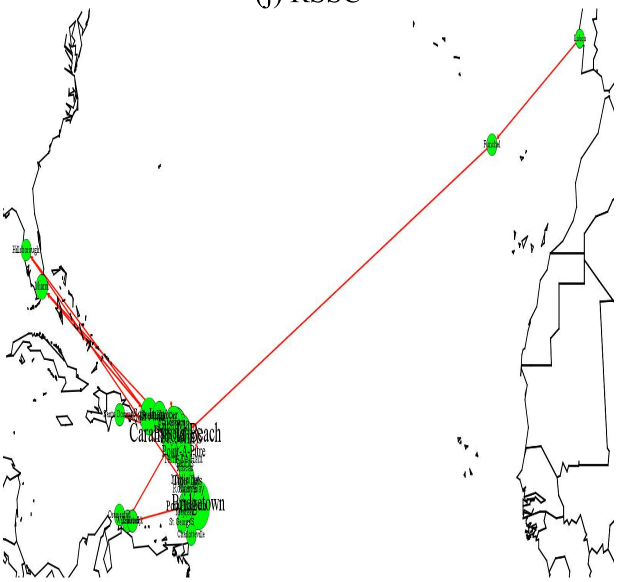
(i) Princess Cruises



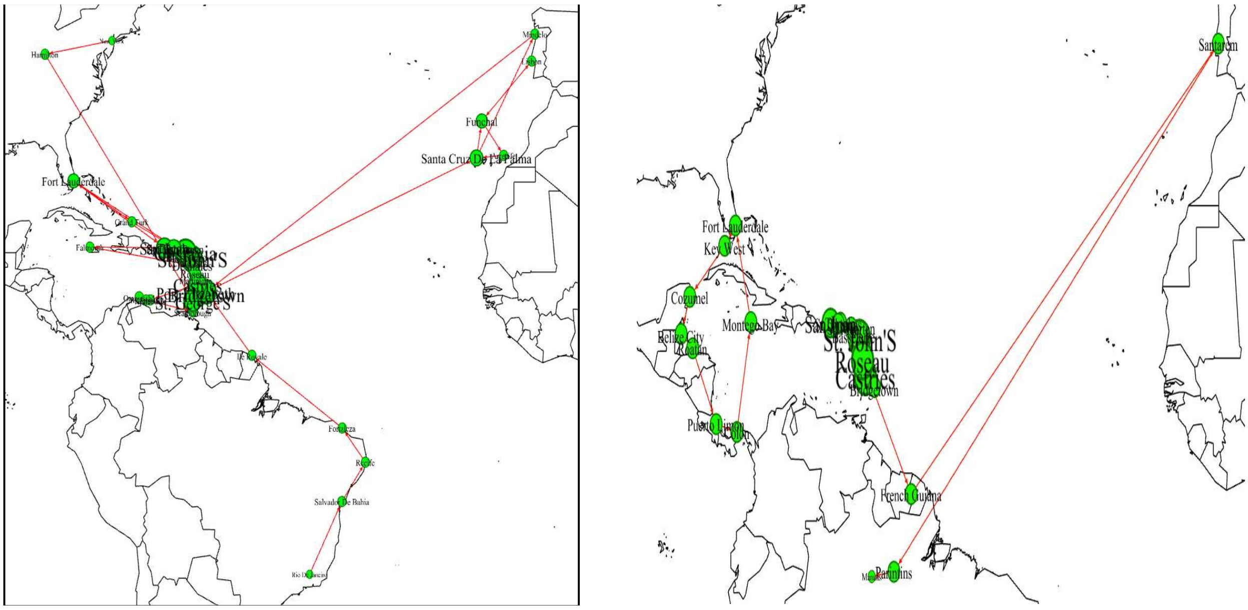
(j) RSSC



(k) RCC



(l) SCL



(m) Silversea Cruises (n) Viking Cruises

Figure 7: Service networks by cruise lines

Source: Authors' elaboration

Table 3: Topological properties of the service network of each cruise line

Cruise line	**Ports**	**Links**	**Network density**	**Average path length**	**Clustering coefficient**	**Assortativity**
CCL	33	93	0.088	3.601	0.261	0.158
Celebrity Cruises	27	76	0.108	**2.957**	0.282	-0.011
Crystal Cruises	27	33	0.047	5.199	0.05	-0.239
Cunard Line	6	6	**0.200**	3.000	0	-
HAL	20	28	0.074	4.047	0.061	-0.005
NCL	41	117	0.071	3.963	0.271	0.044
Oceania Cruises	30	68	0.078	3.528	0.289	0.150
Ponant	29	48	0.059	5.156	0.311	0.322
Princess Cruises	28	42	0.056	7.747	0.236	**0.518**
RSSC	18	35	0.114	3.899	**0.379**	0.306
RCC	**45**	**143**	0.072	3.417	0.277	0.184
SCL	29	63	0.078	3.365	0.254	-0.270
Silversea Cruises	34	67	0.060	4.237	0.284	0.106
Viking Cruises	21	24	0.057	3.771	0.162	0.408

Note: Highlighted numbers are the most efficient value of each measure that the cruise line has.

Table 3 shows the topological properties of each cruise service network. As mentioned above, RCC has the biggest network with the largest number of ports and links. This implies that the cruise line focuses on the Caribbean cruise market more than other areas. The cruise line is also the biggest cruise company in the Caribbean and has been servicing cruise shipping in this area for a long time compared to other companies. Therefore, RCC might be more familiar with ECA regulations in the Caribbean, allowing them more ease for operating services in line with the regulations.

Cunard Line has the highest network density since the cruise line has the smallest number of ports and links. Thus, all ports in this network have high potential connectivity. The smallest number of ports leads to the network having the highest efficiency as its ports can connect easily to each other with a low shortest path, reflected by its lowest average path length.

Regent Seven Seas Cruises has the highest clustering coefficient. A port in its network has the highest chance of being connected by neighbours around a port, reflecting a high intra-connecting among ports within the network. A high clustering coefficient also reflects that those ports rely on hubs to connect to others.

Nine cruise lines have an assortative mixing with positive assortativity coefficients, indicating that high degree ports in their networks connect to each other. This reflects that the service networks of these cruise lines show a rich-club phenomenon. Princess Cruises has the highest assortativity coefficient of 0.518, followed by Viking Cruises, Ponant and Regent Seven Seas Cruises. The highest assortativity of Princess Cruises indicates that the ports with a high degree have the highest chance of being connected by other high degree ports. Celebrity Cruises, Crystal Cruises, HAL and SCL have negative assortativity coefficients, meaning that high degree ports are connected to ports with low degrees. Interestingly, the network of Cunard Line does not show the assortativity coefficient since all ports have the same degree.

To sum up, RCC holds the biggest share of the cruise shipping network in the Caribbean Sea by benefiting from being a pioneer for cruising in this area. Therefore, the cruise line is familiar with cruising policies and ECA regulations in this area. Likewise, other cruise lines with large networks like NCL, Oceania Cruises and Silversea Cruises have no ports in ECAs play any important roles in their networks. In contrast, smaller networks such as those of Celebrity Cruises, Crystal Cruises, HAL, and Princess Cruises have ports in ECAs play as important key ports. This is because voyages of these networks depart from ports that are not in the Caribbean.

4. Implications

Cruise lines bear operating inside ECAs entail a heavier financial burden in terms of wastewater management, emissions, and energy. This can lead to unwillingness in operating their services inside ECAs as it lowers operating margins and higher unit costs. In the competitive global business environment, it can be challenging to a certain extent for cruise lines to keep pace with new environmental regulations whilst maintaining profitability. Local governments and IMO can provide technical support and a financial incentive in supporting the transition of cruise lines to greener shipping with the latest abatement technologies. The use of LNG can be further promoted to minimise greenhouse gas emissions and comply with strict ECA regulations. However, LNG is not yet ready for cruise ship propulsion. The rationale behind this is due to safety concerns regarding the storage of LNG onboard as well as the logistical challenges of LNG supply. Most cruise ports lack LNG facilities, and existing cruise ships have to be retrofitted to store LNG safely. Ports need to provide LNG facilities, which can be part of a government initiative to promote more sustainable tourism.

Cruise itinerary design is determined by market situation and conditions such as seasonal demand, tourist satisfaction, a balance between onshore and onboard time, ‘must see’ destinations, and trip duration. Operational factors must also be considered, such as nautical accessibility, berthing capacity of ports in the itinerary, and perhaps more complex, intermodal transport, which requires the synchronisation between ports of calls and air transfers in longer itineraries spanning different countries (Rodrigue and Notteboom, 2013). These affect the structure of the cruise network. Cruise passengers are the leading stakeholders of cruise tourism, which is pivotal that cruise lines design and implements itineraries and products based on passengers' behavioural intentions and preferences. Port authorities should collaborate with destination managers to provide unique experiences inside

ECAs to attract cruise lines to call at ports inside ECAs, which lead to ports inside ECAs having a tighter relationship.

The COVID-19 pandemic has put passengers on high alert, whereby tourists more than ever are concerned about wellness tourism. Responsible cruise tourism mainly focuses on minimising negative social, environmental, and economic impacts. ECA regulations align very closely with this increasing trend of responsible cruise tourism. That is, most tourists and cruise lines still overlook the notion of responsible cruise tourism. Thus, the promotion and enlargement of the cruise tourism market in ECAs should be conducted thoroughly and critically. In addition, cruise lines that comply with ECA regulations incur additional operational and administrative costs, which in turn causes an increase in the price of cruise packages in order to offset this additional cost. Travellers being price sensitive, might otherwise choose a different cruise package. Port authorities in ECAs may have to provide lower passenger fees and lower dockage tariffs to attract cruise lines.

Ports with low connectivity outside ECAs should promote themselves as hubs by increasing connections to other ports outside ECAs. This may benefit cruise lines to minimise costs relevant to entering ECAs areas. Port authorities should promote their ports by providing promotions to attract cruise ships to visit their ports, such as reducing port fees, renovating facilities, or even organising attractive activities.

Only a small number of cruise lines design their itineraries visiting ports in ECAs. This is because cruise lines do not want to bear costs for entering ECAs. Policymakers should consider redesigning regulations to attract more ships to visit the areas, and some regulations may need to be more flexible. These may make the network more efficient, and ports have more connections.

The cruise shipping network analysis generates a new idea of evolution and exhibits a new spatial organisation pattern, which addresses the cooperation and specialisation of each connected cruise port. It is required to coordinate their related interests to intensify their coherent connectivity and collaboration. The cruise port network contains regions and countries with various interests, encountering complicated governance matters and regional cooperation. The network is scattered with different functions of the primary hub and secondary hub ports. It also maintains spatial contact by the network, giving equal development chances to individual centres. Authorities and governments can use these to generate the co-competition to strengthen the close coordination and minimise management costs (Wang et al., 2018).

5. Conclusion and future research

This study analysed the effect of ECA regulations on the cruise shipping network in the Caribbean using the data of 127 cruise ports connected by 596 cruise links. The analysis results show that the network is a sparse network in which ports have a relatively low likelihood to connect to each other. In addition, the network is a small-world network with a short average path length and a high clustering coefficient. The network also has the rich-club phenomenon, reflecting ports with a high degree connect to other high degree ports. Ports outside ECAs play more important roles than ports inside ECAs. Miami, Fort Lauderdale, and St. John'S are hubs of the network with high connections. Intermediary ports are Bridgetown, Fort Lauderdale, and St. John'S, while ports with high reachability to others are Rio De Janeiro, Salvador De Bahia and St. George'S.

In terms of comparison between cruise lines, Royal Caribbean Cruises has the biggest service network with the largest number of ports and links. This is because the cruise line benefits from being a pioneer for cruising in the Caribbean. Royal Caribbean Cruise designs voyages consisting of ports outside ECAs. In contrast, smaller cruise lines provide their services covering ports in other areas, and some ports are in ECAs.

The findings from the above analysis are helpful for cruise lines, port authorities and policymakers. Cruise lines can improve their service network and can redesign the network with higher efficiency. Port authorities and policymakers, especially in ECAs, may promote their destinations to have more connections by reducing the barriers preventing cruise ships from entering. They may also provide unique value in terms of historical scenery inside ECAs to attract more travellers.

Although this study provides interesting findings, there are still some limitations. Firstly, the study is only focused on the Caribbean region. To generalise the research study, future research may consider other regions like Asia, North America, and Arctic recognised as remarkable ECAs. Secondly, the current study uses a complex network approach to examine the cruise shipping network only from the network perspective. Future research may adopt the Automatic Identification Systems (AIS) data with the bottom-up pollution emission models to comprehensively analyse cruise activities and examine the environmental impacts of cruise shipping. This study analysed a binary network, which did not consider the weights of links (the frequency of cruise shipping). Future research may analyse the weight of links in the network to reflect more insight into cruise operations and service networks. This study analysed only the current network that has already been implemented ECA regulations. Future research may consider comparing the network before and after the ECA implementation.

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Controlling Shipping Greenhouse Gas Emissions in Hong Kong: Policy Considerations

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Abstract

The development of maritime transport contributes to the exacerbated global warming. Global warming is responsible for severe environmental issues and attracts international attention. Efforts are made to protect the environment by adopting measures to regulate greenhouse gas (GHG) emissions from the shipping sector. Since Hong Kong (HK) owns about three percent of the world's ships and its port is one of the world's busiest ports, it is important to exam the regulatory and policy measures adopted in HK and discuss the necessity of introducing any complementary or supplementary policy measures for controlling GHG emissions from shipping.

By looking into the measures adopted in the International Maritime Organization (IMO) conventions and the corresponding policy and regulatory measures adopted by HK, the paper highlights the main problems associated with the inadequacy of the HK's existing emission mitigation measures and discusses the way forward. It concludes that the current measures in HK in controlling GHG emissions from shipping are not sufficient, and there is a need to strengthen the corresponding measures. The measures for the internal reinforcement and external collaborations are accordingly proposed in this paper.

Keywords: Greenhouse Gas Emissions (GHG), Shipping, International Maritime Organization, Hong Kong (HK), Great Bay Area (GBA)

I. Introduction

Climate change is a global challenge; and the goal of reducing carbon emissions to reach carbon neutrality by 2050 has been brought forward in the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development. Hong Kong (HK) as a Special Administrative Region of China is also bound to the Paris Agreement. HK government has formulated a number of strategies and initiatives for substantial Greenhouse Gas (GHG) emission reductions. Such GHG emission reduction strategies and initiatives are largely focused on the sectors of buildings, public transport, and electricity generation.

Fuels and exhaust gas emissions associated with ships and their operation have recently elicited more and more attention at both international and national levels. The International Maritime Organization (IMO) has amended its convention and adopted targets to reduce GHG emissions from international shipping. Based on the policy "one country, two systems", HK is a contracting party to different IMO conventions including those for regulating air pollution from shipping. However, it is criticised that the seriousness of GHG emissions from shipping is underestimated, while the IMO instruments have not gone far enough. Therefore, it is important to scrutinise the adequacy and effectiveness of the existing policy and regulatory measures in HK and to explore the feasibility of introducing complementary or supplementary domestic policies; this is particularly necessary since HK owns about three percent of the world's ships and its port is one of the world's busiest ports.

Accordingly, this paper aims to investigate the existing measures, and to discuss the challenges to and opportunities for reducing GHG emissions from shipping in HK. After this Introduction, Part II is dedicated to outline the existing regulatory framework on the international level. Part III is focused on examining the measures in HK. Part IV discusses the necessity and capability of internal reinforcement and external cooperation for HK to strengthen its measures for controlling GHG emissions from shipping. The article concludes that, given the importance of controlling GHG emissions from shipping, it is necessary for HK to consider supplementary measures such as the adoption of some market-based measures; in addition, it is perhaps important and possible to strengthen the collaborations with cities in the Great Bay Areas and Mainland China.

II. Controlling GHG Emissions from Shipping and International Measures

The first United Nations (UN) conference on the human environment took place in Stockholm in 1972, and this marked a turning point in the development of international environmental law and policies, although climate change was not on the conference agenda at that time. Nevertheless, the United Nations Environment Programme (UNEP) was formed as a result. In 1988, the World Meteorological Organization (WMO) and the UNEP established the International Panel on Climate Change (IPCC) to collate and assess evidence on climate change. The IPCC has so far produced five comprehensive Assessment Reports (AR) detailing our knowledge on climate change, its causes, potential impacts and response options. In its latest one, the IPCC emphasises that humans have been the "dominant cause" of global warming since the 1950s (The fifth Assessment Reports, 2014).

The United Nations Framework Convention on Climate Change (UNFCCC) is the main multilateral forum focused on addressing climate change. It mainly aims at stabilizing GHG concentrations in the atmosphere at a level that would "prevent dangerous anthropogenic interference with the climate system". The UNFCCC was negotiated from February 1991 to May 1992 and was opened for signature at the June 1992 UN Conference on Environment and Development – also known as the Rio Earth Summit. It entered into force in 1994, ninety days after the 50th country's ratification was received. As a matter of fact, the UNFCCC does not contain any specific national or international targets for reducing GHG emissions, but it does contain a number of points that have become foundational principles in international climate change debates. These include "taking account of countries' different responsibilities and capacities" and "the importance of precautionary measures".

Parties to the UNFCCC continued to meet regularly to consider further actions to address the climate change threat. As a result, the Kyoto Protocol was agreed in 1997. The Kyoto Protocol provides for an operational framework for the UNFCCC "by committing industrialized countries to limit and reduce GHG emissions in accordance with agreed individual targets". It was the first document with legally binding obligations for limits and reductions, and there are currently 192 parties to the Kyoto Protocol. The period of applicability was set for the years 2008 to 2012 as its first obligation period, and for 2013 to 2020 being its second obligation period. In order to continue the international climate protection process after 2020, a new milestone convention was adopted in 2015, this being the Paris Agreement. The Paris Agreement entered into force in November 2016 and it, for the first time, included a specific target for limiting global warming to well below 2°C above the pre-industrial levels of 1750. It was believed that 2°C of warming is a critical limit, which, if surpassed, will lead to an increasing risk of more heat stress, storms, inland flooding, air pollution, the rise of global sea levels, and other serious consequences (The Intergovernmental Panel on Climate Change (IPCC), 2014). In the Resolution adopted by the UN General Assembly in the same year, "take urgent action to combat climate change and its impacts" is listed as Goal 13 of the 2030 Agenda for Sustainable Development. Furthermore, a special report released by the IPCC in October 2018 stated that "rapid and far-reaching" changes would be needed to keep the global temperature rise to below 1.5°C above pre-industrial times. The report also said that measures would have to include reducing human-caused carbon dioxide (CO_2) emissions by 45 per cent by 2030 from 2010 levels and reaching "net-zero" emissions by 2050. This means that any remaining emissions would need to be balanced by removing CO_2 from the air (IPCC, 2018). Very recently, after 13 days' intense negotiation, the COP26 was concluded on 13th November 2021 with parties representing almost 200 countries agreeing the Glasgow Climate Pact.

When the UNFCCC agreed the Kyoto Protocol, shipping was not included within the emission reduction requirements, and this position is also maintained in the Paris Agreement. However, GHG emissions from international shipping cannot be allowed to grow uncontrolled. It is recognized in the UNFCCC that international shipping is a significant emitter of GHG, because according to the statistics it contributes about 3% of global carbon emissions (United Nations Conference on Trade and Development (UNCTD), 2019). The

UNFCCC assigned the International Maritime Organisation (IMO), a specialised UN organisation, to be responsible for setting rules for regulating GHG emissions from international shipping.

The IMO considers different technical and operational measures for controlling GHG emissions from shipping, but the progress has often been criticised. In 2011, the IMO adopted, *et alia*, the Energy Efficiency Design Index (EEDI) applicable to new ships and the Ship Energy Efficiency Plan (SEEMP) covering all ships. The SEEMP is an important tool in practice to reduce fuel oil consumption and CO_2 emissions, respectively, in ship operation. These regulations are added as Chapter 4 entitled "Regulations on Energy Efficiency of Ships" of Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL73/78). They entered into force in 2013 and apply to all ships of 400 gross tonnage and above, irrespective of flag and ownership. In 2017, the IMO Assembly adopted a strategic direction entitled "Respond to Climate Change". In 2018, the Marine Environmental Protection Committee (MEPC) of the IMO adopted the resolution and initial IMO Strategy on reduction of GHG emissions from ships, which sets out a vision to reduce GHG emissions from international shipping. Achieving the goals of the initial IMO GHG strategy will require a mix of technical, operational and innovative solutions applicable to ships. From 1 January 2019, ships of 5,000 gross tonnage and above shall submit fuel oil consumption data to their flag State and the IMO. Meanwhile, IMO has published the fourth GHG study in 2020(IMO,2020). Recently, in the 76th session of MEPC, which was held remotely with a limited agenda from 10 to 17 June 2021, members agreed to put two new measures into effect at the start of 2023 – the Energy Efficiency Index for Existing Ships (EEXI) and the Carbon Intensity Indicator (CII) (IMO, 2021).

III. Controlling GHG Emissions and HK's Measures

Hong Kong (HK), as a Special Administrative Region of China, is bound to the Paris Agreement. HK government has formulated different strategies and institutional initiatives for substantial GHG emission reductions. In compliance with HK's responsibilities under the Paris Agreement and the carbon emission goals, the "Hong Kong's Climate Action Plan 2030+" was proposed in 2017. In 2020, HK Government furthermore announced HK's Climate Action Plan 2050. In both plans, green transport is deemed as one of the major decarbonisation strategies, since the transport sector (shipping included) is listed as the second largest GHG emitter in HK.[1]

The measures related to carbon emissions are currently mainly focused on three aspects. The first aspect is to use cleaner fuel and renewable energy (RE); the HK government has been developing and encouraging RE in both public and private sectors. The second aspect is to promote energy efficiency and carbon audits in buildings. For example, the Buildings Energy Efficiency Ordinance (Cap. 610) requires four major building service installations in new buildings, as well as in existing buildings undergoing major retrofitting (i.e., air-conditioning, electrical, lift and escalator, and lighting installations) to comply with the energy efficiency standards and requirements specified in the Building Energy Code. The third aspect is to use energy-efficient transport and cleaner vehicles. One typical example is that the Government promotes the use of electric commercial vehicles. A $300 million Pilot Green Transport Fund was set up in March 2011 to encourage the public transport sectors and goods vehicle operators and charitable/non-profit-making organizations to test out green innovative transport technologies.

Accordingly, there have been a considerable number of GHG emission reduction strategies and initiatives in place in HK, most of which, however, are focused on the sectors of buildings, public transport, and electricity generation. Meanwhile, decarbonisation in shipping is not explicitly addressed in the "Hong Kong's Climate Action Plan 2030+", neither in the "Hong Kong's Climate Action Plan 2050".

As far as shipping is concerned, 2,603 vessels, boasting a total of 130 million gross tonnage, were registered in HK as of December 2020 (Marine Department, 2021). With constant arrivals and departures of the ships, HK

[1] It accounted for about 18% in 2019. See "Greenhouse Gas Emissions in Hong Kong by Sector". In 2019, electricity generation was the largest source of carbon emissions, accounting for about 60% of the total emissions in HK, followed by transport (about 18%), waste (about 70%, mainly from landfills), other end use of fuel (about 5%) and industrial processes and product use (about 4%).

remains one of the busiest ports globally. It is recorded that a total of 88,000 sea-going vessels and river-trade vessels arrived HK in 2020 (Marine Department, 2021). In addition, being situated in the Pearl River Delta (PRD) region, maritime activities in the whole region further affect HK's air quality. Although the policies that deliver major transitions in the domestic energy system may have important implications in the shipping sector's CO_2 mitigation, regulatory measures that specifically address the issues involved in reducing GHG emissions from the operations of both local ferries and ocean-going vessels should necessarily be in place. The urgent need to fight against climate change, together with the complexities existing in the shipping sector, suggest a need to review the current regulatory framework for reducing GHG emissions from shipping.

As far as the specific regulatory measures in HK are concerned, on the one hand, HK, based on the "one country, two systems" policy, is a contracting party to IMO conventions. Annex VI of the MARPOL is accordingly implemented in HK through the Merchant Shipping (Prevention of Air Pollution) Regulation (Cap.413 sub. leg. P). On the other hand, efforts have been made to collaborate with the cities in the Greater Bay Areas (GBA) and the Mainland China to protect the surrounding marine environment.

According to the Marine Department of HK, HK requires the ships registered in HK to maintain the quality standard that are consistent with the international conventions. In addition, the "Flag State Quality Control System" (developed in 1999) and "Pre-Registration Quality Control System" (introduced in 2003) are in place to monitor and maintain the quality of HK ships. HK also actively exercise port state control in accordance with the provisions in the IMO Resolution and the "Tokyo Memorandum Of Understanding Port State Control Manual" (Marine Department, 2021). Accordingly, the Marine Department shall ensure that non-HK registered ships visiting HK comply with the requirements of various international maritime conventions (Marine Department, 2021).

In general, HK is greatly concerned about air quality control, as shown, for example, in its "5-yearly Mandatory Air Quality Objective Review", where it is recorded that the HK government is in regular dialogue with different stakeholders, including those from the marine transport sectors. Nevertheless, despite all efforts made, the issues relating to CO_2 emissions from shipping in HK waters is merely passively following the measures from the IMO. There lacks a strong support from the top-design work plan, and the control and target system for the carbon emissions from shipping does not seem to be clear and complete. Although shipping is the most carbon-efficient mode of transport, it is already predicated that, given the continuous expansion and growth of international shipping and trade, maritime CO_2 emissions are projected to increase significantly in the coming decades. HK will suffer the same. Therefore, to maintain shipping's sustainable development, some more proactive actions are needed in HK.

IV. Discussions

4.1 Are the Existing Measures Adequate?

As discussed above, the regulation for reducing GHG emissions from international shipping in HK is the Merchant Shipping (Prevention of Air Pollution) Regulation (Cap.413 sub. leg. P). The reduction measures including the EEDI and SEEMP provided in the Chapter IV- "Ship Energy Efficiency Measures" of the amendment to MARPOL73/78 are accordingly implemented in Divisions 8 and 9 of Part 2 of said regulation in HK. However, these two measures have their own defects, which will be discussed immediately below. In addition, the Shipping and Port Control Ordinance (Cap.313) provides for "the regulation and control of ports and of vessels in HK or in the waters of HK, the regulation and control of repairs and breaking up of vessels, cargo handling on vessels and pollution caused by vessels in the waters of Hong Kong, the regulation for and control of construction or reclamation works in which vessels are used and for other matters affecting vessels, navigation and the safety of vessels at sea (whether within or beyond the waters of HK)" (the Preamble, the Shipping and Port Control Ordinance); apparently, this ordinance does not regulate GHG emissions from shipping. Meanwhile, the Merchant Shipping (Local Vessels) Ordinance (Cap.548) only regulate issues relating to local vessels; and no specific provisions touch upon the reduction of GHG emissions.

EEDI provides a technological threshold for ships to meet the energy efficiency goals (Shi, 2016), which aims to reduce CO_2 emissions and environmental pollution (TOKUŞLU, 2020). They apply to all new ships with 400 gross tons or above;[1] that also means that EEDI only applies to newly constructed ships, and the existing ships are thus not covered (Tanaka, 2016). Meanwhile, due to the limited experience and research data available, the EEDI standards at first only apply to bulk carrier, gas carrier, tanker, container ships, general cargo ships, refrigerated cargo ships and combination carriers with traditional propulsion mode.[2] In 2014, the MEPC adopted resolution MEPC.251(66) to further revise the ship energy efficiency rules, so that the EEDI standard was extended to Liquefied Natural Gas (LNG) carriers, roll-on roll-off(ro-ro) cargo ships(vehicle carriers), ro-ro cargo ships, ro-ro passenger ships and cruise passenger ships having non-conventional propulsion.[3] By applying EEDI, the new ships will be more energy efficient with its hull optimization, engines, propellers, etc.(TOKUŞLU, 2020). Recent studies have also shown that ships energy efficient measures are applicable and beneficial for reducing GHG emissions (TOKUŞLU, 2020). However, the above-described restricted range of application may arguably undermine the effectiveness of the EEDI (Shi, 2016).

The SEEMP is an operational measure that builds a system to improve the energy efficiency of a ship in a cost-effective way (IMO, 2011). It objects to reduce the GHG emissions through energy-efficient operation of vessels (IM, Choe and Park, 2019). Since 2013, all existing and new ships over 400 tonnes shall comply with the guidelines set out in the SEEMP.[4] It seeks to improve a ship's energy efficiency through steps including planning, implementation, monitoring and self-evaluation and improvement.[5] However, IMO's guidelines are not legally binding and can only provide support and guidance to implement the provisions of amendment of Annex VI of MARPOL73/78(Li,2012). Therefore, the normative effect of SEEMP is very limited (Tanaka, 2016); and the lack of a reduction target may also reduce the effectiveness of the SEEMP. Meanwhile, it is argued that some operational measures have negative impacts on international seaborne trade (Shi, 2016).

Since the above-described technical and operational measures have different limitations or drawbacks in reducing GHG emissions, debating about the adoption of the market-based measures (MBMs) is an ongoing hot topic on both domestic and international levels. MBMs have been widely discussed within MEPC since 2000 when the IMO proposed them in its first GHG study (Shi, 2016). Nevertheless, adoption of MBMs and the specific implementation measures are still very controversial. Although the amendment to Annex VI of MARPOL73/78 does not explicitly mention shipping emission reduction through MBMs, from the perspective of the role that may be played by the MBMs, and the attitude of MEPC shown in the previous meetings, formulating emission reduction measures based on MBMs seems to be the next development direction of reducing GHG emissions from shipping in the international arena.

MBMs may be understood as a means that encourages a desired behavior through financial incentives (Jorgensen, 2021). By applying MBMs, it is arguable that the external charges of the emissions can be internalized (Psaraftis, 2012). The following table (see Table 1) shows ten MBM proposals that have been submitted to the IMO so far.

Table 1: MBMs proposed by governments and observer organizations at the IMO

Proposal	**Proposer**	**Reference**	**Main Contents**
International Fund for GHG Emissions from Ships (GHG Fund)	Cyprus, Denmark, the Marshall Islands, Nigeria and International Parcel Tanker Association	MEPC 60/4/8	Building an international reduction goal for shipping sector; emissions above the target line would be offset mainly by purchasing approved emission reduction credits.
Leveraged Incentive Scheme (LIS)	Japan	MEPC 60/4/37	GHG Fund contributions are collected on marine bunker. Part of above fund is refunded to vessels which meet or exceed agreed efficiency benchmarks; and they

[1] See Division 8 of Part 2 of Merchant Shipping (Prevention of Air Pollution) Regulation (Cap. 413 sub. leg. P)
[2] See Regulation 21 of MEPC.203(62).
[3] See regulation 21.1 of MEPC.251 (66).
[4] See Division 9 of Part 2 of Merchant Shipping (Prevention of Air Pollution) Regulation (Cap. 413 sub. leg. P)
[5] See "2012 Guidelines for the Development of a Ship Energy Efficiency Management Plan", MEPC 63/23 Annex 9.

			would be regarded as " good performance ships" .
Port State Levy	Jamaica	MEPC 60/4/40	Charging a uniform emissions fee on all ships calling at their respective ports based on the amount of fuel consumed by the respective ship on its voyage to that port.
Ship Efficiency and Credit Trading (SECT)	The United Sates	MEPC 60/4/12	All ships need to comply with the mandatory energy efficiency standards; and an efficiency-credit trading programme would be thus established.
Vessel Efficiency System (VES)	World Shipping Council	MEPC 60/4/39	Establishing mandatory efficiency standards for new and existing vessels; and if vessels fail to meet the mandatory standard through technical modifications would be subject to a fee applied to each tonne of fuel consumed.
Global Emission Trading System (ETS)	Norway	MEPC 61/4/22	To set a sector-wide cap on net emissions from international shipping. A number of allowances (Ship Emission Units) corresponding to the cap would be released into the market each year via an international auctioning process; and the units could then be traded
Global Emissions Trading System (ETS)	The United Kingdom	MEPC 60/4/26	This ETS proposed is different from the Norwegian's ETS proposal because of the method of allocating emissions allowances (via the national auctioning) and the approach for setting the emissions cap(set with a long-term declining trajectory)
Emissions Trading System (ETS)	France	MEPC 60/4/41	To set out other details on auction process design; but in all other aspects this proposal is very similar to the Norwegian ETS proposal
Market-Based Instruments: a penalty on trade and development	Bahamas	MEPC 60/4/10	The imposition of any fees should be proportionate to the contribution by international shipping to international CO_2 emissions
Rebate Mechanism (RM)	International Union for Conservation of Nature	MEPC 60/4/55	This suggests compensating developing countries for the financial influence of an MBM.

(Sources: https://www.imo.org/en/OurWork/Environment/Pages/Market-Based-Measures.aspx; visited 19 February 2022)

Apparently, the MBMs proposed in these proposals include such different types as the ETS, GHG tax mechanism, and others. ETS is mostly based on fuel or energy efficiency, setting a ship emission limit. Ships can obtain emission rights by auction or free distribution, and the excess emission rights can be traded. ETS is different from the GHG tax mechanism because, under the ETS, the price of emission rights is often determined by the relationship between supply and demand in the market. This drives the emission parties to pursue higher emission reduction technologies through the market. ETS can then achieve the goal of optimal allocation of resources and development of emission reduction technology at a lower cost through market regulation. GHG tax mechanism, on the other hand, is to collect tax from ships based on GHG emissions and to establish a fund for promoting the development of shipping emission reduction technology or capacity-building of the developing countries. This kind of tax mechanism is derived from the theory of the environmental tax. It has the effect of double dividend, stably and continuously exerting the pressure of emission reduction on the responsible party and promoting it to choose a more favorable way of emission reduction under the pressure, which is conducive to the optimal allocation of resources.

MBMs have gained regulatory supports in certain regions; and some domestic carbon trading markets are established: for instance, ETS becomes one important legislative mean for European Union (EU) to control carbon emissions from shipping industry (Parker, 2006.) The EU member States participate in the ETS (Psaraftis, 2012). Ellerman and others (Ellerman and et al., 2010) think that "…although some "glitches" need to be fixed, the EU-ETS is basically sound and can become a prototype for a global climate policy regime.' Besides, ETS have also been introduced to several cities and provinces of the People's Republic of China (PRC) (Lo and Francesch-Huidobro, 2017). However, the shipping sector is not included in those practice. ETS would perhaps provide participants from shipping sector with flexibility to choose between the implementation of emission reduction measures within its own sector or offsetting those CO_2 emissions with other sectors; and this flexibility could benefit the shipping industry, since in-sector emissions reductions may be expensive and have inherent limitations. However, the establishment of ETS is quite complex. For tax mechanism, particularly if the internationally unified tax mechanism is to be adopted for shipping emission reduction, the determination of tax rate would be a primary and complex work; furthermore, collection of taxes would have an impact on the cost of international shipping, increase the burden and consequently lead to a series of economic impacts.

The adoption of MBMs will bring opportunities and challenges to HK at the same time. MBMs, by promoting GHG emission reduction by means of market regulation, is considered as a necessary supplement to technical and operational measures (Shi, 2014). However, the uncertainty of a tax or ETS mechanism, as discussed above, is difficult to avoid. Also, HK is to some extent dependent on Mainland China's national policy directions concerning the governance of climate change, as immediately discussed below (Lo and Francesch-Huidobro, 2017). Although several cities and provinces of Mainland China, as pilot districts, have built experimental ETS markets, MBMs have not yet received much attention for developing a country-wide reduction strategy (Lo and Francesch-Huidobro, 2017). Since the indispensable conditions for such MBMs to be efficiently implemented in Mainland China remain immature (Lo and Francesch-Huidobro, 2017), this would also bring questions to HK's adoption of MBMs.

4.2. Strengthening Cooperative Actions with GBA and the Mainland China?

Greater Bay Area (GBA) includes Hong Kong SAR, Macao SAR, and other nine cities in the PRD region. At the end of 2017, it has a total of 56,000 square kilometers and a total population of about 70 million, which is one of the regions with the strongest economic vitality and plays a strategic role in the overall situation of national development (CPC Central Committee, the State Council, 2019). This region also has HK international shipping center, Guangzhou, Shenzhen and other important ports with the highest throughputs of the world (CPC Central Committee, the State Council, 2019). However, on the other hand, GHG emissions from shipping also greatly contribute to poor air quality of the region (Ng, 2017). Therefore, it may be necessary for all cities in the region to consider launching join actions to reduce GHG emissions from shipping.

4.2.1 The Measures Adopted in the Mainland China: Status Quo

For fulfilling its obligations under the international conventions to reduce GHG emissions from shipping and ensuring the sustainable development, Mainland China gradually takes varied measures and carries out its legislative work.

On March 12, 2012, China's Ministry of Industry and Information Technology issued the "*12th Five-Year Plan for the Development of the Shipbuilding Industry*", which was mainly aimed at expanding the influence of China's shipping industry in the world. In order to achieve this aim, it was necessary, among other things, to strengthen the energy efficiency requirements for ship design and construction (Ministry of Industry and Information Technology, 2012). In order to implement this plan, the Ministry of Transport allocated industry emission reduction targets to the shipping industry; and this emission reduction target required shipping companies to reduce their energy consumption and CO_2 emissions per unit of trading volume by 15% and 16% respectively from the 2005 level by the end of 2015 (Ministry of Industry and Information Technology, 2012). China's shipping industry is very concerned about IMO's work on GHG emissions, since only if it complies with IMO regulations, the shipbuilding industry, as a major part of China's shipping industry, can meet the requirements of existing and future potential customers, which also explains why China supports the application of MARPOL 73/78 Annex VI and its amendments. In addition, compliance with international rules is not only related to the responsibility of performance, but the shipping industry can also achieve domestic emission reduction targets, as indicated above (Zhang, 2014).

China has not enacted specific national legislation regulating GHG emissions from ships. Nevertheless, some policy documents and technical specifications of the Ministry of Transport and other departments in China have stipulated the GHG emission intensity index of ships. The "*12th Five-Year Plan for Energy Conservation and Emission Reduction in Highway and Waterway Transportation*" released in 2011 stipulated CO_2 emission intensity index in the section of its "Main Indicators". [1] In the same year, *the* "*Overall Implementation Plan for Promoting Energy Conservation and Emission Reduction in Water Transportation*" was issued, and the provisions were made from four key aspects: policies and regulations, standards and specifications, demonstration and promotion, and key technical research.[2] As for the controlling air pollution, China's Ministry of Transport issued the "*Pearl River Delta, Yangtze River Delta, Bohai Sea (Beijing-Tianjin-Hebei) Waters Ship Emissions Control Zone Implementation Plan*" in 2015, which stipulated that from January 1, 2016, the sulfur content of ship fuel used by ships during berthing in the waters of the Pearl River Delta, Yangtze River Delta and the Bohai sea shall not exceed 0.5%. From 2019, all ships entering and leaving the above waters will be subject to this emission reduction regulations. [3]

With the amendments to Annex VI of MARPOL 73/78 taking into effect, in the "*Technical Rules for Statutory Inspection of International Seagoing Ships*", the Maritime Bureau of PRC incorporated the provisions of the "ship energy efficiency rules" through an amendment.[4] China Classification Society has also updated the relevant inspection rules and guidelines in time, including the "*Guidelines on Survey and Verification of the Energy Efficiency Design Index (EEDI) of Ships*" (took into effect in 2016), the "*Guidelines to the Preparation of Energy Efficiency Management Plan (SEEMP) for Ships*" (took into effect in 2013), the "*Rules for the Certification of Energy Efficiency Management for Ships*" (took into effect in 2012) and a series of guidelines and specifications to assist in the practical operation of energy efficiency rules for ships. Besides, in order to implement IMO's measures to improve the design level of ship energy conservation and emission reduction through the EEDI, China issued the "*Fuel Consumption Limit and Verification Method of Operating Ships*" and

[1] Notice on the Issuance of the "12th Five-Year Plan" for Energy Conservation and Emission Reduction in Highway and Waterway Transportation, available at http://www.gov.cn/zwgk/2011-07/08/content_1902139.htm (accessed 8 February 2022)(in Chinese).

[2] The "Twelfth Five-Year" Water Transport Energy Conservation and Emission Reduction General Promotion and Implementation Plan was released, available at http://www.gov.cn/gzdt/2011-09/28/content_1958186.htm (accessed 8 February 2022) (in Chinese).

[3] "China Establishes Emission Control Zones for the First Time," available at http://www.xinhuanet.com/politics/2016-02/04/c_128700341.htm (accessed 8 February 2022) The Ministry of Transport issued the Implementation Plan for Ship Emission Control Zones in the Pearl River Delta, Yangtze River Delta and Bohai Sea Rim (Beijing-Tianjin-Hebei) Waters, available at http://www.gov.cn/xinwen/2015-12/04/content_5019932.htm (accessed 8 February 2022) (both in Chinese).

[4] "Notice of the Maritime Administration of the People's Republic of China on the Correction of the Relevant Provisions of the Technical Rules for the Statutory Inspection of International Vessels", available at: https://www.msa.gov.cn/html/xxgk/cbjsfg/gjcb/20200731/E0CF62D5-6D71-4D90-8D20- 76AE20956F83.html (accessed 8 February 2022)(in Chinese).

the "*CO_2 Emission Limit and Verification Method of Operating Ships*" in 2012.[1] In compliance with the policy of "ship emission control area" (ECA) in MARPOL 73/78, China began to establish ship emission control areas in coastal waters in 2015, as mentioned above. In 2016, China issued the "*Emission Limits and Measurement Methods of Exhaust Pollutants from Ship Engines (China's First and Second Stages)*", which controls the emission of air pollutants from ships with stricter standards and has continuously increased the scope of water areas that limit the sulfur content of fuel oil used by ships since 2017. In 2018, the Maritime Bureau issued the "*Measures for the Collection and Management of Ship Energy Consumption Data*",[2] requiring ships entering and leaving China's ports with a gross tonnage of 400 tons or more or with a main propulsion power unit of 750KW or more to collect data on ship fuel consumption, sailing time, sailing mileage, cargo turnover and other data according to the specified methods and procedures, so as to provide a basis for the construction of ship carbon emission monitoring, reporting and verification (MRV) system.

4.2.2 The Possibility of Collaboration?

There have been beneficial cooperation attempts between HK and GBA as well as the Mainland China. The most distinctive example is the development of the domestic ECA. In 2012, HK industry proposed "Fair Winds Charter"; all shipping companies that signed the Charter agreed to voluntarily change to fuel with at most 0.5 percent sulphur content while at berth in HK waters (LAURSEN, 2015). In October 2014, Shenzhen stated its intention to follow HK's voluntary efforts with an incentive scheme, and to work with HK towards an application to the IMO by 2018 to create an Emission ECA for the Pearl River Delta. As a consequence, China's Ministry of Transport built three ECAs, including PRD, Bohai sea and the Yangtze River Delta.

In 2017, the cooperation agreement that a Shenzhen-Hong Kong office for marine emissions and control should be built within the context of the cooperation agreement on prevention and control air quality from vessels was signed (China Port, 2020). In 2018, relying on the regional characteristics of Dapeng Bay covering the waters of Shenzhen and Hong Kong, Shenzhen Maritime Bureau proposed to establish a "Dapeng Bay ship air pollutant emission control pilot area" jointly initiated by the Maritime Bureau of the Ministry of Transport, Shenzhen Municipal People's Government and the Environment Bureau of the HKSAR, so as to further promote the integration of ship emission control actions in the PRD through tripartite cooperation. In December 2018, after the issuance of the "*Implementation Plan of Ship Air Pollutant Emission Control Area*", Shenzhen Maritime Bureau also actively communicated with HK Maritime Department, and made efforts to build a "green alliance" for ship air pollutant emission control by integrating and coordinating all forces. After the establishment of the "green alliance", Shenzhen Maritime Bureau actively cooperated with the Maritime Department of Hong Kong to explore the establishment of an information notification mechanism for violations of laws and regulations in the ship emission control area, promote the establishment of a joint monitoring system for ships in Shenzhen and HK under the jurisdiction of Shenzhen, coordinate the establishment of unified supervision standards for ship emissions between Shenzhen and HK, and promote the integration of regional ship emission control actions (China Port, 2020).

Accordingly, the above-exemplified cooperation attempts have laid a solid foundation for further collaborations concerning the GHG emission reduction from shipping sector in the region. As discussed, the GBA area plays an important strategic role in the overall national development. Continuously promoting the green and low-carbon development of GBA can play an exemplary role in China's carbon peak and carbon neutralization. According to the "O*utline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area*", multi-

[1] "Announcement on the release of four transportation industry standards such as fuel consumption limits for operating ships and verification methods", available at: https://zjhy.mot.gov.cn/zzhxxgk/jigou/ysfwc/201909/t20190927_3277680.html; and http://std.samr.gov.cn/hb/search/stdHBDetailed?id=8B1827F274DCBB19E05397BE0A0AB44A.(accessed 8 February 2022)(in Chinese).

[2] "Regulation on Data Collection for Energy Consumption of Ships", available at: https://www.dromon.com/wp-content/uploads/2019/01/Data-Collection-for-Energy.pdf (accessed 8 February 2022) (in Chinese).

channel approaches need to be proposed to promote the supervision and assessment of emission targets of carbon peaking and carbon neutralization working bodies in GBA; concrete joint actions are thus called for.

V. Conclusions

Decarbonization in shipping is a long-term work and faces great challenges. It not only needs to invest a lot of money and time, but the involvement of many different stakeholders also increases the difficulty. The challenges in controlling GHG emissions from shipping that HK faces are apparent. These include firstly, in terms of carbon emission control, there is a lack of support of top-level design and upper-level regulation; secondly, the control and target systems of carbon emission are not clear and complete; and thirdly, the institutional means to promote green and low-carbon development in shipping needs to be reinforced.

The current measures in HK mostly follow the IMO's rules and are not sufficient. How to strengthen the measures for controlling GHG emissions from shipping needs to be urgently addressed. This paper identifies two possible means: On the one hand, HK may consider adopting MBMs to supplement the existing technical and operational measures; but uncertainties and complexities are unavoidable. On the other hand, there has already been a good foundation for HK and other GBA cities to control marine emissions, thus it is possible to further strengthen the cooperation; and take effective and collaborative measures to reduce GHG emissions from shipping in the region.

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Assessment of Container Terminals Competitiveness in the Brazilian Market: A Cluster Analysis

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Abstract

Purpose – The purpose of this article is to present an analysis of the competitiveness of Brazilian container port terminals, and discuss the implications for the sustainable development of this sector in Brazil in the context of container ship size maximization.

Design/methodology/approach – A cluster analysis was developed. Thirteen criteria were selected in the analysis taking into consideration both the previous literature and the characteristic of Brazilian ports.

Findings – The classification shows that the third group of terminals (Santos Brasil, BTP and Paranaguá) has the highest average values in eleven out of the thirteen criteria, standing out mainly in annual capacity, number of plugs, GDP hinterland. This is the most competitive group with the highest frequency of ship visits. It is also interesting to find that this group of ports has a limitation regarding the operational draft that limits the port sector when receiving large ships.

Practical implications - Discussions are drawn that, despite the growth in the size of ships, the ports of Brazil receive ships with smaller capacity compared to ships that operate in the main commercial lines. With the expected inclusion of New Panamax-class ships operating in the Brazilian coast, container terminals have restrictions due to limited operational draft. Conclusions are drawn as to the potential for implementing strategies and policy interventions on clusters.

Originality/value – The values of this study rest on the lack of studies on Brazilian container terminals in the literature, and the inclusion of competitiveness criteria considered important in the Brazilian context. Furthermore, the study represents an application inspired by the current debate in the Brazilian port sector, which presents the country's urgent problem of receiving large capacity ships.

Keywords: Brazilian container terminal, Cluster analysis, Port Competitiveness, Port policy

1. Introduction

The competitiveness of seaports is a matter of interest to companies, governments and international organizations. This is due to the role of ports in acting as facilitators of international trade and country development (Panayides, 2003; Kaliszewski *et al*., 2020).

In recent years, container shipping companies have restructured and reformed their alliances (Yang *et al.,* 2011), which significantly improves their bargaining power (Liu *et al*., 2020) with the terminals in the world. *This context not only changed port infrastructure and operations, but also affected many ocean carriers' decisions (Trujillo et al., 2018).* The increase in market power and container logistics, marked by the use of large ships, results in a reduction in the number of hub ports. High investment in larger capacity ships restricts their calls to large ports as they provide greater scale gains. Thus, large volumes of containers are consolidated in hub ports and later sent by smaller ships to regional ports (Haralambides, 2019; *Haezendonck and Langenus, 2019).*

This implementation has an impact on global shipping service through the cascading effect: due to the entry of larger ships into major traffic, ships that were previously used on far-eastern-Europe trade lines are replaced and transferred to low-volume secondary lines. This is the case for the East Coast of South America (Merk, 2018). In this constant process of increasing the size of ships, terminals continuously invest in their facilities to receive large ships (Wray, 2017). It should be noted that the relationship between ports and ships is increasingly important to be analyzed as larger ships allow shipping lines to benefit from economies of scale, but terminals and port authorities are driven to make significant investments in equipment and accessibility. The high requirements in terms of adaptive capacity of the terminals triggered a debate about the distribution of costs and benefits between shipping lines and port operators with the operation of larger ships (Notteboom et al., 2017).

Several factors interfere in the competitiveness of ports from the perspective of shipping lines: port location; port berth availability; port costs, port efficiency; port depth (Talley and Ng, 2013). In Brazil, the frequency of ships is a critical issue due to the increase in the size of ships, limited operational draft and the reduction of frequency of ships at the terminals (Souza *et al*., 2021). In 2008, the container ship with the highest capacity in Brazil had 5,905 TEUs. In 2019, the largest ship had 11,923 TEUs (Solve Shipping Intelligence, 2020). Despite the increase, these ship capacity values are below the levels found on the main commercial shipping routes, whose ships have more than 18,000 TEUs. These values show the limitation of the port sector in Brazil in terms of the possibility of receiving large vessels. In parallel, the number of port calls in the country decreased by 25% between 2008 and 2019 (Solve Shipping Intelligence 2020).

Due to the urgent debate on the challenge of port development in Brazil, the main objective of this paper is to analyze the competitiveness of Brazilian container ports and discuss the implications for sustainable development of Brazilian container port terminals in the context of ship size maximization, using a specific database from the port sector in Brazil developed using data collected from the container terminals and with public data.

In order to have a better analysis of the competitiveness pattern of container terminals with different competitive advantages, a cluster analysis is applied with thirteen criteria to group the investigated Brazilian container terminals. The cluster technique helps to identify groups of container terminals in which there are great similarities between terminals within each formed group, but large differences in relation to other groups of terminals. The thirteen criteria were selected based on a qualitative survey with port specialists in Brazil, and on the literature review of national and international studies. It is noteworthy that the database used in this paper comprised information collected directly from the terminals. The availability of data allowed the application of cluster analysis.

The contributions of this article are triple. Firstly, we highlight the scarcity of publications dealing with the analysis and the competitiveness profile of the terminals in countries which have witnessed a fast development of ports recently, such as Brazil. There is a limited number of studies on port competition in Latin America and Africa (Lagoudis *et al*., 2017) and the number of studies on Brazilian ports in the literature is even lower when compared to other areas (Galvão *et al*., 2013; Wanke and Barros, 2016). Studies in the area of cargo transportation in Brazil are more limited due to the difficulty of obtaining data from the sector. This study collected specific data at the container terminal level. Secondly, this paper includes variables not only related to terminals, as adopted by the study developed by Cabral and Ramos (2014), but also variables not yet explored by studies on Ports in Brazil and likely developing countries. The results obtained in this article can be used for other developing countries with similar characteristics to the study area analyzed. Thirdly, the article contribution is an application inspired by the current debate in the Brazilian port sector, which presents the country's urgent problem in receiving large-capacity ships, thus it has important implications to the policymakers.

The remainder of the paper is structured as follows. The second section provides a literature review. Section three describes the method and data used. The fourth section presents the results, discussion and policy implication. The last section draws the conclusions and suggestions are put forward for future studies.

2. Literature review applied to the port sector

According to Lagoudis *et al.,* (2017), the port competition analysis can be classified into four categories: i) Port productivity and efficiency; ii) Port performance; iii) Port selection and 4) Port competitiveness. According to Merk (2013), a competitive port is a port that is chosen by carriers more regularly than other ports. Due to the fact that the emphasis of port competitiveness is on the port choice (Yeo *et al*., 2008), extensive research has been undertaken in different considerations that port customers have. Shipping companies evaluate ports according to their own criteria (Mulder and Dekker, 2017). The literature points out several factors considered important for shipping lines. The main factors found in the literature are: (i) Location (Lirn *et al*., 2003; Tongzon and Sawant, 2007; Guy and Urli, 2006; Da Cruz *et al*., 2013; Tai and Hwang, 2005); (ii) efficiency (Tongzon and Sawant, 2007; Guy and Urli, 2006; Da Cruz *et al*., 2013; Panayides and Song, 2012); (iii) Charges (Tongzon and Sawant, 2007; Guy and Urli, 2006; Da Cruz *et al*., 2013); (iv) Infrastructure (Tongzon and Sawant, 2007; Guy and Urli, 2006; Da Cruz *et al*., 2013); Kavirathna *et al*., 2018); (v) Intermodality (Chou, 2010); (vi) Political issues (Gohomene *et al*., 2016). Souza *et al*. (2021) conducted qualitative interviews with shipping lines operating in Brazil and highlighted the main port choice factors in the perspective of ocean carriers in Brazil. Factors such as GDP Hinterland, port location and characteristics of port infrastructure (e.g., portainers, operational draft, availability of berths) play a major role. It should be emphasized that there is a lack of quantitative studies on port choice in Brazil in the perspective of ocean carriers.

According to Tovar and Rodríguez-Déniz (2015), port efficiency and port clustering are two aspects that have received different attention in the literature. Port efficiency has been extensively studied using DEA and SFA (Cullinane and Wang, 2010; Cullinane *et al*., 2006; Barros, 2006; Odeck and Bråthen, 2012; Rios and Maçada, 2006; Schøyen and Odeck, 2013; Tongzon, 2001). In DEA and SFA, the output produced is usually the result of a combination of inputs such as labor, capital and materials (Paço and Pérez, 2013). This fact limited us to the application of these techniques due to the restrictions of input variables and data availability.

Cluster analysis serves as a set of techniques that constitute an approach to exploratory data analysis that aims at sorting a set of different objects into groups. Cluster analysis is used to discover structures in data (Abonyi and Feil, 2007). In the context of port market, developing clusters of ports in the sample is important to benchmark against one another, in order to identify sources of inefficiency and measures to be adopted (Cullinane and Song, 2006). The existing port literature has paid relatively little attention to cluster analysis of port classification. For instance, Cabral and Ramos (2014) conducted a cluster analysis to evaluate the competitiveness of terminals in Brazil with a database for 2009, including the following variables: container movement, number of berths, berth length, berth depth, port fees, consignment fee, average board and waiting time. Tovar and Rodríguez-Déniz (2015) applied cluster analysis to Spanish ports, using data relating to the input parameters for the estimation of port cost functions. Fancello *et al*. (2014) analyzed container ports in Mediterranean using hierarchical cluster analysis to classify terminals into different clusters relating to their characteristics. More recently, Saeed and Cullinane (2021) performed cluster analysis to the data on five variables that comprise the shipping bilateral connectivity index (LSBCI) for the trading partners of China, Singapore and Hong Kong.

This paper contributes to the literature by first adapting the cluster analysis and evaluating the policy implication in the context of maximizing the ship size for the Brazilian container terminal sector. Second, we propose new variables, considering the characteristics of ports in Brazil: i) number of portainers (important for receiving ships); Maximum LOA (important to receive large ships); number of plugs (Brazil is the largest meat exporter in the world); number of gates (important for port access). We also include variables that are not strictly related to the characteristics of the terminal but are important: GDP hinterland of terminals and variables related to ships and carriers in each terminal (frequency of ships and number of maritime carriers). Despite the importance of these variables, previous studies in Brazil did not include these competitiveness criteria

3. Method and material

This section is divided into two subsections. The first section presents the technique related to the algorithm adopted. The second subsection presents the data collected from different sources.

3.1 k-means clustering algorithm

Data clustering is the unsupervised classification of patterns into groups where *N* objects within same group are more similar to their neighbors than those in other groups. It is very useful in pattern classification (Jain *et al*., 1999). Two different clustering algorithms to form the groups were tested in this study: k-means and Hierarchical (AGNES - Agglomerative Nesting) cluster/algorithm. The *k*-means is an iterative method that minimizes the within-class sum of squares for a given number of clusters. The algorithm starts with an initial guess for the cluster centers. Each observation is then placed in the cluster to which it is closest. In the Hierarchical algorithm, each observation is initially placed in its own cluster, and the clusters are successively joined together in order of their closeness. For cluster analysis implementation, we used the stats package (*k*-means algorithm) and cluster package (AGNES algorithm) for analysis in *R* (*Maechler et al., 2019*; R Core Team, 2020).

According to Everitt (2011), cluster analysis is not an automatic task, but an iterative process involving trial and error. Thus, from a database composed of 13 variables and 17 container terminals, the results showed that the best algorithm is the *k*-means in order to interpret the differences observed between the groups of container terminals formed in the cluster analysis. We executed the code in *R* using the *stats* package with the k-means algorithm (*R* Core Team, 2020). Such algorithm is one of the most useful tools of unsupervised machine learning techniques and has been used many times in the literature to find relationships between explanatory variables (MacQueen, 1967).

The k-means algorithm aims to classify a set of *n* observations into *k* groups, defined in terms of their respective feature vectors. The purpose of the algorithm is to define *k* centroids, one for each of the *k* groups. These centroids are initially randomly distributed across the space delimited by the set of *n* observations. The next step is to take each of the *n* points and associate them with the nearest centroid. When no point is pending, the first step is concluded, and an initial grouping is done. At this point, it is necessary to recalculate *k* new centroids of the groups resulting from the previous step. After having these *k* new centroids, a new link must be made between the same data set points and the nearest new centroid. These steps must be repeated as the *k* centroids change their location when compared to the centroids of the previous iteration. The algorithm ends when the centroids do not move further (Hartigan, 1975).

3.2 Database: Container terminals and variables

This study analyzed seventeen container terminals located in different regions in Brazil (Figure 1): i) North: Vila do Conde; ii) Northeast: Pecém, Suape and Salvador; iii) Southeast: Vitória, Multiterminais, ICTSI, Sepetiba, BTP, DPW and Santos Brasil; iv) South: Paranaguá, Itapoá, Navegantes, Itajaí, Imbituba and Rio Grande, as shown in the Figure 1.

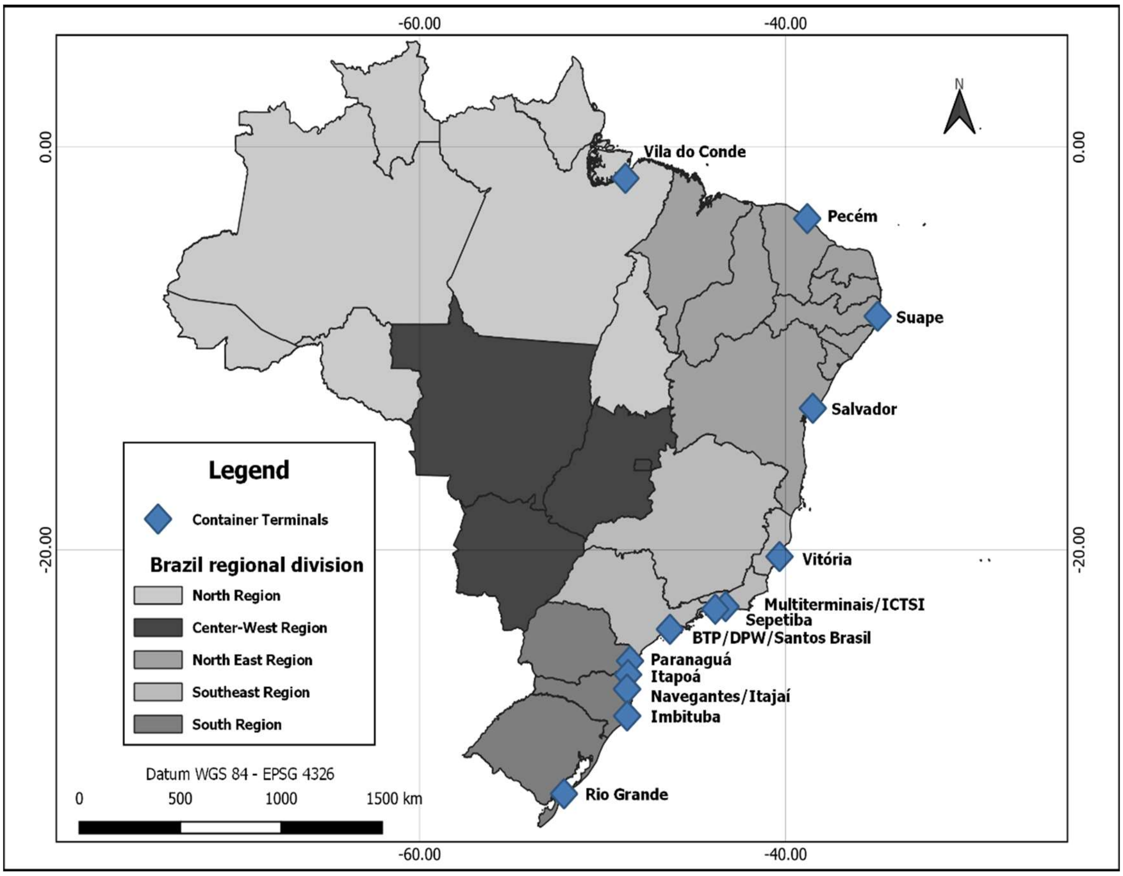


Figure 1: Container Terminals in Brazil analyzed in this study

It should be noted that some terminals analyzed in this paper are located at the same port. The Port of Santos has three terminals (BTP, Santos Brasil and DPW). The Port of Rio de Janeiro has two terminals (ICTSI and Multiterminais). Terminals in the same port may present different characteristics in terms of their infrastructure (e.g. number of portainers, capacity), frequency of ships and number of shipping lines.

The selection of variables considered the literature review presented in Section 2 that considers aspects of location and infrastructure as important factors for port choice in shipping lines' perspective (Lirn *et al*., 2003; Tongzon and Sawant, 2007; Guy and Urli, 2006; Da Cruz *et al*., 2013; Tai and Hwang, 2005; Kavirathna *et al*., 2018). We seek to include two variables related to the carrier's performance (frequency of ships and number of ocean carriers in operation), ten variables related to container terminals and one related to the GDP hinterland associated with the terminals, since the location of the port is an important factor according to the literature (Lirn *et al*., 2003; Guy and Urli, 2006; Tongzon and Sawant, 2007). The thirteen variables are presented in Table 1.

Eleven variables were collected from data provided by Solve Shipping Intelligence (2020) which performed the data collection in the terminals analyzed by distributing a questionnaire. Questionnaires were answered by top terminal executives who provided the most up-to-date data possible. Data were collected in December 2020. In case of data not available (number of portainers and number of berths) for some terminals, we used public data (ABRATEC, 2020) from the terminals. The GDP hinterland data were obtained from IPEA (2009) that determined the states associated with at each port (hinterland area), and IBGE (2018) with the GDP data of each state. Table 1 also shows the analyzed criteria and the data source. Statistics related to the sample are summarized in Table 2.

Table 1: Description of variables

Variable	Description	Source
Frequency of ships (calls/ week) in long distance services	Number of ship calls per week in all maritime services	Solve Shipping Intelligence (2020)
Number of ocean carriers	Number of shipping lines in operation in terminals	Solve Shipping Intelligence (2020)
Operational draft (m)	Maximum draft of the ships allowed in each terminal	Solve Shipping Intelligence (2020)
Maximum LOA (m)	Maximum length of a vessel allowed in terminals	Solve Shipping Intelligence (2020)
Total area (m²)	Total terminal area (m²)	Solve Shipping Intelligence (2020)
Number of plugs	Number of plugs for refrigerated containers in terminals	Solve Shipping Intelligence (2020)
Annual capacity (TEU)	Annual handling capacity (TEU)	Solve Shipping Intelligence (2020)
Static capacity (TEU)	Total static capacity (TEU) for cargo storage	Solve Shipping Intelligence (2020)
Number of berths	Number of berths where the ship docks to make the loading and unloading of cargo	ABRATEC (2020)
Number of portainers	Quantity of portainers (port crane) that aims to move cargo from the ship to the pier and vice versa (loading and unloading service)	ABRATEC (2020)
Extension of berths (m)	Total extension of berths	Solve Shipping Intelligence (2020)
Number of gates	Number of terminal access gates	Solve Shipping Intelligence (2020)
GDP of primary hinterland (R$ million)	GDP (R$ million) associated with each primary hinterland of the terminal	IBGE (2020); IPEA (2009)

Table 2: Statistics related to the sample

Variables	Average	Median	Minimum	Maximum
Frequency of ships (weekly)	9.6	10	1	17
Number of ocean carriers	9.4	10	1	15
Operational draft (m)	13.2	13.5	10.7	15
Maximum LOA (m)	340.1	350	244	368
Total Area (000 m²)	383.5	400	87	848
Number of plugs	1205.6	1000	50	3624
Number of gates	7.8	7	4	17
Annual capacity (TEU)	1073338.6	721500	217000	2500000
Static capacity (TEU)	22536.6	21500	7393	50469
Number of berths	2.8	3	1	4
Number of portainers	5.6	6	0	13
Extension of berths (m)	821.2	810	254	1108
GDP of primary hinterland (R$ 1.000.000)	1118.4	684.441	100.109	3520.349

4. Results and discussion

As this is a multidimensional analysis, it was considered that the variables should have the same analytical dimension, therefore, we normalize the data so that all the values of the feature vector range from 0 to 1.

A partitioning was obtained for three groups plotted in a two-dimensional plane for each of the considered characteristics. This number of clusters considers the value of k that converged in a smaller number of iterations for the scenario of fixed centroids. This value was later corroborated by the Elbow Method (*Thorndike, 1953)*, which indicated that there were no more significant changes in the variance of the values of the elements of each group after the value k=3 (Figure 2). Within each cluster, the terminals are similar to each other. Compared to the terminals of the other groups, there are differences.

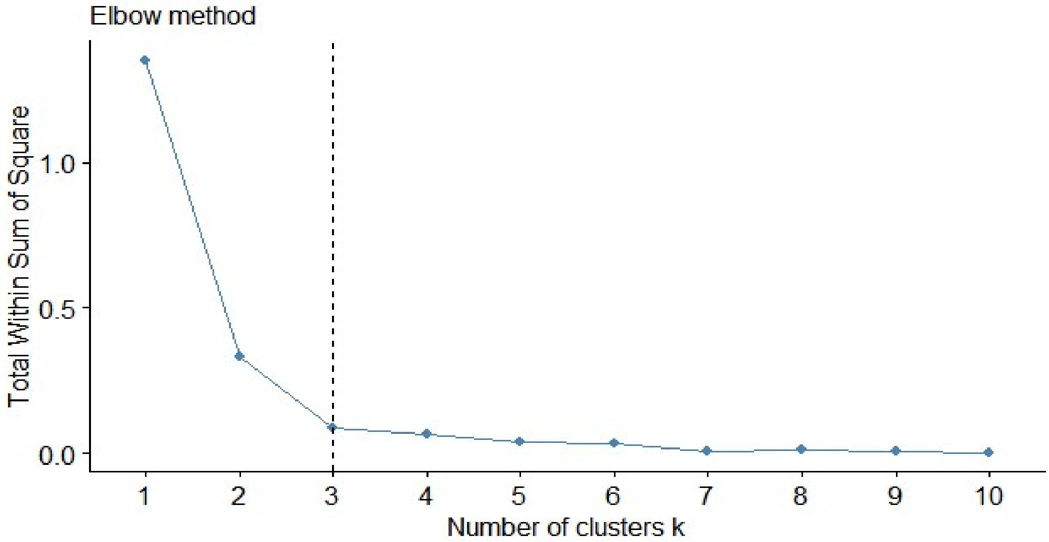


Figure 2: Optimal number of clusters according to Elbow method

Table 3 shows the terminals included in each cluster and quantity by region in Brazil.

Table 3: Groups formed using k-means algorithm

Cluster	Terminals	Quantity by region of Brazil
Group 1	Vitória, Vila do Conde, Pecém, Suape, ICTSI, Itajaí, Sepetiba, Imbituba, Salvador	North (1); Northeast (3); South (2); Southeast (3)
Group 2	Itapoá, Navegantes, DPW, Rio Grande, Multiterminais	South (3); Southeast (2)
Group 3	Paranaguá, BTP and Santos Brasil	South (1); Southeast (2)

Some interesting findings for the groups are shown below:

(1) **Group 1** consists of 9 terminals. This group has terminals located in the north (Vila do Conde) and northeast (Pecém, Suape and Salvador) regions. The others are located in the South region (Imbituba and Itajaí) and the Southeast region (ICTSI, Vitoria and Sepetiba).

(2) **Group 2** comprises three terminals in the South region (Itapoá, Navegantes and Rio Grande) and two terminals in the Southeast region (DPW and Multiterminais).

(3) **Group 3** comprises a terminal in the South region (Paranaguá) and two terminals in the Southeast region (BTP and Santos Brasil).

It should be highlighted that division of terminals into groups was marked by the economic activity of Brazil. Group 1 has container terminals in the north and northeast regions. Groups 2 and 3 have terminals only in the South and Southeast regions. In Brazil's GDP, the Southeast region has the largest share (53%), followed by the South region (17.2%); Northeast (14, 2%); Center-west (9.9%) and North (5.7%).

It is also worth mentioning that container terminals in the same port were classified into different groups, mainly due to operational characteristics because container terminals in the same port may have differences in terms of infrastructure, for example

- Port of Santos: The DPW terminal is allocated to the second group. In relation to BTP and Santos Brasil (third group), the DPW terminal has fewer plugs, gates, annual capacity, static capacity, number of portainers and number of carriers compared to Santos Brasil and BTP.

- Port of Rio de Janeiro: ICTSI is in the first group, and compared to Multiterminais (second group), it has fewer frequency of ships, total area, number of plugs, number of gates, annual capacity, static capacity and berth extension.

4.1 Analysis of the groups

Table 4 shows the statistical analysis (average, minimum and maximum) for each terminal group (Group 1, Group 2 and Group 3) in terms of the proposed 13 variables. Analyzing the transition from Group 1, Group 2 to Group 3 (Table 4), we can observe an increase in the average level of several factors, except for the operational draft and total area.

Table 4: Descriptive statistics according to the terminals in each cluster

	Average			Minimum			Maximum		
	Group 1	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**	**Group 1**	**Group 2**	**Group 3**
Frequency of ships (Weekly)	7.2	10.8	15.0	1.0	8.0	13.0	12.0	13.0	17.0
Number of carriers	8.1	9.0	14.0	1.0	4.0	13.0	13.0	14.0	15.0
Operational Draft (m)	13.3	13.2	12.8	10.7	11.5	11.3	14.7	15.0	13.5
Max LOA (m)	332.0	349.2	349.3	244.0	340.0	340.0	366.0	366.0	366.0
Total Area (000 m²)	251.9	537.8	521.0	87.0	251.0	477.0	585.0	848.0	596.0
Number of Plugs	560.2	1744.4	2244.0	50.0	442.0	1108.0	1372.0	2800.0	3624.0
Number of Gates	5.9	7.8	13.3	4.0	6.0	7.0	10.0	10.0	17.0
Annual capacity (TEU)	514084.1	1324000.0	2333333.3	217000.0	1000000.0	2000000.0	721500.0	1500000.0	2500000.0
Static capacity (TEU)	14061.4	26300.0	41689.7	7393.0	21500.0	34600.0	34000.0	30000.0	50469.0
Number of Berths	2.6	2.8	3.3	1.0	2.0	3.0	4.0	4.0	4.0
Number of Portainers	3.9	6.4	9.7	0.0	5.0	8.0	9.0	9.0	13.0
Extension of berths (m)	697.1	900.0	1062.3	254.0	800.0	980.0	1040.0	1100.0	1108.0
GDP of primary hinterland (1.000.000 R$)	532.5	1,299.0	2,575.0	100.1	405.2	684.4	1,373.7	3,520.3	3,520.3

Classifying the average values into three levels Low (L), Medium (M) and High (H) for the thirteen criteria, we verified that (Table 5):

(1) Group 1 has 12 criteria at the lowest level, while having the highest level of operational draft;

(2) Group 2 is in an intermediate situation, with 12 criteria at medium level. This group has the highest average value in total area;

(3) Group 3 presents the highest values in 12 criteria and is the most competitive group. However, it is the group that has the lowest operational draft.

Table 5: Characterization of clusters through the mean of the criteria

Criteria	Group 1	Group 2	Group 3
Frequency of ships (Weekly)	LOW	MEDIUM	HIGH
Number of carriers	LOW	MEDIUM	HIGH
Operational Draft (m)	HIGH	MEDIUM	LOW
Max LOA (m)	LOW	MEDIUM	HIGH
Total Area (000 m²)	LOW	HIGH	MEDIUM
Number of Plugs	LOW	MEDIUM	HIGH
Number of Gates	LOW	MEDIUM	HIGH
Annual capacity (TEU)	LOW	MEDIUM	HIGH
Static capacity (TEU)	LOW	MEDIUM	HIGH
Number of Berths	LOW	MEDIUM	HIGH
Number of Portainers	LOW	MEDIUM	HIGH
Extension of berths (m)	LOW	MEDIUM	HIGH
GDP of primary hinterland (1.000.000 R$)	LOW	MEDIUM	HIGH

Analyzing the average values in Table 5, the findings suggest:

(1) **Group 1**: The criteria analyzed indicate that this group presents lower values on the most variables in relation to the other clusters: Frequency of ships, Number of carriers, Max LOA, Total Area, Plugs, Gates Annual capacity, Static capacity, Number of Berths, Number of portainers, Extension of berths. However, it should be noted that the operational draft in this group has the highest average value among the three groups. This group has two terminals with an operational draft of more than 14 meters (Suape and Sepetiba). The Suape terminal is located on coast in the northeast region (State of Pernambuco) and the Sepetiba terminal is located on the coast of southeast region (State of Rio de Janeiro). The average GDP associated with the hinterland of Group 1 has the lowest value. This group has three terminals located in the Northeast region and one located in the North region, regions with less economic activity in Brazil.

(2) **Group 2**: Except for the average operational draft, this group presents higher values for all competitive criteria in relation to the terminals of Group 1 (Table 4). This group includes the Rio Grande terminal (located in the southern region) which has an operational draft of 15 meters, the largest among the terminals analyzed in the study. Group 2 has terminals basically in the South and Southeast regions, regions of greater economic activity in Brazil. The GDP of the corresponding hinterland is more than twice as high as the GDP of the hinterland of Group 1. Regarding the frequency of ships and number of carriers, this group presents slightly higher values compared to Group 1.

(3) **Group 3**: Two terminals (BTP and Santos Brasil) are located at the Port of Santos, in the State of São Paulo, the state with the highest GDP and the largest population in Brazil. The third terminal (Paranaguá) is located in the State of Paraná, South region, south of the State of São Paulo. This group presents higher values in most of criteria,

except for the operational draft and total area. It is noteworthy that this group has, on average, the lowest operational draft value among the three groups. The GDP hinterland of this group has a value of 4.8 times greater than that of Group 1, and a value of 1.98 times that of Group 2. The third group has a large advantage in terms of frequency of ships and number of carriers in relation to the other groups.

It is important to note that Terminals in Group 3 are among the top three in the ranking of terminals with the greatest movement during 2020 in exports and imports in Brazil, shown in Table 6. Additionally, in the ranking of the 10 largest export terminals, Group 2 has 5 terminals and Group 1 has 2. In the ranking of the 10 largest import terminals, Group 2 has 4 terminals and Group 1 has 2. These results show the dominance of terminals classified in Group 3 by cluster analysis.

Table 6: Ranking of Port Terminals (TEU)

Export and Import: January 2020 - November 2020

	Exports				**Imports**		
Rank	**Terminal**	**TEU**	**Group/Cluster**	**Rank**	**Terminal**	**TEU**	**Group/Cluster**
1	BTP	580.568	3	1	SANTOS BRASIL	370.12	3
2	PARANGUÁ	374.431	3	2	BTP	358.722	3
3	SANTOS BRASIL	330.508	3	3	PARANAGUÁ	210.836	3
4	NAVEGANTES	250.027	2	4	NAVEGANTES	199.143	2
5	RIO GRANDE	207.26	2	5	DPW	159.67	2
6	DPW	165.213	2	6	ITAPOA	156.695	2
7	ITAPOA	169.013	2	7	ITAJAI	116.381	1
8	ITAJAI	121.118	1	8	CHIBATÃO	76.604	not analyzed
9	SALVADOR	75.218	1	9	SUAPE	58.985	1
10	MULTITERMINAIS	62.618	2	10	RIO GRANDE	56.931	2

Source: Datamar (2021)

4.2 Discussion on results

In fact, the third group, the most competitive group, consisted of terminals that stand out on average in different competitive criteria and compared to Group 1, it has on average: Frequency of ships (2.08 times more); Number of carriers (1.72 times more); Total Area (2.06 times more); Plugs: (4 times more); Gates (2.25 times more); Annual capacity (4.5 times more); Static capacity (2.97 times more); Number of portainers (2.49 times more); Extension of berths (1.52 times more); GDP of primary hinterland (4.85 times more). The biggest advantages are related to GDP Hinterland, Annual Capacity, Number of Plugs, while the disadvantage lies in the operational draft.

1. *GDP hinterland*: Group 1 has terminals with a low level of GDP hinterland and low frequency of ships. Group 2 presents higher values in terms of GDP hinterland and frequency of ships. Group 3, in turn, is located at the top with the highest level of frequency of ships and GDP hinterland. An exception is the Paranaguá terminal (which does not have a high GDP hinterland) but has a high level of frequency of ships. One explanation for this fact is that the Paranaguá terminal is located below the State of São Paulo, close to an area of high economic activity, which benefits this terminal. This result is in line with Souza *et al*. (2021) that showed, through in-depth interviews, the most important factor in the perspective of shipping lines operating in Brazil when choosing a port is the GDP Hinterland associated to each port.

The Port of Santos, for example, is the port that has the largest hinterland area in the country, comprising states from different regions (UNB, 2012). Despite the limitation of operational draft and the need for dredging, the Port of Santos benefits from its location close to the largest industrial concentration in the country, which favors more frequency of ships due to the greater movement of cargo. This situation can be compared to the situation of the Port of Rotterdam in Europe, which is located close to the major production/consumption centers of the European continent (Moreira, 2009). Shipping companies aim to serve the largest economic areas (Wiegmans *et al*., 2008; Park and Min, 2011), and the port activity corresponds to the dynamics of the economy in the hinterlands (He *et al*., 2019). In the context of Brazilian market, the State of São Paulo has the highest industrial concentration, and this is the biggest asset of the Port of Santos. The privileged location of this port, close to the largest industrial park in Brazil, favors greater cargo handling in the Santos terminals, which attracts ocean carriers.

2. *Annual Capacity*: We can see that there is a transition between the groups from 1 to 3 and a positive relation can be identified between the annual capacity and frequency of ships, as shown in Figure 3. Group 1 has terminals with a low level of annual capacity and low frequency of ships. Group 2 presents intermediate values in terms of annual capacity and frequency of ships. Group 3 is located at the top with a higher level of frequency of ships and annual capacity.

3. *Number of Plugs*: It is worth noting that the hinterland of the ports in the Southeast and South Regions has a high presence of frozen meat exporting companies. Brazil is the world's biggest beef exporter (Bloomberg, 2021). The Paranaguá Terminal is the one with the largest number of plugs. The greater availability of plugs for refrigerated containers in Group 3 shows this importance, especially in exports to Asia, traditionally the main destination of chicken meat produced in Brazil.

4. *Operational Draft*: Notably, a positive relation is not observed between frequency of ships and operational draft. Verifying frequency of ships and operational draft, we can see that there is no pattern and transition between the groups as we have seen in the others, shown in Figure 4. In fact, Group 3 has the highest average level of frequency of ships, but the terminals present in this group do not have the highest operational draft values. Six Brazilian terminals (Rio Grande, Sepetiba, Imbituba, Suape, Multiterminais and ICTSI) with the highest average number of operational drafts are not included in Group 3. The average operational draft in these six terminals is 14.3 m, while the average frequency of ships per week is 7.2. The GDP hinterland associated with these six terminals is low 769.92 (R$ 1.000.000).

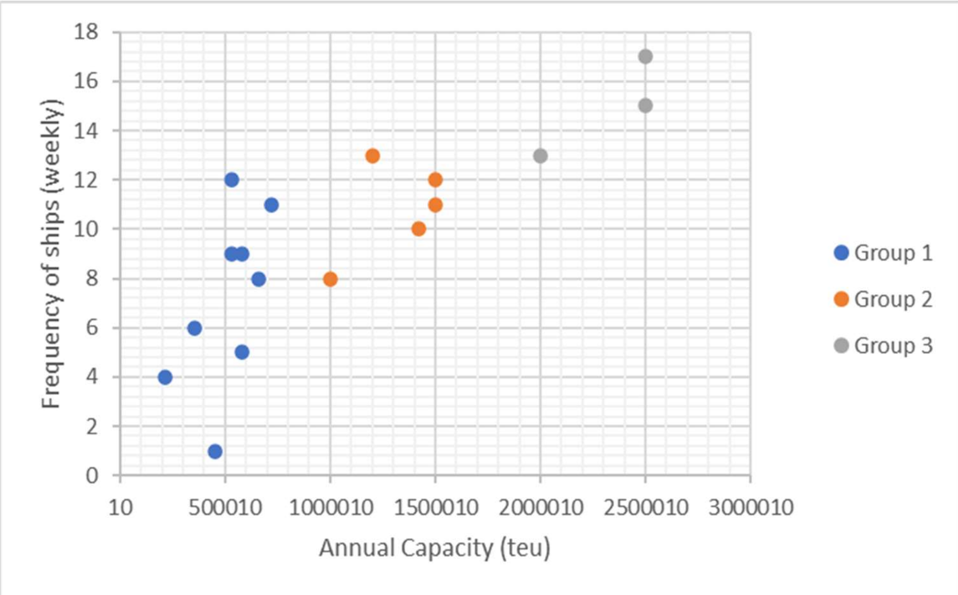


Figure 3: Annual Capacity (TEU) x Frequency of ships by Groups of terminals

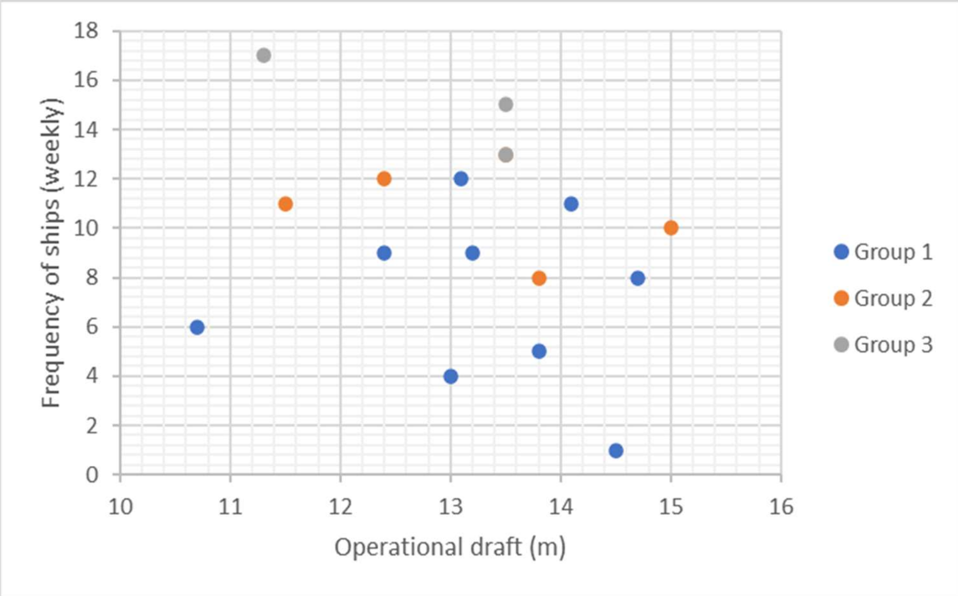


Figure 4: Operational Draft (m) x Frequency of ships by Groups of terminals

4.3 Policy implications

An important fact that should be observed in Brazil is the concentration of economic activity in the State of São Paulo, where the Port of Santos is located. Despite being a country of continental dimensions, Brazil presents an economy in which approximately 31% of the national GDP is represented by the state of São Paulo (IBGE, 2018). This fact makes Port of Santos the potential port to concentrate the frequency of ships.

On the contrary, the group of terminals with the highest level of operational draft presented low values of GDP hinterland associated, which shows that the area of influence of these terminals is limited in Brazil. A possible policy to increase the competitiveness of these terminals is the government to invest in long-distance rail connections to increase the hinterland area of these terminals to extend their market shares. Rail container transport is underdeveloped in Brazil, and most cargo transported by rail mode is bulk (iron ore and soy) (Souza *et al*., 2021b). The length of the Brazilian rail network amounts to around 29,320 kilometers. This length is equivalent to an average density of 3.5 Km/1000 km^2 of territorial area and still does not serve a significant number of states (ANTF, 2021). Other countries have the following density values (Km/1000 km^2): USA (29.8); India (20.8); Argentina (13.3); China (13.2); Russia (5.1); Australia (4.8) (ANTF, 2018). The development of land rail transport of containerized cargo in Brazil can encourage the connection of container terminals located outside areas of greater economic activity, improving the competitiveness of the port sector.

The global trend of using larger ships puts pressure on ports. By the end of the 1980s, the ships had a draft of 13 meters with LOA of 285 meters. From 2013, the developed ships began to have a draft of 15.5 meters and 400 meters (LOA) (Table 8) (International Transport Forum, 2014). Currently, the Brazilian port sector is preparing to receive *New Panamax class ships,* with 366 m long and 15.2 m draft. The arrival of larger ships on the Brazilian coast shows evidence of the limitation for many Brazilian terminals. The average operational draft of the 17 terminals analyzed in this study is 13.2 meters. In all maritime services, 60% of the container ships in operation on the Brazilian coast have a maximum draft equal to or greater than 14 meters. In the Brazil – Asia Service, half of the ships have a maximum draft equal to or greater than 15 meters (Solve Shipping Intelligence, 2020). This fact increases pressure on ports due to the limited depth in Brazilian ports.

Table 8: Evolution of container ships.

Class	Year	Capacity (TEU)	LOA (m)	Draft (m)
Fully Cellular	1970-	1000-2500	215	10
Panamax	1980-	3000-3400	250	12.5
Panamax Max	1985-	3400-4500	290	12.5
Post Panamax	1988-	4000-5000	285	13
Post Panamax Plus	2000-	6000-8000	300	14.5
New Panamax	2014-	15000	366	15.2
Triple E	2013-	18000	397	15.5

Source: International Transport Forum (2014)

Currently, the largest capacity vessel in operation on the Brazilian coast has a capacity of 12,200 TEU (UNCTAD, 2020). Figure 5 shows the maximum container transport capacity (TEU) of container ships in countries on different continents. It is noteworthy that South American countries in the pacific ocean (e.g. Peru, Ecuador and Colombia) serve larger ships compared to the Brazilian market.

The maximum value of the capacity of ships in operation in Brazil represents a limitation when new orders for container ships are verified. Figure 6 represents orderbook fleet capacity breakdown by TEU size range. Moreover, 78% of the orders correspond to vessels with a capacity above 12,500 TEU. Orders for new container ships with a capacity between 10,000 TEU – 12,499 TEU represent only 6% of the total (Alphaliner, 2021). Orders for ships with a capacity of less than 12,500 TEU represent a small share, which shows the trend of the global shipping service to use increasingly larger ships, while Brazil has restrictions. This context shows that Brazil needs to define a policy in the port sector to maintain competitiveness against other neighboring countries.

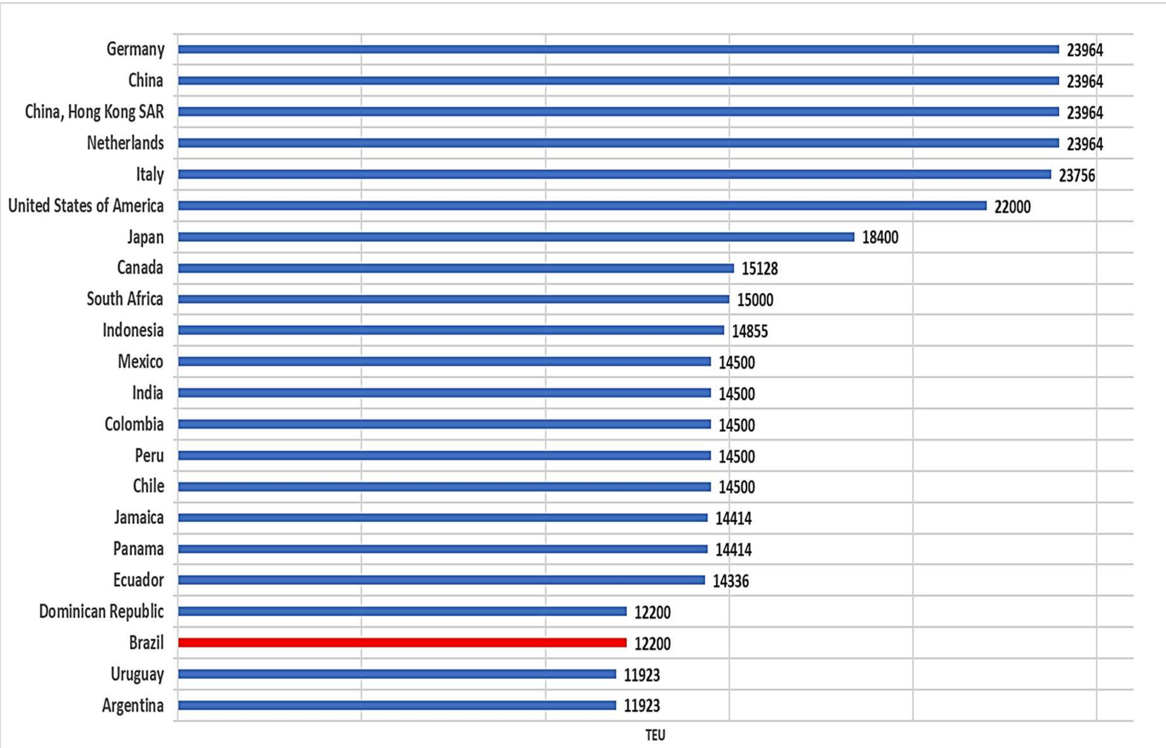


Figure 5: Maximum container carrying capacity (TEU) of container ships accommodated by ports in different nations

Source: UNCTAD (2020)

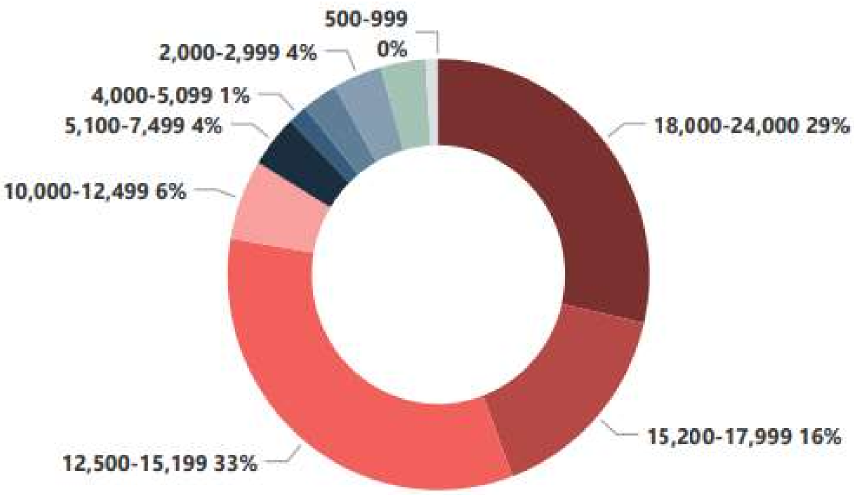
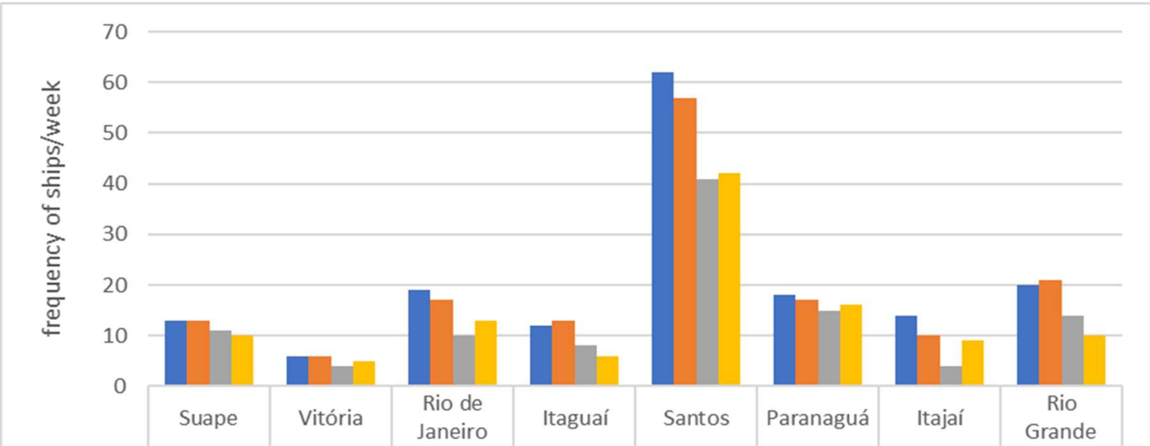


Figure 6: Orderbook Fleet Capacity Breakdown by TEU size range
Source: Alphaliner (2021)

In parallel, considering the increase in the size of container ships, there is a general reduction in the number of frequency of ships in Brazilian ports. In December 2008, the frequency of ships per week in the country was 222; in December 2019, the number was reduced to 166. As examples, the Ports of Santos and Rio de Janeiro showed a reduction of 32%; Itaguaí and Rio Grande had a reduction of 50% (Figure 7) (ANTAQ, 2020). Itaguaí is one of the terminals with the highest operational depth on the East Coast of South America.



	Suape	Vitória	Rio de Janeiro	Itaguaí	Santos	Paranaguá	Itajaí	Rio Grande
dec/08	13	6	19	12	62	18	14	20
dec/10	13	6	17	13	57	17	10	21
dec/15	11	4	10	8	41	15	4	14
dec/19	10	5	13	6	42	16	9	10

Figure 7: Frequency of ships per week 2008-2019 in Brazilian Ports
Source: ANTAQ (2020)

The reduced number of services decreased the demand for berths, increasing idle capacity. Consequently, competition for services between terminals and the need for investments to receive larger ships increased. Therefore, the growth in the size of ships makes dredging one of the most strategic interventions for many Brazilian ports, especially Santos, the only Brazilian port among the 100 largest in the world (Cabral and Ramos, 2014) with an operational draft of 13.5 metal, but below Rotterdam, Shanghai and other international ports that have expanded into the sea, with operational drafts exceeding 15 m. In addition, the constant investment in infrastructure and equipment is fundamental to maintain the competitiveness of the terminals. However, Magano (1995) highlights that the fragility of the port infrastructure is caused by lack of management policies when exploring the then Law of 1993, in Brazil, the Law for the Modernization of Ports. The recent Law on Ports, from 2013, by removing the fragile autonomy of the Port Authorities and privatizing these Administrations further raises the issue.

Therefore, the relevant authority needs to decide whether to invest in the Port of Santos to be the hub port in the country or invest in another Brazilian port with greater depth (e.g Itaguaí, Pecem, or a new port) to become the hub port. Efficiency and depth are the main competitiveness factors of *hub ports* in Asia (Tai and Hwang, 2005). Thus, if Santos is maintained as the main port of Brazil in the long term, the future of the Port of Santos may not necessarily be in the navigation channel, but outside it, with the construction of deep-water terminals outside the Bay of Santos. In the Port of Rotterdam, the Dutch Port Authority has expanded the port to deep water. The depth in Rotterdam is 20 meters, enough to meet larger ships (Port of Rotterdam, 2021).

5. Conclusions and directions for future research

This study classified 17 Brazilian container terminals into three distinct groups based on competitiveness criteria using *k*-means algorithm. This paper's contribution to the literature is framed in terms of assisting Brazilian port market providing important elements that support the market in Brazil and its characteristics, with a view to stimulating debate on issues related to port competitiveness and government investment strategies in the long term, in particular, investments for the Brazilian port sector to be able to receive larger ships. Additionally, the development of rail transport to the connections of terminals located outside the area of greatest economic activity can induce competition between terminals in Brazil. Another contribution of the paper lies in using important variables in the context of Brazilian terminals not explored by other studies applied to the Brazilian market. In relation to previous studies developed in Brazil (Cabral and Ramos, 2014), this article sought to contribute to the literature on port terminals in Brazil, performing a cluster analysis including important variables such as frequency of ships, number of ocean carriers, number of plugs and GDP hinterland associated to each terminal.

The first cluster corresponded to nine container terminals that present limitations in most of the analyzed criteria, which reflects the low frequency of ships. On the other hand, the upper cluster presented higher values in many criteria analyzed and have a higher ship call average. However, the study indicates that the limitation of the operational draft is an obstacle in Brazil and is a factor that must be urgently analyzed by the port sector and public agents due to the dynamics of maritime trade. Brazil needs to invest in ports with greater operational draft or expand the Port of Santos into the sea to become a deep-water port.

An obstacle to the development of the study is the lack of data on container terminals in the country, especially in the North and Northeast regions. For future studies, we suggest the inclusion of new variables considered important from the perspective of shipping companies (port cost and cargo handling efficiency). Additionally, this study also suggests including variables related to cabotage services in Brazil, as this type of transport is increasing market share in Brazil. Future research should also address the market, possibly adopting a longitudinal perspective and involving the testing for the most influential variables in the perspective of shipping lines, in order to provide a full analysis of the drivers of competitiveness in Brazil.

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Investigating the Impact of Artwork Logistics Service Quality on Customer Loyalty Using Customer Service Satisfaction and Customer Trust as Mediators

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Abstract

Purpose – The purpose of this study is to identify the relationship among artwork logistics service quality, customer satisfaction, customer trust, and customer loyalty. The mediating effects of customer satisfaction and customer trust between artwork logistics service quality and customer loyalty are also investigated.

Design/methodology/approach – The selected customers who had ever used artwork logistics services were invited to participate in the questionnaire survey and 100 valid responses were received. Structural equation modeling technique was adopted to estimate the relationships among the proposed constructs.

Findings – The results demonstrated that both direct and indirect effects from artwork logistics service quality on custom loyalty were significantly and positively identified. Furthermore, the impacts of customer satisfaction with the logistics service and customer trust on customer loyalty were also estimated to be significant and positive. Lastly, customer satisfaction was identified to have a full mediating effect in the relationship between artwork logistics service quality and customer loyalty while customer trust had a partial mediating effect in the same relationship.

Research limitations/implications – This study only received 100 valid sample for empirical analysis as the users of artwork logistics services were limited and not easy to contact. Future studies could use snowball sampling or long-term tracking to collect sufficient samples.

Practical implications – The results proved that artwork logistics service quality, satisfaction and trust all positively influence customer loyalty, and the positive impacts of service quality respectively on satisfaction and customer trust are also proven significant. Besides, the results also proved that service satisfaction and customer trust positively mediated the effect from service quality toward customer loyalty.

Originality/value – The artwork logistics service is a special logistics operation. It needs more professional skills and operations. This study selected such logistics service as a case and the research work can benefit to academic research.

Keywords: Artwork logistics, service quality, customer satisfaction, customer loyalty, customer trust, mediating effect.

1. Introduction

With the improvement of the quality of life, people have paid more and more attention to literary and artistic activities, and the development of the art industry such as art fairs or trading activities has also increased year by year. According to McAndrew (2020), total global art sales climbed from \$ 39.5 billion in 2009 to \$ 64.1 billion in 2019, an increase of 62 %. Meanwhile, the number of transactions increased from 31 million times in 2009 to 40.5 million times in 2019, the highest in the past 10 years. Therefore, the needs of art transportation have been stimulated.

Artwork has the characteristics of high value, difficult preservation, and natural deterioration; hence, the transportation of art deeply relies on professional and specialized logistics services to assist in the operation of art packaging, transportation, and exhibition to meet the needs of customers. The art transportation is not like a usual transportation and mostly has not been a focus of academic studies. Thus, how the logistics service qualities of the artwork affect customer satisfaction, trust, thereby loyalty is a question worth to tackle. It especially meets the academic gap and practical operations. The purpose of this research is to explore the influence of the service quality of artwork logistics services on customer satisfaction, customer trust, and customer loyalty.

2. Literature Review

Artwork has special requirements when transported due to that the works of art also have a special value for their owners despite other noticeable characteristics. The art transporters need to have specialized in packing, installation, and transporting and offer customized services to satisfy their customers' needs (Bolboaca, 2010). Figure 1 demonstrates the general process of art work logistics. Packing, shipping, handling, and installation are the four important parts for artwork transportation. The service quality of artwork logistics is therefore strongly dependent on those professional operations.

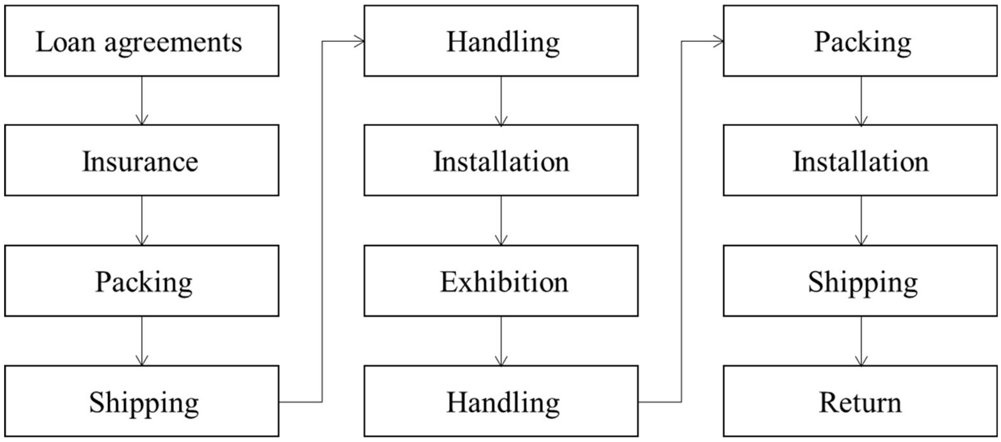

Figure 1 General Process of Artwork Logistics

According to Thai (2013), logistics service providers need not only to provide fast and safe services, but also need professional knowledge and understanding the needs of customers. In addition, they also need to show caring attitudes and professional behaviors to customers. These are the keys leading to high service quality. Many studies have concluded that logistics service quality will strongly and positively affect customer satisfaction (e.g. Murfield et al., 2017; Meidutė-Kavaliauskienė e t al., 2014; Gil- Saura et al., 2018; Ho et al., 2012; Selim e t al., 2019; Uvet, 2020).

Furthermore, logistics service quality also has a great impact on customer loyalty. Tontini et al. (2017) mentioned that not only the logistics service quality has an impact on customer satisfaction but also on loyalty. Studies from Juntunen et al. (2013) and Özoğlu and Büyükkeklik (2017) also have the same conclusion that logistics service quality positively and significantly affect customer loyalty. Juga et al. (2010) further confirmed that despite a positive relationship existing in between service quality and customer satisfaction and loyalty, the customers' overall satisfaction with service quality will positively affect customer loyalty. Such relationship was also evidenced by Singh (2015) and Otsetova (2017).

Meanwhile, in the study of Ramazan and Salih (2014), high service quality of a logistics service would result in high customer trust of the service. Paparoidamis (2019) pointed out that logistics service quality such as product quality, sales service quality, handling customer problems, etc. will positively affect customer trust. The study of Huma et al. (2019) found that logistics service quality positively and significantly influenced customer loyalty and customer trust. Musinguzi (2009) identified that the more customers trust the logistics service provider, the more customer loyalty to the company. Wallenburg et al. (2011) studied the relationship between trust and loyalty in the German logistics industry and found that if customers have confidence in the service provider's services, customers will continue to use the logistics services in the future. In summary, seven research hypotheses are proposed for this study.

H1: The service quality of an artwork logistics company has a positive and significant impact on customer satisfaction.

H2: The customer satisfaction of art logistics companies has a positive and significant impact on customer loyalty.

H3: The service quality of the artwork logistics company has a positive and significant impact on customer loyalty.

H4: The service quality of an art logistics company has a positive and significant impact on customer trust.

H5: The trust of the art logistics company has a positive and significant impact on customer loyalty.

H6: Customer satisfaction has a positive and significant mediating effect on the influence of service quality on customer loyalty.

H7: Customer trust has a positive and significant mediating effect on the influence of service quality on customer loyalty.

3. Methodology

3.1. The Path Model

Following the research hypotheses developed in previous section (H1-H7), the model framework is illustrated in Figure 2.

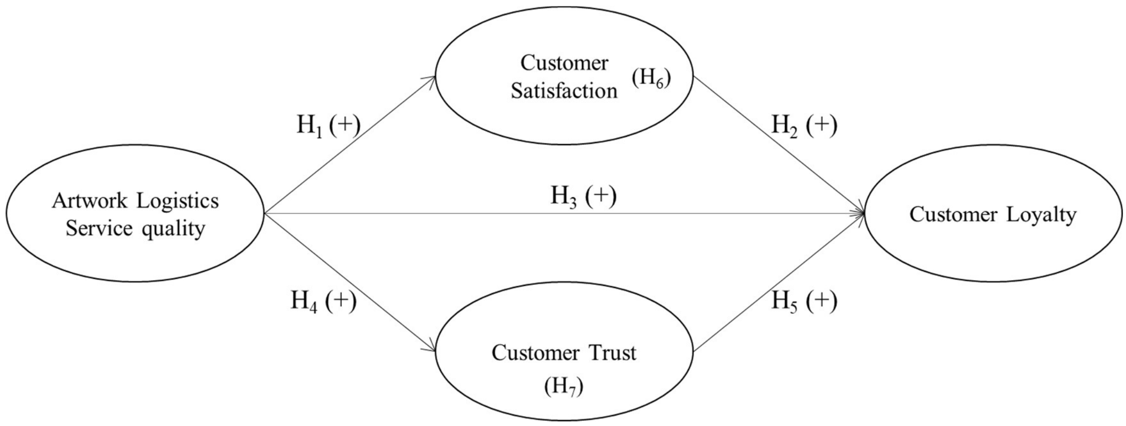

Figure 2 The Model Framework

To verified the path relationships in the model (Fig. 2), this study used two-step approach proposed by Anderson and Gerbing (1988) to conduct an SEM analysis. In the first step, a measurement model using confirmatory factor analysis was built to examine the reliability and validity of the research model based on the collected data. In terms of reliability, two thresholds that were commonly used in SEM analyses are applied to test the reliability for the model. Firstly, the composite reliability (CR) values of each construct are calculated and should be greater than 0.7 (Hair etal.,1998). The second threshold requires that the average variance extracted (AVE) values of each construct meet 0.5 or more (Fornell and Larcker,1981).

As for the validity, three kinds of validities are examined to ensure the validity of the research model in this study. First, the convergent validity is tested through the criteria of all factor loadings being greater than 0.5, all CR values of each construct being greater than 0.6, and the AVE values of each construct being greater than 0.5 (Fornell and larcker,1981). Second, to ensure that there is a significant difference between each construct pairs, the discriminant validity is tested by observing if the square root of one construct's AVE value is greater than the correlation coefficients between the construct and all other constructs. If so, the discriminant validity of the research model can be ensured (Shiou and Luo,2013).

3.2. Measurement

The measurement for the four constructs adopted from literature review to ensure the content validity are listed in Table 1. There are five sub-constructs: tangibility, warranty, empathy, responsiveness, and reliability, under the construct of art logistics service quality.

Table 1 Constructs and items

Art Logistics Service Quality		
Tangibility	TAN1	Storage area in line with artwork temperature and humidity regulations
	TAN2	Storage area is near Taipei city center
	TAN3	Set viewing room in storage area
	TAN4	Storage area provides independent storage service
	TAN5	Storage area is equipped with qualified fire protection system
	TAN6	Storage area has access control and 24-hour security mechanism
	TAN7	Qualified pest control measures in the storage area
	TAN8	Clean and tidy environment in the storage area
	TAN9	Transportation vehicles have full temperature and humidity control mechanism
	TAN10	Good appearance of transport vehicles
	TAN11	Vehicles are equipped with GPS real-time positioning system
	TAN12	Clean and well-dressed staffs
	TAN13	Provide real-time management information inquiry system for the artworks
Warranty	WAN1	Operators have expertise in artwork transportation and provide instructions
	WAN2	Operators have professional skills in hanging and displaying works
	WAN3	Reasonable pricing for services
	WAN4	Confidentiality of customer and product (artwork) information
	WAN5	Operators are professional and careful in their work
	WAN6	Safety of transporting works by air and sea
	WAN7	Safety of fixing the work in the box
Empathy	EMP1	Flexible adjustment of delivery time and location according to customers' needs
	EMP2	Provide customers with insurance-related consultation and services
	EMP3	Provide customers with suggestions on the placement of their works
	EMP4	Provide various service packages according to customer's budget
	EMP5	Customer service and operation staff with foreign language ability
Responding	RES1	Ability to handle customer inquiries in a timely manner
	RES2	Ability to handle customer complaints in a timely manner
	RES3	Ability to handle customer order changes in a timely manner
	RES4	Proactively provide customers with real-time information on the delivery
	RES5	Ability to quickly respond the unexpected situations and handle them appropriately
	RES6	Proactively review the condition of packages and packaging materials
	RES7	Operations adhere to standard operating procedures

Table 1 (Cont.) Constructs and items

Art Logistics Service Quality		
Reliability	REL1	Appropriate packaging methods and materials are selected according to the artwork characteristics
	REL2	Operators use packaging materials in accordance with contract specifications
	REL3	Employees have received well orientation training
	REL4	The artwork arrives without damage
	REL5	The artwork is delivered on time and in accordance with the contract
	REL6	Reliability of the sea and air transportation schedule
Customer Satisfaction of Art Logistics Service		
CSS1	I feel professional in how the current company designs the packaging to protect the work	
CSS2	I am satisfied with the cleanliness and tidiness of the storage area of my current company	
CSS3	I am satisfied with the way my current company arranges the work in the storage area	
CSS4	I am satisfied with the service attitude of the current company	
CSS5	I am satisfied/happy with the decision of choosing the current company	
CSS6	Overall, the experience of using the service of the current company is pleasant	
Customer Loyalty		
CL1	I will continue to use the art logistics service of the current company	
CL2	I would recommend my current company's art logistics services to my peers	
CL3	I usually talk to others about positive news about my current company	
CL4	When I have a need for artwork related services, I ask my current company first	
CL5	I think my current company is very dedicated to service	
Customer Trust		
CT1	The current company is reliable	
CT2	The service is reliable and professional	
CT3	They always keep their promises to their clients	
CT4	The company is always responsive to customer issues	

3.3. Data

This study adopted the questionnaire survey to collect data. There were five parts in the questionnaire. The first part of the questionnaire is to inquire the background information of the respondents. The second to the fifth parts are the measures for art logistics service quality, customer satisfaction, loyalty, and trust, respectively. Likert's 5-point scale was used to measure respondents' perceptions regarding the four constructs.

The questionnaire was distributed to the customers who had used the services of art logistics, including individual artists, art galleries, art collectors, and curators, etc. A total of 110 questionnaires were distributed via emails or personal contacts starting from December 2020, and received 100 valid questionnaires (respondents) in the end of April 2021.

The majorities of the respondents were artists, owners of galleries, and art curators. The background of the respondents was mostly composed by female, accounting 55%, less than 35 years old, 62%, and having related working experiences in less than five years, accounting 46%.

The descriptive statistics for all the measurement items are listed in Table 2. The items in each construct (and each sub-construct) are ranked by their means from highest to lowest. Table 2 shows that TAN6 (Storage area has access control and 24-hour security mechanism), WAN7 (Safety of fixing the work in the box), EMP1 (Flexible adjustment of delivery time and location according to customers' needs), RES7 (Operations adhere to standard operating procedures), and REL2 (Appropriate packaging methods and materials are selected according to product characteristics) are the items with the highest means respectively in the five sub-constructs of Art Logistics Service Quality: Tangibility, Warranty, Empathy, Responding, and Reliability. It indicates that the customers highly value the services related artwork security/safety and the way of operation.

Regarding to the rest three constructs, CSS4 (I am satisfied with the service attitude of the current company), CL5 (I think my current company is very dedicated to service), and CT3 (They always keep their promises to their clients) receive the highest scores respectively of Customer Service Satisfaction, Customer Loyalty, and Customer Trust.

Table 2 Descriptive statistics of measurement items

Measurement		Mean	Variance
Art Logistics Service Quality			
Tangibility	TAN6	4.16	0.6206
	TAN5	4.11	0.7049
	TAN1	4.08	0.6804
	TAN7	4.03	0.9385
	TAN9	4.03	0.6153
	TAN8	3.97	0.7567
	TAN11	3.77	0.6031
	TAN13	3.76	0.5883
Tangibility	TAN4	3.74	0.5378
	TAN12	3.74	0.5378
	TAN2	3.63	0.4577
	TAN10	3.60	0.6263
	TAN3	3.55	0.5732
Warranty	WAN7	4.20	0.6263
	WAN5	4.13	0.5587
	WAN6	4.11	0.6645
	WAN2	4.07	0.6314
	WAN4	4.05	0.5732
	WAN1	3.94	0.7236
	WAN3	3.92	0.6198
Empathy	EMP1	3.95	0.4722
	EMP2	3.91	0.5272
	EMP3	3.85	0.5934
	EMP5	3.65	0.6136
	EMP4	3.90	0.5758
Responding	RES2	4.01	0.4536
	RES1	4.00	0.5959
	RES5	4.00	0.5859
	RES3	3.97	0.4848
	RES6	3.91	0.6557
	RES4	3.73	0.5474
Reliability	REL2	4.19	0.6605
	REL5	4.17	0.5264
	REL6	4.13	0.4577
	REL3	4.07	0.4900

Table 2 (Cont.) Descriptive statistics of measurement items

Measurement		Mean	Variance
Art Logistics Service Quality			
Reliability	REL1	4.03	0.6637
	REL4	3.98	0.4844
	REL7	3.96	0.4428
Customer Service Satisfaction			
CSS4		4.08	0.5390
CSS6		4.07	0.5304
CSS1		4.05	0.4924
CSS5		3.99	0.6565
CSS2		3.95	0.6944
CSS3		3.95	0.5934
Customer Loyalty			
CL5		4.07	0.5506
CL1		4.03	0.4738
CL3		4.01	0.4746
CL4		4.01	0.4746
CL2		3.99	0.5151
Customer Trust			
CT3		4.09	0.4262
CT2		4.08	0.4582
CT4		4.05	0.4924
CT1		4.04	0.5034

4. Results

4.1. Measurement Model Results

Table 3 shows the measurement model results. Firstly, it can be seen that the Cronbach's α value of each construct (sub-construct) ranges from 0.8906 to 0.9446, which are all greater than 0.7. Meanwhile, the CR values range from 0.9205 to 0.9576, which are greater than the 0.7 as well. Therefore, the reliability of each construct is acceptable. Secondly, AVE value for each construct (sub-construct) is greater than or equal to 0.5. Moreover, the factor loading for each variable (the measurement item) is also greater than 0.5. It meaning that the measurement meets convergent validity. Finally, the square root of the AVE value of each construct is greater than the correlation coefficient between the different constructs (Table 4). This indicates that a good discriminant validity is maintained among constructs.

Table 3 Measurement Model Results

Measurement		Factor loadings	Cronbach's α	CR	AVE
Art Logistics Service Quality					
Tangibility	TAN1	0.777	0.9120	0.9253	0.5000
	TAN2	0.546			
	TAN3	0.679			
	TAN4	0.631			
	TAN5	0.754			
	TAN6	0.838			

Table 3 (Cont.) Measurement Model Results

Measurement		Factor loadings	Cronbach's α	CR	AVE
Art Logistics Service Quality					
Tangibility	TAN7	0.829	0.9120	0.9253	0.5000
	TAN8	0.784			
	TAN9	0.781			
	TAN10	0.558			
	TAN11	0.654			
	TAN12	0.559			
	TAN13	0.733			
Warranty	WAN1	0.862	0.9390	0.9504	0.7327
	WAN2	0.867			
	WAN3	0.833			
	WAN4	0.826			
	WAN5	0.840			
	WAN6	0.862			
	WAN7	0.900			
Empathy	EMP1	0.854	0.8906	0.9205	0.7010
	EMP2	0.906			
	EMP3	0.874			
	EMP4	0.872			
	EMP5	0.655			
Responding	RES1	0.871	0.9229	0.9382	0.6854
	RES2	0.906			
	RES3	0.910			
	RES4	0.718			
	RES5	0.869			
	RES6	0.850			
Reliability	REL1	0.847	0.9260	0.9425	0.7333
	REL2	0.816			
	REL3	0.885			
	REL4	0.750			
	REL5	0.881			
	REL6	0.823			
	REL7	0.784			
Customer Service Satisfaction					
CSS4		0.886	0.9342	0.9481	0.7531
CSS6		0.824			
CSS1		0.844			
CSS5		0.865			
CSS2		0.867			
CSS3		0.918			
Customer Loyalty					
CL5		0.924	0.9446	0.9576	0.8186
CL1		0.903			
Customer Loyalty					
CL3		0.879			
CL4		0.898			
CL2		0.920			
Customer Trust					
CT3		0.933	0.9389	0.9535	0.8044
CT2		0.926			

Table 3 (Cont.) Measurement Model Results

Measurement	Factor loadings	Cronbach's α	CR	AVE
Customer Trust				
CT4	0.905	0.9389	0.9535	0.8044
CT1	0.837			

Table 4 Correlation Matrix among constructs

	AVE	Art Logistics Service	Customer Service	Customer Loyalty	Customer Trust
Art Logistics Service Quality	0.7000	**0.8400**			
Customer Service Satisfaction	0.7531	0.7874	**0.8678**		
Customer Loyalty	0.8186	0.7324	0.8298	**0.9047**	
Customer Trust	0.8044	0.6469	0.7884	0.8317	**0.8969**

Note: The value of the bold diagonal represents the square root of AVE, and the non-diagonal is the correlation coefficient between each construct.

4.2. Structural Model Results

Figure 3 demonstrates the results of the structural model. The paths in Figure 3 are all estimated to be significantly positive indicating that the hypotheses, H_1, H_2, H_3, H_4, and H_5, are all supported. That is to say, customer perception of art logistics service quality has positively direct and indirect impacts on customer loyalty. Customer satisfaction and customer trust play mediating roles between art logistics service quality and customer loyalty.

We further conducted a Sobel t test (Sobel, 1982) to examine the significance of the mediating effects both of customer satisfaction and customer trust. The results showed that the t values were 6.663 and 6.492 respectively for the customer satisfaction mediating test and customer trust mediating test. However, the direct effect of art logistics service quality on customer loyalty became insignificant when one of the mediating constructs – customer satisfaction was only considered in the model. This means that customer satisfaction has a full effect to mediate the impact of art logistics service quality on customer loyalty. In contrast, customer trust partially mediates the impact of art logistics service quality on customer loyalty. In conclusion, H_6 and H_7 are supported.

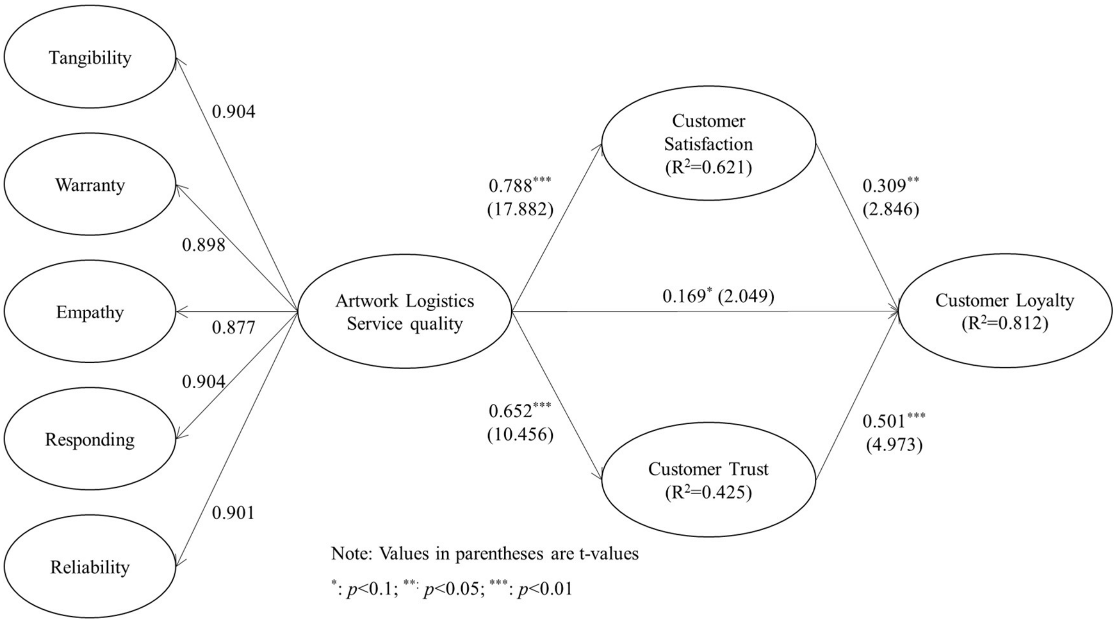

Figure 3 Structural Model Results

5. Conclusions

Through empirical analysis, it is found that the hypotheses proposed in this study were all tested and sustained. The quality of artwork logistics service has a positive and significant impact on logistics service satisfaction, customer trust and logistics service loyalty. Artwork logistics service satisfaction and customer trust also have a positive impact on logistics service loyalty. Furthermore, customer satisfaction with artwork logistics service has a full mediating effect in the relationship between artwork logistics service quality and customer loyalty, and customer trust has a partial mediating effect in the relationship between artwork logistics service quality and customer loyalty.

The managerial implication of this study is that customer satisfaction with art logistics service can be enhanced by demonstrating professional skills in artwork handling and operations. Meanwhile, the art logistics company also needs to keep promises to customers in the service process and taking the initiative to consider the interests of customers. Art logistics companies should also pay attention to the gap between customers' expectations of service and the service they actually get, and whether the process of providing services is effective in creating a sense of trust for customers.

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The Impacts of Interpersonal Conflicts and Work-Family Conflicts on the Job Performance of Seafarers – The Moderating Role of Organizational Commitment

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Abstract

Purpose – The purpose of this study is to identify the relationships among interpersonal relationship conflict, work-family conflict, job burnout, job performance and organizational commitment among seafarers.

Design/methodology/approach – We surveyed 202 seafarers and used Smart PLS 3.0 to conduct a structural equation modeling analysis.

Findings – The results demonstrated that the impact of interpersonal relationship conflict and work-family conflict on job burnout were both significant. In addition, interpersonal relationship conflict and job burnout have significant negative effects on job performance. Lastly, organizational commitment negatively moderates the relationship between job burnout and job performance among seafarers.

Research limitations/implications – This study only involves two independent variables as stressors on seafarers; future studies can incorporate more stressors to explore their influence on job performance.

Practical implications – Managers should develop strategies to strengthen organizational commitment in seafarers, which will reduce the impacts of job burnout on job performance and thus improve job performance.

Originality/value – This study extends the existing perceptions of the effects of interpersonal relationship conflict and work-family conflict among seafarers. Organizational commitment was proven to be a key moderating variable in terms of reducing the impact of job burnout on job performance.

Keywords: Seafarer, Interpersonal relationship conflict, Work-family conflict, Job burnout, Job performance, Organizational commitment

1. Introduction

It has been reported that 90% of international trade is carried out by ships (Yuen et al., 2020), which means that seafarers play a vital role in the context of the shipping industry in terms of global trade activities. Seafaring is a special profession in which workers typically face a variety of stressors associated with different situations. They are easily subjected to psychosocial and physical stressors, including high levels of leadership responsibility, separation from family, loneliness, fatigue, sleep deprivation, workplace noise, and the movement, vibration, and heat taking place on the ship (An et al., 2020). According to Jex (1998), the main job-related stressors can be divided into five dimensions: role stressors, workload, interpersonal conflict, situational constraints, and perceived control, in that order. In the case of seafarers, the demands of their job (i.e., separation from family, varied work shifts, and frequently changing work teams) leave them with little time and opportunity to spend extended periods of time with their colleagues and close family members. Furthermore, it has been widely suggested that chronic job stress will eventually lead to job burnout (Beheshtifar and Omidvar, 2013; Elit, et al., 2004). In this regard, we identified interpersonal relationship conflict and work-family conflict as the stressors examined in this study. Based on the literature review, it is argued that both types of conflict have a significant positive impact on job burnout, thereby lowering job performance among seafarers. In addition, this study also examines the moderating role of organizational commitment between job burnout and job performance. The rest of this paper is presented as follows: Section 2 reviews studies related to interpersonal conflict, work-family conflict, job burnout, job performance, and organizational commitment, which are used to develop the research hypotheses posited in this study. The methodologies used in this study are described in

Section 3; Section 4 reports the results of an empirical equation modeling analysis carried out in this study; Finally, the conclusions of this study and the suggestions for future research are summarized in Section 5.

2. Literature review

2.1. Interpersonal conflict

Cartwright and Cooper (1996) stated that interpersonal relationships with supervisors, colleagues, and subordinates comprise one of the major stressors in the workplace. Scarnera et al. (2009) pointed out that interpersonal relationships are one of the most important sources of stress at work. Haq (2011) suggested that interpersonal relationship conflicts are comprised of emotional factors including friction, tension, animosity, and impatience. Interpersonal conflict refers to existing opinions that will lead to conflicts between individuals and others in an organization (Wu et al., 2018a). Since crew members have to work with colleagues of different classes or from different countries when they are on board, factors such as differences in values, work attitudes and even cultural differences between them may cause problems in getting along with each other. Therefore, effectively handling interpersonal relationships is also a challenge for seafarers.

2.2. Work-family conflict

Greenhaus and Beutell (1985) pointed out that work-family conflict is a form of inter-role conflict where the role pressure is mutually incompatible in specific respects in the work and family domains. Karatepe and Bekteshi (2008) proposed that spending more time than expected in the workplace will lead to conflicts between work and family. Wu et al. (2018b) defined work-family conflict as incompatible role pressure between work and family. Ji et al. (2020) posited that work demands for seafarers (i.e., separation from their family) will generate the work-family conflict because they spend more time and resources on work and devote less to their families.

2.3. Job burnout

Freudenberger (1974) was the first to apply the term "burnout" to describe a syndrome characterized by failure, physical fatigue, and exhaustion due to excessive demands for energy, vitality, and resources. Maslach (1982) defined burnout as a psychological syndrome involving emotional exhaustion, depersonalization, and a diminished sense of personal achievement that occurs among various individuals who work with other people in challenging situations. The difference between job stress and job burnout is that the latter is a long-term process responding to the former. With increasing literature on burnout, Golembiewski et al. (1983) later found that employees working in commercial organizations suffer from job burnout. They suggested that burnout is a progressive phenomenon characterized in its early stages by depersonalization and in later stages by emotional exhaustion. Maslach et al. (2001) defined job burnout as a psychological syndrome that occurs in response to chronic interpersonal stressors on the job. Chung et al. (2017) conducted a study of seafarer burnout and put forward the idea that burnout is a state of chronic stress, which is typically a syndrome characterized by exhaustion, cynicism, and lack of efficacy among employees. Wu et al. (2019) defined job burnout as negative feelings in the workplace that include such things as physical and mental exhaustion, diminished job performance, and reduced enthusiasm for work.

2.4. Job performance

Jamal (1984) considered job performance as an action during which an individual can successfully complete tasks or goals assigned to him/her. Hall and Goodale (1986) indicated that job performance is the manner in which employees execute their jobs, arrange their schedules, provide technologies and skills, and assist and manage their colleagues. Campbell (1990) defined job performance as a personal behavior that staff members perform in order to achieve an organization's expectations and norms, as well as a need to respond to the role of the organization. Balouch and Hassan (2014) defined job performance as the way employees carry out their work and whether they perform their job well or not. Ahmad and Afgan (2016) defined job performance as the overall output that people provide to their employers. Liu et al. (2020) suggested that job performance is the measurable results of completing tasks within a specified time.

2.5. Organizational Commitment

Mowday et al. (1982) defined organizational commitment as the relative degree of individual recognition within and input to a specific organization. Meyer and Allen (1991) suggested that organizational commitment is composed of affective commitment, continuance commitment, and normative commitment. Affective commitment refers to the degree of emotional attachment, identification, and participation of employees within an organization. Continuance commitment refers to an employee's awareness of the costs associated with leaving an organization. Normative commitment refers to a feeling of being obligated to continue working. Goulet and Frank (2002) regarded organizational commitment as a behavior comprising a series of behavioral intentions and attitudes that have a certain degree of influence on the behavior of members of an organization. Dee et al. (2006) pointed out that organizational commitment is personal willingness to contribute to an organization and to remain loyal to that organization. Bouraoui et al. (2007) stated that when employees are emotionally attached to their organizations, they are more remain in them. Koo et al. (2020) defined affective commitment as a state in which employees associated with the company at which they are employed for.

2.6. The impacts of interpersonal relationship conflict and work family conflict on job burnout

Since Jex (1998) put forward the idea that role stressors, workload, interpersonal conflict, situational constraints, and perceived control are the major job-related stressors in the workplace, the nature of stressor-burnout relationships has been widely discussed and studied. Job burnout is considered to be a consequence of long-term stress, and it is correlated with many negative reactions toward the job (Beheshtifar and Omidvar, 2013). Elit et al. (2004) found a strong association between experiencing high stress and high burnout among physicians. Hu et al. (2015) found that the stress from interpersonal relationships is positive correlated to job burnout. Burke and Greenglass (2001) found that work-family conflict is associated with higher levels of psychological burnout among nursing staff, which means a nurse who reports greater work-family conflict also reports higher levels of emotional exhaustion and cynicism. Wu et al. (2019) found a positive correlation between work-family conflict and job burnout among construction professionals. Because the crew must work in a hierarchical personnel system and must be separated from their families for a long period of time, the confusion and conflicts between interpersonal and family relationships may cause the crew to burn out on their jobs. Therefore, we propose the following hypotheses:

H_{1a}: Interpersonal relationship conflicts among seafarers have a significant positive impact on job burnout.

H_{1b}: Work-family conflicts among seafarers have a significant positive impact on job burnout.

2.7. The impacts of interpersonal relationship conflict and work-family conflict on job performance

The relationship between stressors and job performance has been extensively discussed. Through a meta-analysis, LePine et al. (2005) found that hindrance-oriented stressors have a negative impact on job performance. Interpersonal conflict is a prevalent and significant stressor, leading employees to feel disconnected, to interact negatively, and to have poor job performance (Mulki et al., 2015). Qayyum et al. (2018) stated that when people run into conflicts, their job performance will deteriorate. Jiang et al. (2021) indicated that interpersonal conflict can undermine job performance by inducing negative affectivity, anxiety, depression, and frustration. As for the relationship between work-family conflict and job performance, Bhuian et al. (2005) concluded that there is a negative correlation between work-family conflict and job performance among sales personnel. Karatepe and Bekteshi (2008) found that spending more time than expected in the workplace will cause work-family conflicts, in turn ultimately damaging the job performance of frontline hotel employees. Nart and Batur (2014) conducted a study on primary school teachers and found a negative correlation between work-family conflict and job performance. Based on the above-mentioned literature, most previous studies have proved both that interpersonal relationship and work-family conflicts have negative impacts on job performance. Based on the fact that the crew members are away from their families for a long time and work with their hierarchical colleagues on board, we propose the following two hypotheses:

H_{2a}: Interpersonal relationship conflicts among seafarers have a significant negative impact on their job performance.

H_{2b}: Work-family conflicts among seafarers have a significant negative impact on their job performance.

2.8. The impact of job burnout on job performance

Wright and Cropanzano (1998) found that burnout, specifically emotional exhaustion, is negatively associated with job performance. Demerouti et al. (2014) stated that burnout is negatively related to supervisor-rated task performance. Abdelhamied and Elbaz (2018) found that emotional exhaustion has a negative impact on organizational performance. Wu et al. (2019) found that job burnout has a negative impact on job performance among construction project managers. It is clear that many studies have demonstrated a negative correlation between job burnout and job performance. Since seafarers have to spend long periods of time away from their families on board and perform many routine tasks in shifts, their resulting job burnout is likely to have a negative impact on their job performance. Therefore, the following hypothesis is proposed in this study:

H_3: Job burnout among seafarers has a significant negative impact on their job performance.

2.9. The moderating effect of organizational commitment

Leiter (1991) proved that emotional exhaustion is highly associated with organizational commitment. Gemlik et al. (2010) found that high levels of burnout among health sector staff were linked with reduced levels of organizational commitment. Buitendach and De Witte (2005) found that a higher level of organizational commitment leads to better job performance. Abdelhamied and Elbaz (2018) proved that organizational commitment has a moderating effect on the relationship between emotional exhaustion and employee performance. It was confirmed that a high level of organizational commitment reduces the influence of emotional exhaustion on organizational performance. The impact of organizational commitment on job burnout and job performance has been explored in many studies, and it has been proven that organizational commitment can moderate the relationship between job burnout and job performance. In the case of seafarers, their organizational commitment to the shipping company they serve may also have a moderating effect on the relationship between their degree of job burnout and their job performance. Therefore, the following hypothesis proposed:

H_4: The degree of organizational commitment of seafarers has a negative moderating effect on the relationship between job burnout and job performance.

Based on the above discussion, this study proposes six hypotheses that were summarized in Table 1.

Table 1: The hypotheses proposed in this study

H_{1a}: Interpersonal relationship conflicts among seafarers have a significant positive impact on job burnout.
H_{1b}: Interpersonal relationship conflicts among seafarers have a significant negative impact on job performance.
H_{2a}: Work-family conflicts among seafarers have a significant positive impact on job burnout.
H_{2b}: Work-family conflicts among seafarers have a significant negative impact on their job performance.
H_3: Job burnout among seafarers has a significant negative impact on their job performance.
H_4: The degree of organizational commitment of seafarers has a negative moderating effect on the relationship between job burnout and job performance.

3. Methodology

3.1. Questionnaire design

The model established in this study is used to ascertain the relationship between interpersonal relationship conflict, work-family conflict, job burnout, and job performance as well as the moderating effect of organizational commitment among seafarers. The relationship between the constructs is shown in Figure 1. An empirical study was conducted using a questionnaire survey to collect the sample data. For the construct measures, we sourced the question items for measuring interpersonal relationship conflict from Wu et al. (2018a) and Adil and Awais (2016). Work-family conflicts were measured using the three question items from An et al. (2020) and Wu et al. (2018a). Job burnout was measured using items in Yuen et al. (2020) and Liu et al. (2020). Job performance, a dependent variable in the research model, was measured using items in Liu et al. (2020), Yuen et al. (2018) and Balouch and Hassan (2014). Lastly, the question items used to measure organizational commitment were sourced from Dinc (2017) and Ehido et al. (2020). The five constructs in the research model and their measurement items are summarized in Table 2.

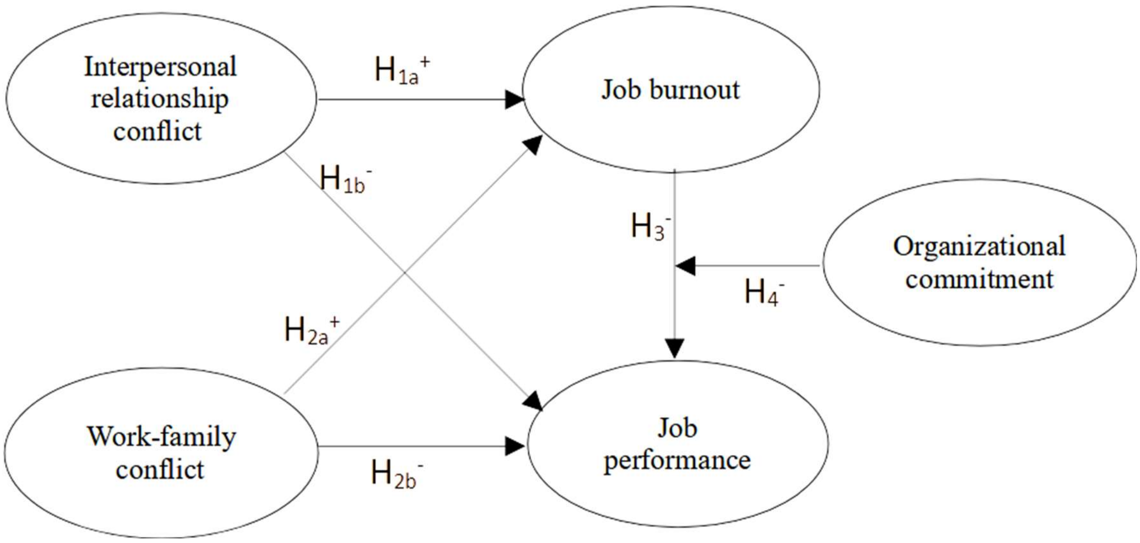

Figure 1: Research model used in this study

Table 2: Measurement items for each construct

Construct	Measure item	Reference
Interpersonal relationship conflict	I am often conflicted or unhappy with my colleagues.	Wu et al. (2018a); Adil and Awais (2016)
	I often feel isolated on the job.	
	I do not want to share things about myself with others.	
	I intentionally hide my feelings.	
Work-family conflict	I have to miss family activities due to the amount of time I have to spend on work responsibilities.	An et al. (2020); Wu et al. (2018a)
	I am often so emotionally drained when I get home from work that it prevents me from contributing to my family.	
	The nature of the job requires separation and not enough time to take care of my family.	
	I feel I am working too hard on my job.	
	Work makes me physically and mentally exhausted.	

Job burnout	It's stressful for me to work all day. Since I started this job, I have become less and less interested in my job. I'm not as passionate about my work and my colleagues as before.	Yuen et al. (2020); Liu et al. (2020)
Job performance	The cooperation between me and my colleagues is very good. I am seldom absent from work. I make few mistakes at work. I complete my tasks efficiently. I am satisfied with my performance because it is mostly good.	Liu et al. (2020); Yuen et al. (2018); Balouch and Hassan (2014)
Organizational commitment	I feel like part of the family at my company. I feel a strong sense of belonging to my company. I feel emotionally attached to this company. I feel as if this shipping company's problems are my own.	Dinc (2017); Ehido et al. (2020)

3.2. Structural equation modelling (SEM) analysis

After finishing the collection of the sampling data, a structural equation modelling analysis was carried out based on the two-step procedure proposed by Anderson and Gerbing (1988). In the first step, a measurement model was built to examine the reliability and validity of the research model based on the collected data. In terms of reliability, two thresholds that are commonly used in SEM analyses were applied to test the reliability of the proposed research model. Firstly, the composite reliability (CR) values of each construct were calculated, all of which should be larger than 0.7 (Fornell and Larcker, 1981, Hair et al., 2014). Additionally, the second threshold requires that all average variance extracted (AVE) values of each construct be larger than 0.5 (Fornell and Larcker, 1981, Hair et al., 2013). Three types of validity were examined to ensure the validity of the research model used in this study. First, the measurement items were sourced from relevant studies to ensure the content validity. Second, convergent validity was tested by verifying that all factor loadings were greater than 0.5 (Kline, 1998). Third, to ensure that there was a significant difference between each construct pair, the discriminant validity was tested by observing whether the square root of the AVE for each construct was greater than the correlation coefficient between the corresponding construct pairs. Discriminant validity was achieved if all square roots of the AVE were greater than 0.5 (Fornell and Larcker, 1981) and were larger than the correlation coefficients between the corresponding construct pairs (Shiau and Luo, 2013).

After an appropriate measurement model was ensured, a structural model was developed to estimate the path coefficients and test the proposed hypotheses. In this study, the structural model was examined using SmartPLS 3.0 statistical software. Hair et al. (2013) pointed out that it can be used to perform repeated bootstrapping sampling 5,000 times, where the t-values served as the criterion to judge whether the path coefficients between the latent variables were significant or not. A t-value greater than 1.96, 2.58, and 3.29 represented significance levels of $p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively. Finally, a path coefficient was used to analyze the strength of the influence between constructs, where a larger value indicated a stronger relationship between the constructs.

4. Empirical study

4.1. Sampling and data collection

The samples of this research were collected from seafarers who participated in professional training courses at National Taiwan Ocean University from September 2020 to December 2020. A total of 225 questionnaires were issued, in which 23 samples were identified as invalid samples. Hence, there were 202 valid samples, and the effective return rate was 89.9%. By analyzing the basic information of the respondents listed in the Appendix (see Table A1), it is found that the majority of respondents were male, and the others were female. In terms of marital status, the ratio of married and unmarried is close to half, i.e., 48% and 52% respectively. We also found that the respondents were mainly over 40 years old (57.4%). In terms of professional positions, 33.7% of the respondents were at the managerial level; 25.2% were at the operational level, and the rest were assistants. As for the departments, the respondents in the deck department and in the engine department accounted for 56.4% and 40.6% respectively, and a small number of respondents worked in the steward department. Lastly, the respondents were engaged in a variety of vessel types, mainly container ships and bulk carriers, of which 45.5% were sailing in the ocean-going market and 54.5% were in the short-sea market.

4.2. The structural model analysis

The results of the measurement model analysis in this study are shown in Table 3. In terms of the reliability analysis, all Cronbach's α values ranged between 0.713 and 0.897, all of which were above 0.7. Simultaneously, the CR values ranged between 0.832 and 0.927, all of which were greater than the threshold (i.e. 0.7). These results ensured the reliability of our measurements. The results of the validity analysis are also reported in Table 3. The AVE of each construct ranged between 0.543 and 0.763, all of which were greater than 0.5, indicating that convergence validity was achieved. Lastly, discriminant validity was tested by examining whether the square root of the AVE of a construct was greater than the correlation coefficients between the construct and other constructs. As Table 4 shows, the discriminant validity of the research model was ensured because each construct met the required threshold.

Table 3: Result of the measurement model analysis

Construct	Observation variable	Load of factor	Mean	Standard Deviation	CR	AVE
Interpersonal relationship conflict	IRC1	0.840	1.921	0.779	0.840	0.571
	IRC2	0.861	2.000	0.884		
	IRC3	0.664	2.376	0.963		
	IRC4	0.630	2.743	0.992		
Work-family conflict	WFC1	0.633	3.847	1.020	0.832	0.628
	WFC2	0.837	2.663	1.027		
	WFC3	0.884	3.322	1.122		
Job burnout	JB1	0.523	2.035	0.624	0.853	0.543
	JB2	0.794	2.772	1.004		
	JB3	0.721	2.871	0.951		
	JB4	0.808	2.480	0.828		
	JB5	0.799	2.574	0.888		
Job performance	JP1	0.752	3.886	0.654	0.860	0.551
	JP2	0.661	4.129	0.677		
	JP3	0.761	3.802	0.731		
	JP4	0.767	3.980	0.629		
	JP5	0.766	3.901	0.660		
Organizational commitment	OC1	0.882	3.797	0.804	0.927	0.763
	OC2	0.940	3.604	0.815		
	OC3	0.932	3.604	0.815		
	OC4	0.724	3.287	0.942		

Table 4: AVE and correlation coefficient matrix

	AVE	Interpersonal relationship conflict	Work-family conflict	Job burnout	Job performance	Organizational commitment
Interpersonal relationship conflict	0.571	**0.756**				
Work-family conflict	0.628	0.245	**0.792**			
Job burnout	0.543	0.537	0.355	**0.737**		
Job performance	0.551	0.434	0.143	0.447	**0.742**	
Organizational commitment	0.763	0.277	0.093	0.456	0.350	**0.874**

Note: The value on the diagonal represents the square root of AVE, and the non-diagonal value is the correlation coefficient between the construct pairs.

In this study, the structural equation model analysis was performed by SmartPLS3.0 software, and the bootstrapping was set to 5000 times according to Hair et al. (2011). The results showed that the coefficient on the path linking work-family conflict to job performance was non-significant because its t-value (0.226) was less than 1.96. The other five coefficients were all significant with t-values larger than 1.96. The coefficient on the path linking interpersonal relationship conflict to job burnout was 0.479 (t=8.743). The coefficient on the path linking interpersonal relationship conflict to job performance was -0.219 (t=2.877). The coefficient on the path linking work-family conflict to job burnout was 0.238 (t=3.487). The coefficient on the path linking job burnout to job performance was -0.240 (t=2.637). The moderating effect from organizational commitment on the relationship between job burnout and job performance was -0.194 (t =3.064). The results of structural model analysis were shown in Table 5 and Figure 2.

Table 5: The results of the hypotheses test

Research hypothesis	t value	result
H_{1a} : Interpersonal relationship conflicts among seafarers have a significant positive impact on job burnout.	8.743	Supported
H_{1b} : The interpersonal relationship conflicts among seafarers have a significant negative impact on job performance.	2.877	Supported
H_{2a} : Work-family conflicts among seafarers have a significant positive impact on job burnout.	3.487	Supported
H_{2b} : Work-family conflicts among seafarers have a significant negative impact on job performance.	0.226*	Rejected
H_3 : Job burnout among seafarers has a significant negative impact on job performance.	2.637	Supported
H_4 : The organizational commitment of seafarers has a negative moderating effect on the relationship between job burnout and job performance.	3.064	Supported

* non-insignificant at $p < 0.05$

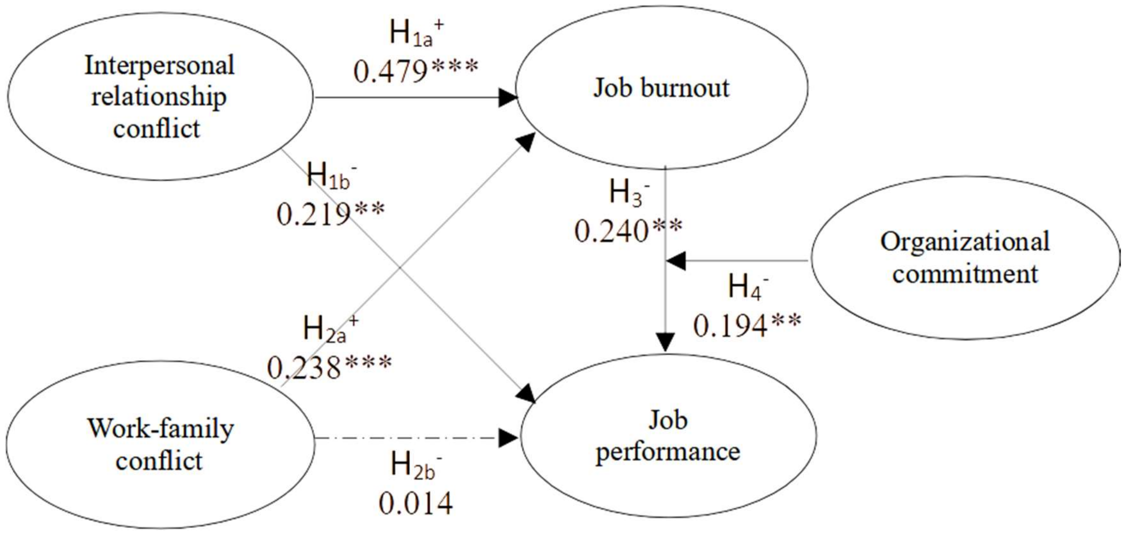

Figure 2: Result of structural model analysis

5. Conclusions

Seafarers play an important role in the shipping industry. In addition to sailing vessels safely and smoothly, they are also responsible for ensuring the goods on board can be delivered on time without damage. In the past, there has been a lot of research investigating the relationship between job burnout and job performance, but less literature has found organizational commitment to be a variable moderating the relationship between job burnout and job performance. To investigate the impact of typical stressors on the job performance of seafarers and fill the gap in the research on this topic, the present study was aimed toward ascertaining the impact of interpersonal relationship conflict and work-family conflict on job performance. Meanwhile, job burnout and organizational commitment were included in the research model as mediating and moderating variables, respectively.

Based on the results of our empirical study, although some studies have demonstrated that work-family conflict negatively affects job performance (e.g., Karatepe and Kılıç, 2007; Bhuian et al., 2005), the impact of work-family conflicts on seafarers' job performance was proven to be non-significant in this study, which is consistent with the findings of Karatepe and Bekteshi (2008) and Nart and Batur (2014). The main reason for this may be the fact that most seafarers' family members have a sense of empathy for the nature of the work of their family members who work on ships and understand that they cannot participate in family activities because they have to work on board a ship. In addition, because of the rapid advancement of Internet technology and low Internet usage rates, seafarers can now also use mobile devices such as cell phones or tablets to conveniently communicate with their family members during non-working hours, thus significantly reducing the degree of physical separation from family members. Therefore, the empirical analysis conducted in the present study showed that work-family conflict did not have significant negative impacts on the job performance of seafarers. It is worth noting that the path coefficient measuring the effects of interpersonal relationship conflict on job burnout (0.479) was greater than that of the effects of work-family conflicts on job burnout (0.238), which means that the former is more likely to cause seafarers to burnout at work.

Furthermore, this study also proved that organizational commitment has a significant negative impact on the relationship between job burnout and job performance. In fact, organizational commitment improves job performance by reducing the negative impacts of job burnout on job performance, meaning that seafarers with high levels of organizational commitment will perform better than those with low levels of organizational commitment. Therefore, shipping companies should take measures to cultivate emotional attachment and foster organizational commitment toward their organization among seafarers. Although interpersonal relationship conflicts and work-family conflicts are both important stressors in the workplace, there are still many other factors worth discussing, such as work environment and workload. Future studies could include more stress variables to investigate the work performance among seafarers and identify ways to relieve stressors so as to improve job outcomes.

Appendix

Table A1: Returned sample statistical distribution

Item	Frequency	Percentage
Gender		
Male	191	94.6%
Female	11	5.4%
Marital status		
Single	105	52.0%
Married	97	48.0%
Age		
Under 25 years	15	7.4%
26-30 years	33	16.3%
31-35 years	19	9.4%
36-40 years	19	9.4%

More than 40 years	116	57.4%
Professional position		
Managerial level	68	33.7%
Operational level	51	25.2%
Assistant level	83	41.1%
Sector		
Deck department	114	56.4%
Engine department	82	40.6%
Steward department	6	3%
Type of vessel		
Container ship	72	35.6%
Bulk carrier	43	21.3%
Oil tanker	15	7.4%
Cement carrier	5	2.5%
Others	67	33.2%
Shipping line		
Ocean-going route	92	45.5%
Short-Sea route	110	54.5%

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Cascading Failure in Liner Shipping Network

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Abstract

Purpose –Suez Canal Disruption hurt the global liner shipping network, the scope, and duration of which are rare. Background of the accident based on canal disruption and restoration: We proposed a new framework to study the evolution of such accident risks in the liner shipping network for one year.

Design/methodology/approach – Overload and congestion at port nodes are the manifestations of risk. To identify the load of each port node on a continuous time series, we added a time factor to the cascade failure model. This model constructed a liner shipping network based on the schedule data and introduced the shortest path selection behavior during load transfer. Then, we constructed a time interval tree model to identify the load of each port node on a continuous time series.

Findings – We identified the node of failure, the time when the failure started, and the duration of the failure. Overload failure of nodes was transmitted to surrounding ports along the shipping route. In the early stages of the disruption, ports with a high density of shipping schedules had strong repair capabilities, while ports with a low density of shipping schedules were prone to overload failures. However, as the channel disruption time increased, those ports with more ship schedules experienced more severe overloads. There was an adaptive capability in the liner shipping network, which can maintain the network state to a certain extent after being disturbed. Singapore and Suez Port were important transit ports, while Shanghai Port, Qingdao Port, and other major world ports in China had little transit role.

Originality/value – For the first time, time series were introduced into the study of liner shipping networks, and identified the spatial and temporal information of the cascade failure process, which facilitates risk management by the relevant organizations.

Keywords: schedule data, time series, overload failures, interval tree statistics; complex network;

1. Introduction

Maritime transportation undertakes 80% of the cargo transportation in international trade and is the backbone of global economic development (UNCTAD, 2020). Since the rise of maritime container shipping in the early 20th century, liner shipping services is an important part of the global supply chain system and have had a positive impact on global trade (Bernhofen et al., 2016). With the rise of network science and data technology, more and more scholars study complex network systems, we can better understand and use them, such as power networks, social networks (Bilecen B et al., 2018), biological networks (Mishra D et al.,2014), road network (Yang Y et al, 2018), etc.

In 2021, the disruption of the Suez Canal caused container ships to be stranded and caused delays in sailing schedules, which in turn led to port congestion worldwide. (Ivanov et al.,2021) point out that the change of some shipping schedules will affect the voyages within the service and the voyages related to the interrupted service. The failure of part of the network structure is likely to cause the paralysis of the entire network， this phenomenon is named cascading failure (Adilson E. Motter and Yingchen Lai, 2002). Exploring the propagation mechanism and evolution law of such emergencies in the network will help to quantify the risk and assist the Operational Control Center of the shipping company in risk control. The classical cascade failure model can identify the transmission process of failure between network nodes, but cannot identify the time information of node failure, which is unfavorable to the risk management of liner companies.

The real liner shipping network contains both time and space information. The liner shipping network consists of two parts, one is a physical network composed of routes, which stores the connection relationship between ports; the other is a service network composed of sailing plans, which stores the time of arrival and departure from the port (Christopher Dirzka, 2022). Taking such a network as the main subject of study, introducing the time factor in the classical cascade failure model solved the problem of port node failure time identification. This allows the innovative points of this paper to be realized.

Furthermore, in the mainstream research methods, scholars build complex networks with shipping line data and study the topological characteristics of the network (Yihong Hua and Daoli Zhu, 2009). In such a network, the connectivity restrictions brought by the shipping schedule are not considered. In the real liner shipping network, the accessibility between port nodes is not only limited by the path but also limited by the time windows. When there are shipping schedules between ports, goods can transport. Considering the time windows in the liner shipping network, we constructed a network based on shipping schedules data.. Figure.1 shows a schematic diagram of the liner network based on route data and based on schedules data. In the diagram on the left, v_n indicates the port nodes, and the line segments between the nodes indicate the connection relationship between the ports. In the right figure, v_n denotes the port, v_n^{moment} denotes the set of the port at different moments, and l_n denotes the ship sailing plan, which contains the inter-port voyage time, residence time in port, and arrival and departure time.

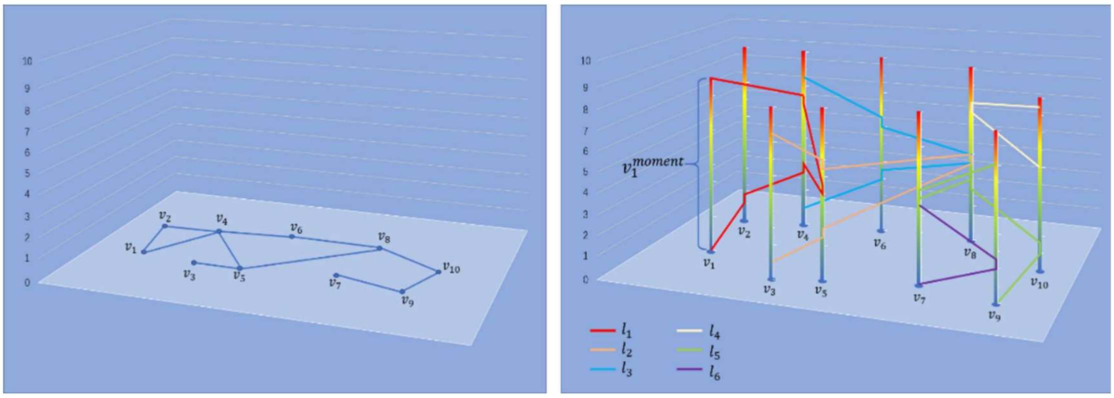

Figure 1. Schematic diagram of the liner network based on route data (left) and based on schedules data (right).

Bringing liner shipping networks with temporal attributes into the classical study of network propagation dynamics is the innovation of this paper. The results of using this strongly planned Spatio-temporal network as the subject of cascading failure studies are the perception of future risks. In such a space-time network, we simulate the situation of the Suez Canal being interrupted and reopened by adding interference and simulate the strength of the interference by controlling the length of the disruption time. Some ships are affected by the channel disruption when sailing, waiting for the canal to open. The direct impact of the disruption is the overall delay in the shipping schedule. The ship schedule change affects the subsequent path selection behavior of cargo transportation and generates the subsequent network node load information. The failure information of the network node is identified concerning the maximum load capacity of that node in the initial load. When there is a failed node in the network, the shipping schedule located at the failed node is lagged or postponed, which in turn affects the subsequent path selection once again. In this way, the risk evolution process in the liner shipping network is identified.

The remainder of this paper is structured as follows: Section2 reviews scholars' research on liner shipping network modeling and other areas of network cascade failure processes. Section 3 presents the theoretical background and research hypotheses. Section 4 describes the network model based on schedule data, the path selection model based on the shortest voyage with the least number of transits, and the cascade failure model. Section 5 provides an empirical analysis. And the results of the analysis are discussed in Section 6. Lastly, section 7 describes the limitations of this paper and directions for future research.

2. Literature

Graph theory is used to quantitatively analyze the topology of the traffic network (Garrison et al.,1994). In the field of transportation, the application of network research methods can effectively identify the importance of nodes and the relationship between nodes, and provide new ideas for data mining for transportation and trade research (Guan Q et al.,2016).

2.1 Network model building

The network modeling in the complex shipping network mainly takes the port as the node and the route between the ports as the edge. In the existing studies, the data types of network modeling are divided into AIS data modeling (Pallotta G, 2013) and route data modeling (Xu M. et al,2020). The former relies on automatic ship identification technology, which is a method of building a shipping network based on trajectory data. This method uses trajectory clustering and speed identification to identify the connection between ports (Peng Peng, 2020) and construct a marine transportation network. Using route data published by global liner companies to build a transportation network is another way of modeling. It uses complex network theory to analyze the topological characteristics of nodes and edges, mainly including degree, centrality, betweenness, network average shortest path, network efficiency, and other indicators (Hu Y and Zhu D, 2009).

Compared with the key information extracted from the AIS data and route data, the shipping schedule data includes the port adjacency relationship in the route, and the arrival and departure time information also(Christiansen M. et al., 2020). Otherwise, shipping schedule data has higher stability and more convenient access (Xu M. et al,2020). Shipping schedule data can be used as the basic data for building the liner shipping network. On the other hand, the shipping schedule is a ship sailing plan designed according to a given port, container ship, and cargo transportation demand forecast (Christiansen M. et al., 2020). Contains the future operational state of this network. As a sailing plan, although there is a deviation between the ship's arrival time and the schedule of the ship, under normal circumstances, this deviation can be estimated (Song Y T and Wang N, 2019).

In the liner shipping network constructed based on ship schedule data, its nodes carry time attributes. The liner shipping network in this paper is evolved from the classical complex network and is suitable as the subject of study for cascade failure model. Applying the cascade failure model to such a strongly planned network will help the risk control department to a certain extent to identify the systemic risks arising from unexpected events. For example, after the occurrence of a corridor contingency, which port nodes will be congested in the future without adjusting the vessel call schedule, and the impact range, start time, and duration of such incidents can be initially perceived by the model.

The traditional typology of complex networks helps people understand the network characteristics of real networks from an abstract concept, but few studies mention the relationship between space and time in complex networks (César Ducruet et al.,2020). Our study is a new attempt to study the characteristics of liner shipping networks from a spatial and temporal perspective

2.2 Cascading Failure Model

Cascade Failure Phenomena from Internet Complex Networks and Power Complex Networks. The exchange of information or energy between node pairs is always completed through the shortest path on the network, and each transfer will create a "load" on the nodes on the shortest path (Adilson E. Motter and Yingchen Lai, 2002). Cascading failure means that one or a small number of elements in the network cannot be used due to failure, causing the redistribution of traffic or load in the network, which in turn causes other nodes to collapse and fail due to excessive load, so that the failure gradually spreads, resulting in a cascading effect. It may eventually lead to the collapse of some nodes in the network or even the entire network.

The cascade failure model is a classical model for studying the risk propagation process in complex network systems. Cascading failure models can effectively sense the load changes of each node in the network during risk propagation. There are more studies on the cascading failure phenomenon in the road network, rail network, and aviation network, but fewer in the liner shipping transportation network.

In terms of road traffic, the failure of some key road sections or intersections will cause successive failures of other road sections or intersections, resulting in a chain reaction that eventually leads to the paralysis of the entire traffic network (Wu Jianjun,2008). An improved mesoscopic traffic flow model, starting from the queue model, speed model, and vehicle movement model, uses the simulation process to study the dynamic characteristics and propagation laws of congestion in complex networks (Li Shubin and Zheng J, 2013).

There are differences in the process of cascading failures between different networks (Joel Cumelles et al.,2021). Combined with the characteristics of air transportation, the author takes the airport processing capacity as the node load, and the take-off and landing of aircraft between airports as the cause of congestion spread, and studies the cascading failure process of air transportation caused by the epidemic.

Scholars cited the load-capacity model of Motter et al. and considered that in the initial, normal state network, the number of times the shortest path of all node pairs passes through a node is the initial load of the node. The initial load of a network node has a strong correlation with the maximum load capacity of the node, and the maximum capacity of the node is usually characterized by a tolerance coefficient. In the transportation network, this explanation is reasonable, because the "passengers" in the transportation network always tend to choose the "shortest path" (Christopher Dirzka. and Michele Acciaro. 2022), and the tolerance factor considers the elasticity of the nodes in the real network to handle the load.

But in these studies, when a node or edge fails, the node or edge is usually removed and never recovered. However, nodes in the network are often in an intermediate state between "normal" and "failed". For example, in the transportation network, there are not many situations in which the traffic intersection is unavailable, and the failure of the node is only characterized by the slowing of the vehicle speed in a certain period, certain road sections, and certain nodes. So, in our cascade failure model, we consider the resilience of the port node.

3. Theoretical background and research hypotheses

The liner shipping network in this paper is a space-time channel formed by container ships navigating between ports. Cargo transportation is the process of movement of goods in this space-time channel. The change in the shipping schedule affects the composition of the time-space channel, thus changing the shortest path in the network and causing the load of the port node to change. Through the measurement of node load changes, the estimation of node failure is realized. When an emergency occurs in the channel, some shipping schedules are delayed, which in turn affects the transportation plan, resulting in the transfer of the original port node load, and some ports are congested because the load exceeds the load handling capacity.

The research hypotheses are as follows: Container ships sail between ports in strict accordance with the sailing schedules issued by liner companies. Container ships are not disturbed by other factors during the voyage except for channel disruptions and port overloads. The carrier always chooses a new route based on the principle of the shortest sailing time and the least number of transits.

4. Methodology

4.1 Liner Shipping Network Model

$G(V,E)$ is the classical liner shipping network model, contains only spatially connected relationships between nodes. This study built a liner shipping network based on shipping schedules as $G(V^{moment},E^{time})$. V^{moment} represented a collection of nodes with time attributes. E^{time} represented arcs between nodes, recorded the time of leaving schedules node, the time of arriving at another node, and the connection between nodes. Different from the classic complex network of routes, the time factor was considered in the liner transportation network in this paper. Figure.1 presents the difference.

$$V^{moment} = \{v_1^T\} \cup \{v_2^T\} \cup \{v_3^T\} \cup \cdots \cup \{v_{port}^T\} \tag{1}$$

$$v_{port}^{T} = \{v_{port}^{t1},\ v_{port}^{t2},\ v_{port}^{t3},\ \ldots,\ v_{port}^{tn}\} \tag{2}$$

Another ship schedule data set is $P = \{p_1, p_2, \ldots p_n\}$, the ship schedule topology was a chain graph of points and lines, $p_n = (v_{p_n}^{T}, e_{p_n})$, $v_{p_n}^{T}$ represents the set of ports with time attributes in the shipping schedule P_n, e_{p_n} is the connection between ports in the shipping schedule p_n,indicated that the ship leaves the port v_1 at time td_1, and arrives at port v_2 at time ta_1, which indicated the ship sails between ports.

$$e_{p_n} = \overrightarrow{v_1^{td_1} v_n^{ta_1}} \quad t_1 > t_2, v_1^{td_1} \in p_n, v_n^{ta_1} \in p_n,\ v_1 \neq v_2 \tag{3}$$

4.2 Path Selection Model

The shortest path problem for all pairs of nodes is central to the study of complex networks, but there was little literature explaining shortest path algorithms in large-scale networks. With the continuous improvement of complex network theoretical research, there are currently complex network research tools for the measurement of complex network characteristics.

For example, the UCNET measurement method and the complex network analysis tool based on the MATLAB function package can input the network topology relationship matrix and weight adjacency matrix, and then the corresponding results can be analyzed. However, the existing software analysis functions cannot meet the calculation requirements of this paper, which are mainly reflected in the difference in the data volume and the particularity of the data structure. First, the traditional complex network model has a small number of nodes and OD relationships, and a single node is unique in space and time, and the time complexity of the solution meets the basic analysis requirements. However, the complex network in this paper considers the time attributes of nodes and a port node that needs to be divided into multiple nodes with different timestamps. From the time complexity of the algorithm, the time complexity of the classical algorithm is too high, which does not meet the research requirements. (Take Floyd's algorithm as an example, its complexity is 1045497^3. Floyd's algorithm is the main algorithm for solving the shortest path of all pairs of nodes in the network.) Second, the shipping schedule data in this paper was based on EXCEL. The OD data in the table is a sparse graph, the matrix method was difficult to store such a huge node pair relationship. Therefore, we developed a model to solve the shortest path between nodes in the liner transportation network, starting from each port at each time and arriving at any other port with the shortest sailing time.

In the liner transportation network, the shortest path was divided into two types: direct and transit paths. For the direct route, we used the construction method of the P network to extract the direct route in the shipping schedule. When two ports are on the same shipping schedule, the ports can be directly connected, not limited to two adjacent ports.

In sailing schedule p_n:

$$p_n = \{v_1^{t_{a1}},\ v_1^{t_{d1}},\ v_2^{t_{a2}},\ v_2^{t_{d2}} \ldots v_m^{tam},\ v_m^{tdm} \ldots v_n^{tan},\ v_n^{tan}\} \tag{4}$$

The number n corresponds to the position of the port in the shipping schedule p_n.For each shipping schedule on each route, we had a data set of the original route R_n.We have1995 sailing dates and 1,045,497 data sets are included in the data aggregation.

$$R_n = \left\{e_{v_1 v_2}^{t_{d1} t_{a2}},\ e_{v_1 v_3}^{t_{d1} t_{a3}},\ \ldots,\ e_{v_m v_{m+1}}^{t_{dm} t_{am+1}} \ldots, e_{v_{n-2} v_n}^{t_{an-2} t_{dn}},\ e_{v_{n-1} v_n}^{t_{an-1} t_{dn}}\right\} \tag{5}$$

During the sailing schedule, the ship sails between ports according to the pendulum mode, and there was a situation of $v_m = v_n$, that, the ship passed through the port once in the process of head and return. When $v_m = v_n$, we took a reasonable direct path. In the model, we extracted direct paths based on P-space. Two ports that belong to the same route and satisfy the time window requirement were direct. In the P-space all ports that belong to the same route are connected.

$$e_{v_k v_m} = min(e_{v_k v_m}^{t_{d1} t_{am}}, e_{v_k v_m}^{t_{d1} t_{an}}) \tag{6}$$

$$e_{v_m v_k} = min(e_{v_m v_k}^{t_{dm} t_{ak}}, e_{v_m v_k}^{t_{dm} t_{an}}) \tag{7}$$

$e_{v_k v_m}$、 $e_{v_m v_k}$are the route with the shortest sailing time between ports in shipping schedule. As a special vector, it also contains the connection relations between nodes and the sailing time. In this way, we had all the direct routes in the liner shipping network, which refer to the shortest feasible sailing times between ports.

The transit path is composed of the initial direct path. For any two port nodes v_i in the networkv_j:

$$e_{v_i v_j} = min\left(e_{v_i v_k}^{t_{di} t_{ak}} + e_{v_k v_j}^{t_{dk} t_{aj}}\right) \qquad e_{v_i v_k}^{t_{di} t_{ak}}、 e_{v_k v_j}^{t_{dk} t_{aj}} \in R \tag{8}$$

$$(t_{ak} - t_{di}) + (t_{aj} - t_{dk}) < \frac{\pi d_{ij}^{Manhattan}}{2*15*1.852} \tag{9}$$

$$t_{ak} \ll t_{dk} \tag{10}$$

The shortest path solution for node pairs in the network has excessive transit. We used port coordinates to solve the Manhattan distance of node pairs, and we consider such a path unreasonable when the navigation time in the path is greater than $\frac{\pi}{2}$ times the Manhattan estimated time. We used an economy speed of 15 knots to estimate the travel time at the Manhattan distance. For all departure times of port v_i, we use the above model to solve the transit route with the shortest time. The combined formula indicates that the transfer of the transfer route must be completed at the same port. The sub-paths all belong to the initial dataset R.$t_{ak} \ll t_{dk}$ means that the arrival time of the ship should be strictly less than the departure time of the successive ships to ensure sufficient operating time.

$$R = R + \alpha e_{v_i v_j} \qquad \alpha = \begin{cases} 0, & i \text{ and } j \text{ exist paths} \\ 1, & i \text{ and } j \text{ no path exists} \end{cases} \tag{11}$$

When a node pair finds a new transit path, we update the initial dataset.

4.3 Cascading Failure Model

The initial load of the node is as follows:

$$L_v^0 = \sum_{i,j \in V, i \neq j} {n(v)_{ij}}/{n_{ij}} \tag{12}$$

In a classical complex network, the length between two adjacent nodes is 1. There were multiple shortest paths between any node in the network. In the liner transportation network constructed in this paper, the nodes are ports with time attributes, and the sailing time between adjacent ports is different. There is only one shortest path for goods to depart from any port at any time. In the liner transportation network constructed in this paper, the number of shortest paths between any nodes is always 1. In liner shipping, the absence of loading and unloading operations will not be a load on the port. In a direct route, the route imposes loading and unloading loads on the origin and destination ports. In the shortest route where a transit occurs, the route generates a loading and unloading load on the port it passes through. So we got the load model in the liner shipping network:

$$L_{total}^{v_k^{[ta,td]}} = L_{loading}^{v_k^{[ta,td]}} + L_{unloading}^{v_k^{[ta,td]}} \tag{13}$$

$$\begin{cases} L_{loading}^{v_k^{[ta,td]}} = n(v_{k\to}^{td}) + n(v_{k\to}^{td})_{ij} & i,j \in V, i \neq j \\ L_{unloading}^{v_k^{[ta,td]}} = n(v_{\to k}^{ta}) + n(v_{\to k}^{ta})_{ij} & i,j \in V, i \neq j \end{cases} \tag{14}$$

$L_{total}^{v_k^{[ta,td]}}$ represents the total load of port k in the network from t_a to t_d, $L_{loading}^{v_k^{[ta,td]}}$ is the loading load, and $L_{unloading}^{v_k^{[ta,td]}}$ is the unloading load. $n(v_{k\to}^{td})$ represents the number of shortest paths from port k to other ports at time td, $n(v_{k\to}^{td})_{ij}$ represents. The number of shortest routes for all node pairs in the network to transfer cargo at port k, $n(v_{k\to}^{td})$、$n(v_{\to k}^{ta})_{ij}$ similarly.

In the real liner shipping network, there are cases where the time of ship calls overlaps. The total load per unit time represents the maximum handling capacity of the port for the load. We divided a year into half an hour and conducted interval statistics on the load of ports in the network.

Then, in the initial shipping schedule network, the initial load handling capacity of the port is obtained, and we defined it as the port time interval capacity C:

$$C_{v_k}^{[t,t+30]} = \sum_{i=1}^{n(V_k^T)} \left(\alpha L_{vk}^{[ta,td]} \Big/ (t_d - t_a) \right) \quad \alpha = \begin{cases} 1 & t > t_a \ and \ t+30 < t_d \\ 0, & else \end{cases} \tag{15}$$

The maximum interval capacity of the port represents the load handling capacity of the port. We took the maximum interval capacity of the port as the initial load of the port.

$$C_{v_k}^{0} = max\left(C_{v_k}^{[t1,t1+30]},\ C_{v_k}^{[t2,t2+30]},\ C_{v_k}^{[t3,t3+30]} \dots C_{v_k}^{[tn,tn+30]}\right) \tag{16}$$

In the classic cascading failure model, the nodes always have a certain tolerance and the additional load in the process of cascading failure.

A similar situation exists in the liner shipping network, when ports are overloaded, ports can always handle incoming cargo at a rate higher than normal operating capacity.

$$C_{v_k}^{max} = (1+\beta) C_{v_k}^{0} \quad \beta > 0 \tag{17}$$

After the disruption is added, some nodes are overloaded. This paper considered the resilience of port nodes. At this time, the port handles the load with the maximum operating capacity, the time of the ship in the port is prolonged, and the overall shipping schedule is delayed.

$$\Delta L = L_v^{after} - L_v^0 \tag{18}$$

$$\overrightarrow{P_c^n} = \Delta L / C_{MAX} + (p_c^n)^0 \tag{19}$$

4.4 Algorithm

The following is the pseudocode of the algorithm in this study.

Table 4. Table of pseudo-code flow

(1)	Load the excel sheet and extract the initial path
(2)	Classify the initial route by departure port and arrival port
(3)	Generate a set of paths with the departure port, and generate a set of paths with the arrival port
(4)	Generate node pairs between ports and save node pair dataset
(5)	Delete the direct path in the collection

(6) *When* the node pair dataset is not empty:

Record the number of node pairs at this time

For node pair *in* node pair dataset:

Extract paths in departure port and arrival port sets based on node pair

When two paths can be connected：

Find the feasible shortest sailing schedule combination under the two paths

If a temporary list exists for the current node pair：

Compare the new results with the data in the temporary list, keeping the shortest voyage path

else：

Save to temporary list

When the temporary list is not empty：

Update dataset with save path

Update the dataset sorted by departure port, arrival port

Remove a node pair from the node pair dataset

When there is no change in the number of node pairs in the node pair dataset：

Break

(7) Generate interval tree container

(8) For path in save path dataset:

Use the interval tree container to accumulate statistics on the load on each node

(9) Process the interval tree and record the peak load of each port node as port capacity

(10) （Add disturbance/delay ship schedules）Update sailing schedule, update the shortest path in the network for the time after the path break occurred

(11) identify the earliest node where failure occurs, to step(8) / break

5. Empirical analyses results

5.1 Data

O-Alliance signed a memorandum of cooperation in April 2017. The shipping companies within the alliance have cooperated on more than 40 routes around the world and released jointly operated routes and shipping schedules. We found the routes operated by the alliance and the annual sailing schedule data on the official website of the lead company (OCEANALLIANCE (coscoshipping.com)). The initial data included 155 ports, 74 global routes, and 1,995 voyages. After preliminary processing, we extracted 1,045,497 direct node pair data from it.

5.2 Empirical analyses

In O Alliance's original liner transportation network, the number of direct routes between node pairs is 1,045,497, accounting for more than 95% of the total number of routes in the network. It showed most of the cargoes in the liner shipping network we studied could be transported directly from one port to another. The hub-and-spoke mode of transport in liner shipping is not evident in this network. Because the liner alliance is a transportation organization for maritime transnational business, the routes it opens are mainly trunk line transportation, and the branch line transportation at the end of the trunk line needs to be completed by the branch line ships of other organizations.

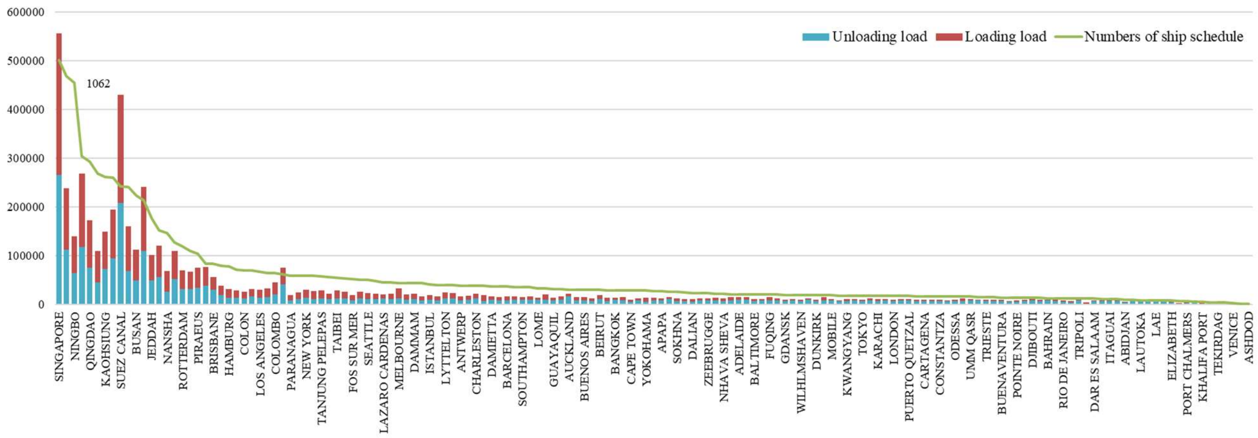

Figure 5.1 Number of sailing schedules and load diagrams at the port in the initial state

Figure 5.1 shows the number of sailing schedules and total load of 155 ports in the O Alliance's liner shipping network in 2020. Ports are arranged in descending order of the number of ship schedules. As shown in the figure, in the port load statistics throughout the year, ports with more ship schedules had more loads, and ports with fewer ship schedules had lower loads. It indicates ports with higher sailing schedules were more often found in the paths chosen by carriers to take higher transshipment business.

However, among the ports with a high number of ship schedules, some of them carried significantly higher loads. To show the hidden port names in Figure 5.1, we zoomed in on parts of the chart. In the liner transportation network of the O-Alliance, the load of Singapore was the highest one. A load of Suez Port is relatively high, which shows that Suez Port also played an important role in the liner transportation network. So as port Klang.

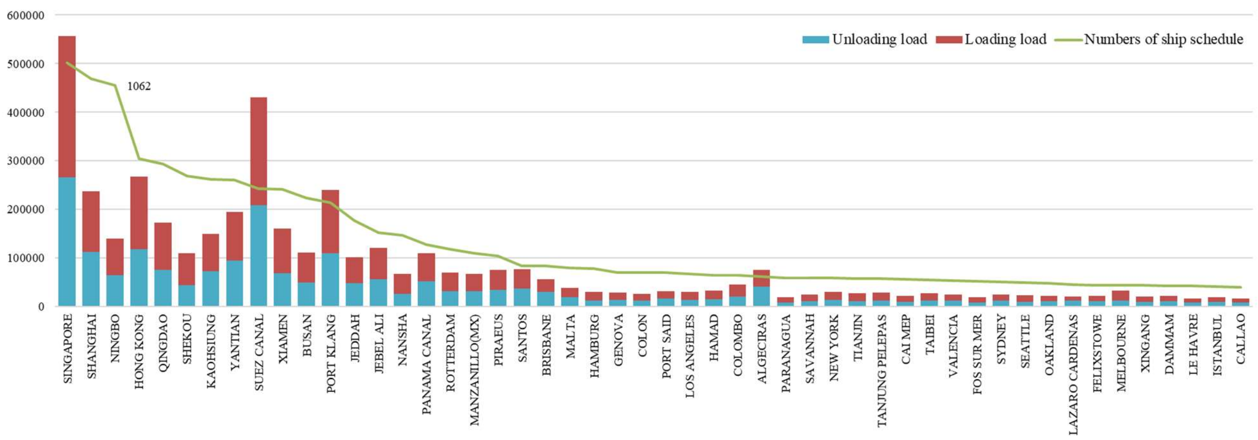

Figure 5.2 Number of sailing schedules and load diagrams at the port in the initial state (Top 50 of the number of sailings)

The performance of Shanghai Port was surprising. Shanghai Port was the second largest port in terms of shipping schedules, and its port load was lower than that of Singapore and Suez. Shanghai Port as one of the largest container ports in China, is an important departure station and destination in the global liner transportation network, it undertook a less transit role. The situation was similar for the top Chinese ports. This shows that China is a major exporter and importer of global trade, and has very different attributes from Singapore. The transportation of liner alliances focuses on the transportation of goods between countries, and port nodes connecting more inter-country transportation take on more loads. The distribution of ports, as shown in Figure 5.3, with the size of the red dots indicating the number of loads carried per unit time in that port.

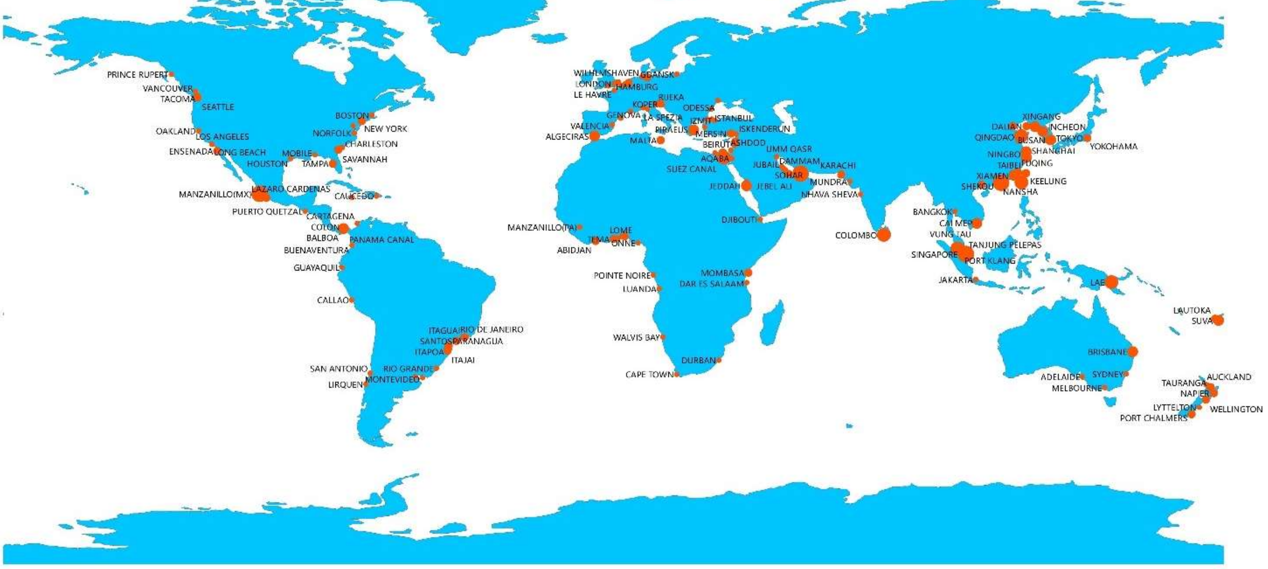

Figure 5.3 Distribution of port nodes based on liner alliance data

In cascading failure models, the node possesses a certain resilience, and the tolerance factor is used to characterize this phenomenon. Define the product of the load in the initial network and the tolerance factor as the maximum carrying capacity of the node, and when the node load does not exceed this capacity, the node does not fail. Conversely, the node fails. When a port is congested, the port will always load and unload cargo at a higher efficiency, so it is reasonable to introduce a tolerance factor in the cascade failure process under study. In the simulation process, we defined the port's tolerance coefficient as 1.1, when the peak load of the port does not exceed 1.1 times the initial load, and the port node does not appear overloaded. In Figure 5.4, We add disruption time at the Suez Canal on March 23rd in the network and increase the intensity of the disturbance by the length of time. Table 5.1 presents segments affected by the disruption of the Suez Canal.

Table 5.1 Segments affected by the disruption of the Suez Canal

Shipping line	The broken connection	Shipping line	The broken connection
AME1	Suez Canal—Piraeus Piraeus—Suez Canal	AEU1	Suez Canal—Felixstowe Piraeus—Suez Canal
AME2	Suez Canal—Malta Beirut—Suez Canal	AEU5	Suez Canal—Rotterdam Rotterdam—Suez Canal
AME3	Suez Canal—Port Said Port Said—Suez Canal	AEU6	Suez Canal—Malta Port Said—Suez Canal
AME6	Suez Canal—Malta Port Said—Suez Canal	GME1	Suez Canal—Port Said Damietta—Suez Canal
MINA	Suez Canal—Malta Damietta—Suez Canal	GME2	Suez Canal—Port Said Iskenderun—Suez Canal
AWE4	Charleston—Suez Canal		

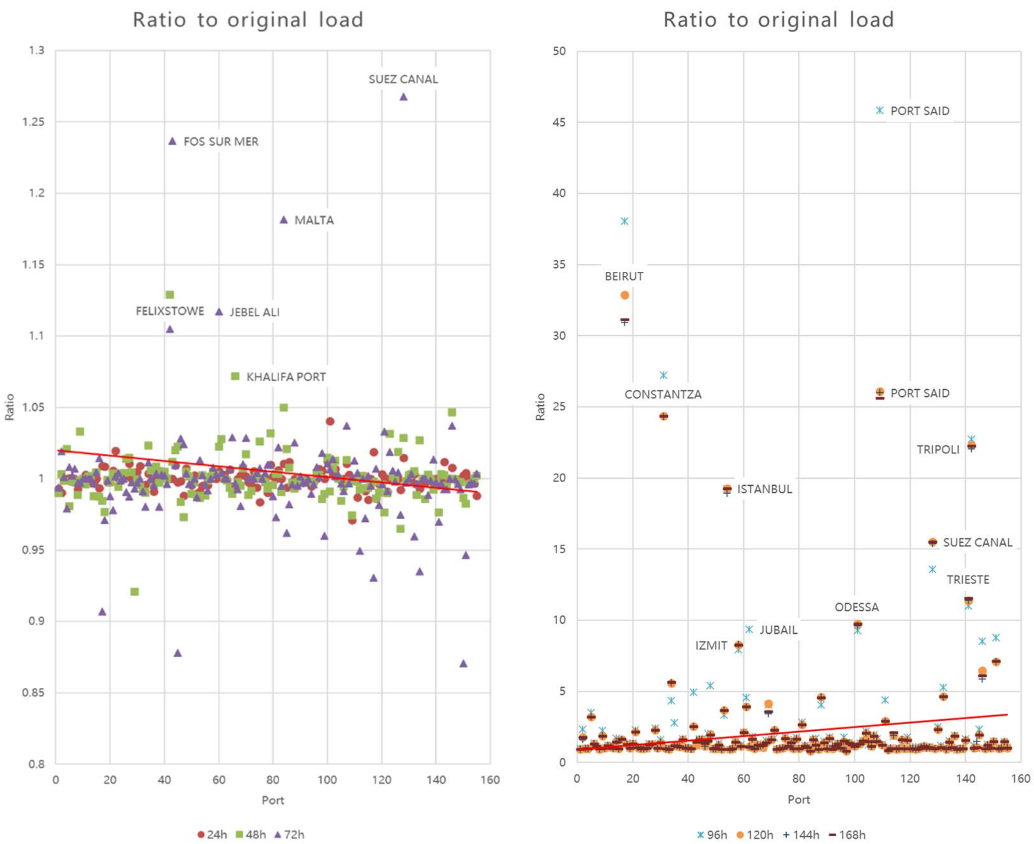

Figure 5.3 Ratio of node peak load to initial load under different disruptions (Ports are sorted in order of initial peak load from smallest to largest)

(1) When the disruption time is 24 hours, the fluctuation range of the peak load of the port does not exceed 5%. As a complex network system, the change in some shipping schedules does have an impact on the entire network.

(2) When the disruption time is 48hours, fluctuations remain low for ports with higher initial peak load. But this time disruption causes a delay in the sailing schedule through Felixstowe, resulting in an overload situation at that port. When expanding the disturbance to 72 hours, Felixstowe, Suez Canal, and Malta which are directly affected by the canal disruption on the schedule are the first to experience fluctuations. As the port at the other end of the route, the port load of Fos Sur Mer also fluctuates. In addition to this, it is easy to see from the trend line on the left that ports with higher initial loads have a weaker performance in terms of overloads in disturbances. Conversely, the port with a low initial peak load fluctuates more. It indicates that the anti-disturbance capacity of the port nodes at this stage is positively related to the capacity of the port to handle cargo.

(3) When the disruption time is extended to 98h, 120h, 144h, 168h, a sudden change in port node overload occurs. It indicates that the disruption of the channel within a certain time is controllable, and when the disruption time exceeds a certain critical value, the network will be paralyzed in a large area. At this time the scatter plot has a similar graphical shape. As the disruption time increases, the similarity is more obvious. The increase in channel outage time affects specific ports, and these specific ports are likely to be critical to recovering the network from the system level.

In the cascade failure process we studied the case when the port tolerance factor is 1.1：

(1) When the interference is added to 24 hours, each node in the network is not overloaded in each period.

(2) When the interference is added to 48 hours, Felixstowe is overloaded from 28/3 7:00-29/3 23:00 when the disturbance is added to 48 hours. The overloaded schedule is only one voyage in the 0AEU5 route. In the current

schedule, the ship's time in port is extended by 1 hour. In the new traversal, the liner shipping network is in a balanced state during the year, and there is no overload of port nodes. The voyage between Felixstowe Port and Suez Port is about 9 days. Because of the long distance, this impact is not directly caused by the congestion of the passage during the sailing period. Considering the preference of cargo owners, the reason for the short-term increase in load is that some cargo owners chose a new transportation route after receiving the congestion information of the Suez Canal.

(3) When the disturbance is added to 72 hours, the Suez port is overloaded from 26/3 11:00-26/3 18:00. At this time, the peak load is 126.5578/half hour, of which the unloading load is 42.4512/half hour, the loading load is 84.106592/half hour, and the 5 voyages on the 0AEU5, AEU6, GEM1, GEM2 and MINA routes are concentrated in port operations.

Because the port is overloaded, ships spend more time in port, their schedules are delayed, and subsequent ships arriving in port delay their schedules because of the wait. So, we carry out a new load measurement after the sailing schedule is adjusted, at this time the overload in the network appears at the port of Fos Sur Mer. The overload time interval is 3/30 7:00-3/30 23:00, the overload load is 6.1/half hour, of which the unloading load is 3.531/half hour, the loading load is 2.563/half hour, and the port initial load is 5.25 / half an hour, the ship's time in port is delayed by 3 hours, and the port load is normal.

Then the overload appeared in the port of Le Havre, the overload time was 4/2 21:00-4/2 22:00. Overload load is 10.84/half hour, of which unloading load is 2.27/half hour, loading load is 8.568/half hour, initial load is 9.55/half hour, of which unloading load is 4.90/half hour, loading load is 4.65/half hour. The two voyages of the AEU6 and ESE1 routes are delayed by 1 hour, and the port load returns to normal.

After updating the shipping schedule, the port Fos Sur Mer was overloaded, the overload duration was 4/15 6:00 -4/16 18:00, the overload load was 5.847/half hour, of which the unloading load was 1.055/half hour, and the loading load was 4.792 / Half an hour; a voyage on the AME1 route is delayed by 2 hours, and the overload disappears. At this point, the network has returned to normal, and the port node overload has disappeared.

After updating the network, SUEZ was overloaded again. The overload time was 4/22 23:00-4/23 00:00. The overload load was 115.288/half hour, of which the unloading load was 56.0322/half hour, and the loading load was 59.2562/half hour. The affected routes are still 5 voyages on 0AEU5, AEU6, GEM1, GEM2, MINA, and the ship's time in port is extended by 2 hours. Port node overload disappears.

(4) When the interference was added to 96 hours, 97 ports in the liner shipping network were overloaded in the new shipping schedule network. A total of 7922-time segments were overloaded with port nodes. At this time, the liner shipping network collapsed. The changes are more complex and further research is needed.

6. Discussion and implications

There are differences in complex networks constructed based on two types of data. In the route-based liner network design, a feasible shortest path can always be found between any pair of nodes, and the topology index does not consider the feasibility of the network itself in reality. In the liner transportation network based on the shipping schedule, some node pairs have no feasible paths in the middle because of time windows.

Ports with strong operational capabilities have more intensive sailing schedules. Because of their connectivity advantages, such ports often assume more roles in transshipment operations. Unexpectedly, among the top ports in the world in terms of throughput, Shanghai Port, Tianjin Xingang Port, and Qingdao Port do not have an outstanding load. Considering the actual situation, these ports are located in China, and China is a big import and export country. Although there are ports with a high density of shipping schedules, they are not important transit ports in the world.

As the interference continues to increase in the liner shipping network, more and more nodes are affected in the network. Ports with high shipping schedule density are less affected, while ports with low shipping schedule density are more affected. As the interference intensifies, the overload is transmitted from the interference point to both ends, eventually leading to the overload of the entire network load.

In the process of cascading failure, the impact of disruption always travels along the route. Under weak interference, the overload transmission disappears in the port near the interference, indicating that the repairability of the port itself has a certain repair effect on the overload. As the interference increases, the interference will disappear in ports with stronger capabilities during the transmission process, but it will intensify in some ports with weaker capabilities. After some time after the current port is overloaded, the overload will be triggered again. In addition, the occurrence of loads is often accompanied by changes in node functions, such as changes in unloading loads and loading loads in some ports. The reason is that the delay of shipping schedules improves the continuity between shipping schedules and increases the number of feasible paths.

To sum up, the cascading failure phenomenon in the liner transportation network has certain regularity. After an emergency occurs, restoring the shipping schedule, increasing the port schedule density, and relieving the load pressure of large ports are the key measures to prevent the disturbance from causing greater impact.

7. Limitations and directions for future research

Because of the limitation of the data itself, this paper does not consider the limitation of ship capacity in each ship period. The inclusion of capacity coefficients in future studies will yield more accurate results. In the cascade failure section, the ship schedule lag situation caused by disruptions is still evolved using a manual model, which is still inadequate in performing simulations of complex situations. The research in this paper is costly. We are not computer science majors, and the implementation of algorithms is the biggest challenge we face. The digitization of the network model with temporal properties, the shortest-circuit algorithm for all node pairs in large-scale complex networks considering time windows, the cascading failure process coding, and the statistical algorithm based on interval tree technology did not have readily available results to use, and the development and debugging of the algorithms took nearly a year of their own time. Secondly, the time cost of the simulation was high, and each simulation took several hours due to computer hardware limitations, not the least of which was the interruption of the program that had been running for several hours resulting in data loss due to negligence. We realized that maybe we should leave the professionals to the professionals. In addition, more powerful complex network algorithms are likely to be the future research direction.

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Evaluating 'Kahoot!' for Maritime Higher Education Courses

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Abstract

- Purpose

  In order to improve students' learning interest and motivation, and to do so through studying an area not before studied, the purpose of this study is to complement existing literature into online learning tools and investigate the implementation effects (e.g. feedback and suggestions from the users) of introducing Online Kahoot! Tests in the Maritime Case Studies Research Course in higher education in Taiwan.

- Design/methodology/approach

  Following the participation of 43 undergraduate students' participation in the Kahoot! tests (including true-false questions and multiple-choice quizzes),10 of these students following random sampling, were invited to participate in qualitative semi-structured in-depth interviews.

- Findings

  Findings show average correct rates were 74% and 70% for true-false questions and multiple-choice quizzes, respectively. Regarding interviews, most interviewees thought Kahoot! testing of benefit and that suitable incentives (e.g. course credit) could engage students in learning. Nevertheless, some years of students were more positive than others, and many had suggestions for not overusing Kahoot! Or for its further development.

- Research limitations/implications

  Interview samples were limited to those who registered for the course in our study.

- Practical implications

  The research findings can help teachers and decision makers in higher education and think about how to effectively implement online Kahoot! teaching and related online platform in the future.

- Social implications

  The contribution of this study help maritime education and practitioners rethink how technological tools (e.g. Kahoot) can impact on learning environment and adjust education training procedures, materials, and implementation procedures.

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- Originality/value

  Kahoot! application in the port or shipping related course of higher course is very limited. This study has presented an original empirical study based on qualitative approach and implementation procedures can be further applied in other universities and countries.

1. Introduction

Much Research has noted the changing face of education in the maritime industry (Demirel and Ziarati, 2013). In Taiwan, there is a call in recent literature for the quality of teaching to be improved and for greater involvement from industry in maritime education, for example through joint industry-academic and innovative lecture series (Hu, 2008). It is particularly important at a university level for individuals to continually retrain in order to remain abreast of recent professional developments in the industry (Ng et al., 2009). Further, to conduct more research to understand undergraduate students' motivations (Pallis and Ng, 2011), there are a plethora of new teaching methods to improve learning performance, such as innovative technological applications. In terms of the continually shifting nature of the industry and how academia responds, some research notes the onus to be on the higher education institutions to keep abreast of the latest developments in the industry and to ensure their courses are up to date (Ng et al., 2009). The advent of COVID-19 and the need to carefully assess the efficacy of any new technology is also a key requirement (Christopoulus and Sprangers, 2021). In Taiwan, during serious COVID-19 pandemic period (since May 2021), most universities have started to adopt various online teaching methods (e.g. google meet, Tronclass, Kahoot, Microsoft team, etc.) to replace (and presumably later complement) traditional physical face-to-face teaching. Such online teaching facilities and a familiarity with them has been increasingly emphasized by education researchers after Covid-19 occurrence (Dhawan, 2020). Previous studies in the maritime education fields have used a range of methods to research the efficacy of pedagogical interventions. Generally such studies use quantitative methods (Tseng et al., 2018; Tseng et al., 2020), although more qualitative methods such as semi-structured interviews are also used (e.g. Gekara, 2009). The training subjects of maritime education in higher education cover much professional knowledge, such as liner shipping, tramp shipping, the cruise industry, port operations and management. The content of each teaching unit involves managerial strategies, engineering planning and evaluation, financial and cost analysis, and other topics. The teaching process needs to proceed in an orderly way and in incremental stages so as to ensure students understand each stage before progressing. To facilitate this, traditional learning evaluation methods often adopt paper-and pencil tests (e.g. quiz, mid-term exam or final exam). However, such evaluation methods may lack learning fun and can not effective identify student's true learning outcome due to the fact that most students always study hard the night before the exam and might forget the testing content after a short time. Also, teachers and students always pay attention to what is the correct answer and are seldom concerned why the wrong answer(s) can not be chosen in the testing content.

In a Taiwanese context, and internationally (Crompton and Burke, 2018) cell phones are a popular phenomenon in the higher education lecture when students can not concentrate on teaching content if the course is boring or difficult to understand, and students often text during lectures and even in exams (Tinder and Bohlander, 2012). Also, students might use their cell phone to chat or look around for non-course information or play on-line games. To date, research on how to address such usage head-on in the classroom is still limited, especially in higher education. In order to fill past research gap and enhance teaching strategy of maritime education, this value of study is to explore student's perception regarding the technology adoption promotion of the courses. Technology adoption in the course have gradually emphasized and could bring positive effects (Qu and Dumay, 2011; Arkorful and Abaidoo, 2015; Popovici and Mironov, 2015; Wu and Lu, 2015; Ngampornchai and Adams, 2016; Chen et al., 2017; Makashina and Filatova, 2017; Alhabeeb and Rowley, 2018; Al-Fraihat et al., 2020; Alomran et al., 2020; Phutela and Dwivedi, 2020; Karkar et al., 2020; Jin et al., 2021). In recent years, Kahoot! has become a popular phenomenon in the education systems in the world and has been verified as a useful teaching software that can improve teaching qualities through interactive feedback since it can improve traditional one-way teaching methods (Baydas and Cicek, 2019; Prieto et al., 2019) (Figure 1). Kahoot! was launched in 2013 and is a game-based response system that can make use of blended learning. Notably, Kahoot! addresses the issue of mobile phone usage head-on as it encourages students to use their cell phones to actively participate in the course content review and test. Thus, if they are using their phones in this way, this reduces the amount of time they can be using them for other purposes, as well as help engage them in the courses being studied.

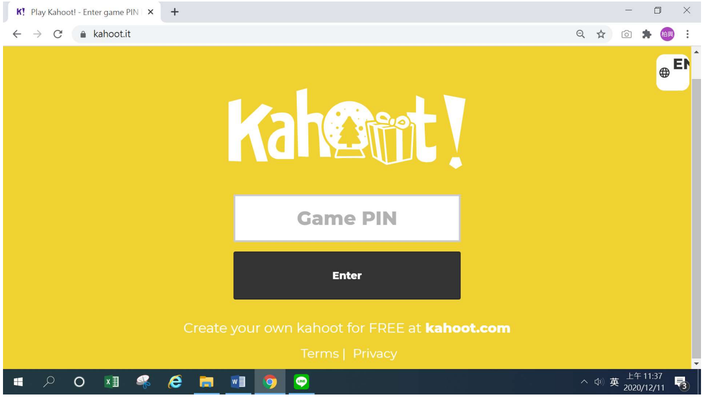

Figure 1: Kahoot! website
Source: Download from Kahoot! official website

Kahoot! can create quizzes made from a series of multiple choice quizzes and allows for the addition of multimedia instruments (e.g. pictures, diagrams, etc.) to the questions to strengthen engagement (Aktekin et al., 2018). Such a digital teaching tool can reduce learning barriers and increase students' learning motivation via a game-based response system (Wang, 2015; Han and Lu, 2019; Li and Wong, 2019; Mei et al., 2019; Zainuddin et al., 2019). Nevertheless, some research finds that although Kahoot! has many benefits for learning, some barriers and obstacles (such as the lack of a reliable wifi connection) can adversely impact on its success (Wang and Tahir, 2021). However, it is argued that not all students, teachers, and related staff comprehensively understand Kahoot! in the university and then use it in the learning procedure and teaching method improvement. In order to improve students' learning interest and motivation, the purpose of this study aims to investigate implementation effects of introducing Online Kahoot! Tests in the Maritime Case Studies Research Course in higher education in Taiwan. It is against this context that this study reports an evaluation of the impact of using Kahoot! iat National Taiwan Ocean University in Taiwan during September 2021-January 2022. Due to the fact that students might have different experiences regarding using Kahoot!, the usage difficulties, challenges and potential suggestions (or comments) from the Kahoot! Users for improving teaching quality were investigated in the interview questions and then considered in the findings. Also, in order to strengthen the learning motivation, key maritime practical information was introduced in the courses (e.g. Suez canal congestion, Impact of COVID 19) in order to bridge the gap between academic theory and practical works.

It is hoped the research findings can also help improve pedagogy on maritime course and adjust online platform application strategy based on students' feedbacks (Pallis and Ng, 2011). Our study sheds light on such matters from qualitative interview analysis that is then explored in depth with students in the course, and complementing studies already done with technology adoption teaching issue (e.g. Pallis and Ng, 2011), and specifically in relation to reviewing the success of Kahoot! (Wang and Tahir, 2021). The remainder of the paper is as follows. Section 2 reviews literature related to Kahoot! and similar techniques. The rationale and procedure for the methodology of using in-depth interviews is provided in Section 3. Research findings are presented in Section 4. Finally, Section 5 discusses these results and draws conclusions for others when using Kahoot!.

2. Literature Review

Kahoot! is a learning web-based original interactive product from Norway. The rapid increase in the availability of interactive technologies (e.g. Kahoot!) has contributed to the development of higher education. This has coincided with and been catalyzed by the Covid-19 context forcing much teaching to go online. This has necessitated a changing face of education for the maritime industry (cf. Demirel and Ziarati, 2013), particularly important given the need to remain abreast of maritime developments (Ng et al., 2009) and the increase of English Medium Instruction in Higher Education worldwide (Hendriks et al., 2018) and specifically in the maritime field (Tseng et al., 2018; 2020). It is not so much the case that traditional methods are in any way inadequate or inefficient, rather, that the necessity for them to be complemented with online tools given recent developments has come to the fore, and to do so in an English Medium. Kahoot! is one of many tools teachers can use to do this; in both traditional and online classrooms. Kahoot! Was chosen for a number of reasons. Firstly, enables teachers to create on-line questionnaires for students to answer these with their digital devices (e.g. smart phone or tablets) (Dellos, 2015; Lichrish et al., 2018). Secondly, Kahoot! is free to use and there are no limits to the number of questions that can be asked. The question designer can also integrate images and sound backgrounds to enrich the questions. After the designer has compiled the questions and system will create a PIN code. Then the user(s) can login the Kahoot! after filling the PIN code and user name(s). Then the user(s) can login the Kahoot! after filling the PIN code and user name(s). Kahoot! can provide immediate feedback on each answer, affording the promotion of reflective learning in formative assessment tasks. Also, Kahoot! allows teachers to identify particular challenges in student learning and take appropriate measures. It is argued that overall Kahoot! can increase students' engagement, motivation and learning (Prieto et al., 2019; Wang and Tahir, 2021) despite the existence of issues that need to be managed such as student's possible fear of losing and technical issues (Wang and Tahir, 2021). Another issue that arguably needs to be managed is that of preventing students' ability to commit material to long-term memory through any Cognitive Overload created by a need to focus on both Kahoot! and the material being taught (cf. Kirschner et al., 2006)

When implementing Kahoot! test, the teacher can set up appropriate time-limit for each question and suspenseful music and then make keep competition alive and make learner engaged it. Students answer the questions displayed at the front screen of the classroom on their personal cell phone. The faster someone answers a question correctly; the more points they get. After finishing each question, right or wrong feedback is provided on student's devices (e.g. cell phone) immediately. In general, the top three highest point scorers are displayed at the front screen of the classroom. The ultimate winner is shown at the end of game. The question can be used for formally evaluate the knowledge of each student in the classroom. Kahoot! has been researched and applied in many fields, such as teaching (Grinias, 2017; Bicen and Kocakyun, 2018; Guardia et al., 2019), English learning (Mahbub, 2020), medical education (Ismail et al., 2019; Tewthanom, 2019), learning technology (Wang, 2015; Cameron and Bizo, 2019), vocational high school (Ratnasari et al., 2018), maritime English teaching (Sartini, 2020), and information education (Baydas and Cicek, 2019; Lee et al., 2019; Liang et al., 2019). Even though significant benefits are mentioned above, some challenges remain (cf. Wang and Tahir, 2021). For example, when finishing the Kahoot! test, the teacher and students can only see the top achievers, whereas low-performance students are not displayed in the classroom. Whilst this does not identify students who not performing well and thereby avoids any loss of esteem, it concomitantly means that the teacher cannot ascertain which students may be struggling and need help. Also, students' testing results can not be accumulated over time since each Kahoot! test needs to create a new account. Thus, the teacher can not effectively evaluate each student's performance over time. These problems could be further improved in the future.

Kahoot! itself can also be seen as being located in the wider context of 'Gamification.' The term 'Gamification' itself often features in Interaction Design or Playful Interaction as a means of enhancing user engagement and productivity (Magnusson and Sobolewska, 2018) and aim to incorporate 'Gaming' into traditional activities. Such techniques are used in a wide range of industries including education (Code Academy, 2017), army recruitment (Cousineau, 2011) and also in healthcare (Garett and Young, 2019). Nevertheless, Gamification is not without its potential drawbacks, and one of these is the finding that it can increase workload for both students and staff (e.g. Siemon and Eckhart, 2017).

With regard to Kahoot!, much research locates Kahoot! in the context of Gamification, and finds it to be successful as a pedagogical tool. In Spain, Ares et al (2018) recognise Kahoots! as a gamification tool and reviewed its use in a university Chemistry course. Using two different groups of students with frequencies of Kahoot! usage, they found that the gamification elements of Kahoot! led to the observation that there had been a prevalent improvement in student learning and marks for students who had achieved a better Kahoot! performance. In a Turkish context, based on 65 undergraduate students' interview questions (e.g. general perspectives about gamification, the effectiveness of Kahoot, the advantages and disadvantages of gamification, and the opinion of students at the end of the application based on their experiences), Bicen and Kocakoyun (2018) investigated the use of gamification approach in the form of Kahoot! in developing student motivation in the Department of Pre-school teaching. They found increased student interest, ambition and motivation for student in the classes where Kahoot! was used. Based on questionnaire analysis data with five-Likert scale for attitude and perception of Kahoot, Lin et al. (2018) conducted student surveys of student use of Kahoot! in 14 week lectures on theoretical and practical dimensions of a English for the Media course in the University Sains Malaysia, Malaysia. Survey data (51 respondents) on the whole, indicated that the students found Kahoot! to be beneficial in terms of: 1) inducing motivation as well as engagement, and 2) fostering and reinforcing learning (for both theoretical and practical aspects).

From the comprehensive perspective of online teaching, the COVID-19 pandemic has catalyzed a shift effect from face-to-face to online teaching and learning in colleges and universities across the globe (Scherer et al., 2021). Hofer et al. (2021) provided some insights (e.g. students' and teachers' knowledge, skills, and attitudes regarding learning and teaching activities) on online teaching and learning in higher education. Yuan et al. (2022) compared 31 teachers' and 145 students' perception of online teaching and learning in Hong Kong education during the COVID-19 pandemic. Their results suggested teachers should not be overly concerned with any potential embarrassment of using cameras and should pay more attention to feedback delivery. El-Soussi (2022) interviewed four university faculty members and explored the impact of the shift from face-to-face teaching to online teaching due to COVID-19, and recommended that online instruction knowledge (e.g. pedagogical, technical and administrative expertise) needs to be carefully created and facilitated in order to develop effective online learning experiences.

3. Methodology

The context of the study and its aim is that during September 2021-January 2022, Kahoot! was applied in the "Maritime Case Studies Research" course (an elective course) at the National Taiwan Ocean University which is the largest shipping management department of higher education in Taiwan. A total of 43 undergraduate students (including 21 senior, 10 junior, and 12 sophomore) registered for and completed this course. The teaching schedule covered 18 weeks, including mid-term exam (week nine) and final exam (week 18). In the first week, Kahoot! and its functions and testing methods were introduced. Then, Kahoot! tests were implemented once every two weeks. The course syllabus addresses offshore wind power, maritime safety, green shipping, maritime piracy and special case issues (e.g. Suze canal congestion). This academic content knowledge is also applied to solve practical maritime problems. The Kahoot! questions included true-false questions (e.g. Knot, Hull & Machinery Insurance, Protection & Indemnity Insurance, Ransom, No cure No pay, General average, United Kingdom Marine Trade Operations (UKMTO), Piracy, International Maritime Bureau, etc.) and multiple-choice quizzes (e.g. Bill of Lading, shipping strategic alliance, flag of convenience, hub & spoke, customs, immigration, quarantine, security, vessel traffic system, Blockchain in the shipping industry, International Ship and Port Facility Security Code, etc.) to review key points during the last 10 minutes of the class. Before formally implementing the Kahoot! test, in August, 2021, prior to the course starting, the Kahoot! questions were reviewed by five senior maritime practitioners and five academic teachers with Kahoot! experience to ensure the questions were appropriate. The results of students' answers were further analysed to identify learning performance. Also, incorrect answers were analysed in order to understand why these answers are chosen. If the Kahoot! testing results were not high overall, the key points were reviewed for students to help improve their learning performance. In sum, seven iterations of Kahoot! were implemented and each included 21 true-false questions and 21 multiple-choice quizzes. For every week, the students who achieved the ranking top three achieved extra credits for their course grading for the semester. Whilst the quantitative results from these iterations provide key data on the effectiveness of Kahoot! at a level of achievement and grading (see Appendix), they do not provide any information on students' perspectives or experiences of using Kahoot! To gain such perspectives and experiences a more in-depth and qualitative investigation was necessary (Hammersley, 2013).

Consequently, after the semester, and in mid-January 2022, to conduct this qualitative investigation, we randomly selected 10 students (three sophomore, three junior, and four senior) who had undertaken Kahoot! tests and conducted in-depth qualitative interviews (Denzin and Lincoln, 2011). Whilst not a large sample, the theory from the findings can be generalized for comparison to other contexts (Flyvbjerg, 2006) and is therefore significant. To generate data that could be analysed in line with previous literature and findings and in order to understand students' opinions (e.g. including feeling, effectiveness, difficulties, challenges, fair credit evaluation, comments and suggestions) and explore potential reasons when using Kahoot! tThe interview questions focused on the perceived effectiveness of Kahoot!, specifically it's effectiveness compared to traditional methods (cf. Hofer et al., 2021), and the effectiveness of Kahoot! as a technology and pedagogical tool (cf. Lin et al., 2018). The questions were designed to help achieve the study aim of evaluating the effectiveness from a pedagogical perspective of the implementation of Kahoot! (see Appendix, Table 1). These questions were:

- "Were you happy when the teacher implemented the Kahoot tests in the course? Why? / Why not?"
- "Did you think adopting Kahoot tests in the course is more effective than previous approaches? Why? Why not?"
- "What are the difficulties or challenges using Kahoot?"
- "Do you think focusing on the technology to use the actual Kahoot tests made it difficult for you to focus on the actual content of the course?"
- "Did you think is it fair when the teacher adopted the score of Kahoot tests to be the parts of course credit? It means the students who have higher test score in Kahoot test will get better scores in the credit evaluation in the end of semester"
- "Do you have any other comments or suggestions about the Kahoot tests in this course? Particularly if you think about them compared to other methods and whether these would be more effective?"

We gained ethical approval for the interviews first from the relevant bodies (Christians, 2011). We recorded the interviews and transcribed them ourselves (Bird, 2005). The interviews in Taiwan were conducted in Chinese for ease of participant communication (Cortazzi et al., 2011). Translation is done from Chinese to English using a Skopos approach to attain as close a meaning as possible to the intended one (Mei, 2018). The interview transcripts were analyzed using a thematic approach (Braun and Clarke, 2006), specifically by the themes of transcription; reading and familiarization, coding and searching for themes, reviewing the themes, defining and naming the themes, and finalizing the analysis (Braun and Clarke, 2013). The three themes that emerged from this thematic analysis are used to present and discuss the data below were as follows: Benefits of Using Kahoot!; Drawbacks with Using Kahoot!; Kahoot! compared to more traditional pedagogical approaches. .

4. Results

Based on 43 undergraduate students' data, regarding Kahoot! tests results, for true-false questions, the average correct rate was 74%. The highest correct score was 91% and the lowest correct rate was 58% (see Appendix Table 2). For the multiple-choice quizzes, the average correct rate was 70%. The highest correct score was 70% and the lowest 12% (see Appendix Table 3). These figures can not be argued to represent students' true learning outcomes. For example, some students may have simply guessed the correct answer, and some students might have been unable to make the choice of answer they wanted in the allocated time limit. Furthermore, it is possible that if some students did not have any interest in the activity they may have simply put down any answer without devoting careful though to the choice they made.

Below, we now present the data from the interviews with students after the completion of the course. Rather than present the data by response to each question, and in line with themes that emerged from our thematic analysis of the data (Braun and Clarke, 2006), the interview results are presented in three sections in order to prioritize and identify the key points. These sections allow us to present and analyze the data around the themes that the data naturally fell under following the thematic analysis (Braun and Clarke, 2006). It is noted whether the student was a senior, a sophomore, or a junior. The three sections are: Benefits of Using Kahoot!; Drawbacks with Using Kahoot!; Kahoot! compared to more traditional pedagogical approaches.

Benefits of Using Kahoot!

One of the benefits of using Kahoot! was felt to be both motivational and one whereby phones were used for learning. For example, one sophomore said that *"When the teacher said we start to test, I found every student pay attention to use the phone… this online teaching method can focus everyone's learning attitude in the course."* Similarly, in the words of another sophomore, *"especially when my name was shown in the ranking, I felt it was a honour. This will encourage me to study hard and answer the question."* The capacity for Kahoot! to involve students' using their phones for learning was also noted by a senior, saying *"generally, many students* *will use their cell phone during the class sometimes. Now the teacher encourage student to use cell phone and such a method can concentrate everyone's spirit."*

As a method of testing, many considered Kahoot! both fair and effective, for example that as a mode of evaluating credit, *"it is no problem and reasonable, the credit evaluation should consider student's performance every week"* (sophomore). Or that *"I think everybody could accept it when the learning process is used for evaluating student's final grade"* (sophomore). Similarly, that if teachers could announce in advance that they will use Kahoot! in the final evaluation, *"I believe that every student will study hard and pay attention to teaching contents and encourage learning motivation"* (junior). This opinion was shared by seniors as well, one saying *"I think it* [credit evaluation] *is necessary. Otherwise, everyone plays Kahoot! without concern."*

Indeed, one benefit was that Kahoot! *"can identify student's learning performance. The teacher can easily understand how to adjust teaching progress and then help particular student to finish course learning" (sophomore). However, teachers needed to be careful not to overuse Kahoot! as "too many Kahoot! testing might bring pressure"* (sophomore). Comparatively, one senior highlighted that Kahoot! *"is good for the first time, but after the second time, the fun feeling has gradually decreased."*

Another benefit of Kahoot! was considered its ease of use for students (sophomore, senior) if not necessarily for teachers (sophomore). Indeed, Kahoot! offered much potential for these students, Firstly, for group work and involving the students in designing the questions: *"maybe it will bring great innovation when the students design the questions. The teacher can use group competition for Kahoot test for other course in the future"* (junior). Similarly,, that teachers could use *"group competition to finish Kahoot! test"* (senior) or that varying the question types would make it more effective (senior), or that *"the student could use anonymous account to play the game"* (senior). The potential of using Kahoot! for English Medium Instruction was also commented on, one senior saying that, *"if the question content is shown in English, it consequently will enhance students' English abilities."* Overall, when talking about the benefits of Kahoot! sophomores appeared most enthusiastic, juniors most nervous, and seniors most considered in contextualizing the benefits with other factors.

Drawbacks with Using Kahoot!

For sophomores and juniors, a key drawback with using Kahoot! was the pressure involved and the fact that it made them nervous. For example that, *"we usually do not know what the questions are before the testing… some students might feel pressures… when the teacher announces the final ranking, I feel really nervous"* (sophomore). This could particularly be the case if it was students' first encounter with Kahoot!; *"maybe some of them have first time to contact Kahoot and could bring very surprise feeling"* (sophomore). All juniors felt the pressure involved with needing to respond in a certain timeframe, one felt that they *"can not say it is a happy time. Each question has limited answer time, such as 10 seconds… if I find that I do not know the answer, I will feel nervous"* (junior). Similarly, that *"I feel there exists some pressure when taking Kahoot!"* (junior). The use of the suspenseful background music was also felt to increase the pressure by one junior, who commented that, *"some background music feels not OK and makes me nervous."*

In terms of whether Kahoot presented drawbacks through overloading students' with too much to think about, most felt this was not the case, only one sophomore was not sure, saying *"it is hard to say"* (sophomore) whether Kahoot! created Cognitive Overload. However, one drawback related to the fact that students could be guessing the answers, *"Sometime I will randomly guess one answer if I do not know the correct answer. The system will record user's answer and speed of answering question. Thus, if I do not know the answer, I will quickly guess one answer. Maybe it will be lucky to choose one correct"* (sophomore). This could particularly be the case if the time to answer the question was very short compared to the complexity of the question itself (sophomore). As another sophomore noted, they could be lucky that they got the answer right through a guess, and *"the system only identifies who chooses the correct answer, it does not ask why this answer was chosen."* Juniors also highlighted the issue of being able to guess, one saying, *"it is multiple-choice, so, some students might guess the correct answers."* Indeed, one junior felt the amount of Kahoot! testing should be limited, and that Kahoot! should not be used in credit evaluations: *"If conducting Kahoot! too many times, it will lose original fun… [and]… if it does not adopt the score of Kahoot as the credit evaluation, it is OK for me."* Such views were echoed by another junior, suggesting that credit was not perhaps the best incentive: *"adding credit is not the*

only choice to be the incentive. Providing some gifts for the top three is another incentive… changing incentive might bring new creation."
In terms of technical drawbacks, there could be issues with cell-phones. As one sophomore commented, "I worry my cell phone network speed is not OK or something wrong in my cell phone when using Kahoot! But it never happen so far." As a potential solution, another sophomore felt that, *"maybe Kahoot! testing could be implemented in the school's computer classroom since error problem might be smaller. However, due to school resource limitation, we can not use computer classroom very often. Thus, it is difficult to implement it"* (sophomore)

For seniors, occasionally the idea of pressure was mentioned, particularly if Kahoot! is used as an exam, for example that *"if the teacher takes Kahoot! as an exam, I will feel pressure and will not feel happy."* Other seniors spoke of potential rather than actual drawbacks, for example that *"it is fair, however, Kahoot! score should not occupy too high a ration"* or that, *"if too many teachers use Kahoot! the student will feel it is not interesting; but, no worry, I believe just few teachers will use Kahoot!"* However, for seniors there were on the whole no drawbacks with Kahoot!, comments such as *"no difficulty"* and *"it is very easy"* were common. Overall, when talking about the drawbacks of Kahoot! sophomores and juniors commented on these the most, with all juniors feeling it made them nervous, whereas seniors were on the whole positive about Kahoot! and saw more potential with it than drawbacks.

Kahoot! compared to more traditional pedagogical approaches

Interviewees offered perspectives on both the superiority of Kahoot! compared to traditional approaches, but also perspectives that suggested traditional approaches were better. One advantage was the efficiency of Kahoot! which calculated results very quickly and meant that *"thus, using Kahoot! is more efficient than traditional pen and paper testing"* (sophomore). However, this was often a qualified perspective, and depended on a number of factors. For example, that the difficulty of the questions needed to be judged accurately, as *"if the questions are all simple or difficult, it can not easily identify student's performance"* (sophomore). Further, that the teacher gave students advance notice of the use of Kahoot!: *"If the teacher could announce each unit with Kahoot! test every week in advanced, the student could have enough time to prepare it. Then when attending the class, the student could realize the learning clearly. Sometime students do not like to ask question in the class"* (sophomore). In addition, relying on Kahoot! alone for evaluation was considered unwise: *"if only Kahoot! is used to evaluate students, this is not suggested"* (sophomore). Furthermore, to use more explanation as to why particular answers were correct was considered key: *"if the teacher can explain why these wrong items can not be chosen, that would be better. Such a method can help student understand the purpose of each testing question and then revise the wrong concepts for the students"* (sophomore).

In contrast to sophomores, juniors were on the whole undecided as to whether Kahoot! was superior to more traditional methods. For example that *"it is hard to compare which one exist higher efficiency"* (junior), or, *"not sure, it depends on how teacher use the Kahoot! test… if the questions are good and can effectively identify student's learning outcome, that would be better"* (junior) and, simply that, *"Kahoot! is an online teaching platform… only few teachers use it"* (junior).

Seniors, however, were generally in favour of Kahoot! over more traditional methods. For example that.. *"adopting online teaching and changing traditional teaching methods can enhance learning efficiency…. Such an online testing method is a good strategy to encourage students to study"* (senior). One senior (in contrast to the junior above) found the background music to help with the learning by creating excitement, saying that *"the questions can be shown by text, picture, and movie…this is more interesting compared to traditional teaching…. The game will show background music and increase exciting or nervous feeling. I feel this moment makes me participate in the Kahoot! game"* (senior). Another senior suggested a database of questions could be built up over time for Kahoot! and that maybe it could be used as well for essays: *"If Kahoot! could add essay test, the speed of typing is quicker than traditional writing and can reduce the writing time of traditional mid-term and final-term exam"* (senior). Thus, overall, seniors were more positively disposed to Kahoot! than either sophomores or juniors compared to traditional teaching methods although one did note that *"Kahoot! can not replace traditional testing and it is an auxiliary method for teaching"* (senior).

5. Discussion and Conclusion

Much of the literature studying the use of Kahoot! is overwhelmingly positive about its qualities (e.g. Tan and Kaur, 2018; Ares et al., 2018; Yunus and Azman, 2019) in a range of subject fields, including that of maritime English teaching (Sartini, 2020). What is more, Kahoot! has been argued to be a suitable method to encourage students to use their phones for learning rather than texting or chatting, which they are apt to do in lectures (Tinder and Bohlander, 2012). Nevertheless, despite this overwhelmingly positive picture, some work does note that, despite drawing positive conclusions regarding Kahoot! overall, some technical challenges remain (Wang and Tahir, 2021).

The above data presented here show a far more nuanced and complex picture in relation to Kahoot! and reveal many complexities about the research aim of the study: specifically the implementation of Kahoot! yes, it is perceived as a positive, but what is revealed as a key academic observation and implication is how different levels of student perceive Kahoot! differently. Although it might be anticipated that the more senior students would find more pressure from Kahoot!, particularly when the scores were being used for credit and the impact this may have on their degree classifications, it was actually the case that more junior and sophomore students felt under pressure. Indeed, junior students commented more than any other group on the pressure they felt through having to generate answers within a certain time limit, and have their names posted on a screen for all to see. The challenge here was not technical (contra Wang and Tahir, 2021), rather, it was pedagogical, and, contrary to our expectations, there was not felt to be an issue with Cognitive Overload (Kirschner et al., 2006) in having to focus on using Kahoot and the lecture content at the same time.

Rather, the academic implication of the extent of how much to use Kahoot! emerges as a key finding in the data above. Rather than simply present Kahoot! as a positive or negative addition, the data clearly show that Kahoot! will be most successful when not overused, and when more explanations are given of wrong answers. On the whole, the above data suggest the use of Kahoot! sparingly, and in a way that provides a complementary approach. It also clearly shows the need to carefully manage how Kahoot! is used with different levels and year groups of students, to carefully be aware of the drawbacks with multiple-choice questions in general, and at the same time shows the potential of Kahoot! for group work and other aspects. Kahoot! overall emerges as a tool of potential significantly beyond its specific goals, whereby the teacher can engage with the answers more to explain why some answers were wrong and others were correct.

Future studies could explore the possibility of such approaches. In addition, future studies could focus on diversity of user experience across different demographics, including the experience of teachers when designing and implementing Kahoot! and the impact it has on their workloads (Siemon and Eckhart, 2017). These studies could apply to different education contexts where, for example, accessibility and technical connectivity may be different in speed and coverage. Furthermore, studies could consider the effectiveness of Kahoot! with learners who have a disability such as a visual impairment, or with neuro-diverse learners. Also, to study the use of Kahoot! And 'gamification' in a range of education cultures. For practical recommendations (e.g. industry, maritime education, and training institutions), the question difficulties of Kahoot! tests (e.g. true-false, multiple-choice quizzes) can be effectively adjusted based on users' backgrounds and learning experiences. Flexible testing time design with appropriate visual situation (e.g. color pictures) is suggested to attract learner's interest and reduce learning pressure. Latest maritime news with important learning topics (e.g. freight rate fluctuation, ship and crews supply/demand problems due to COVID 19, maritime market changes and impacts due to the Ukrainian-Russian War in 2022) are recommended to choose as testing questions in order to link academic testing questions and practical maritime knowledge. We do not suggest or imply that Kahoot! would be less effective in such contexts (indeed, it may be more effective), rather we suggest that such studies would help determine the effectiveness of Kahoot!. For others using Kahoot!, we suggest the following considerations and approaches around the academic and managerial implications with Kahoot! to both explain the usage of Kahoot! to students and also to gain the most from Kahoot! pedagogically:

Appendix

Table 1: Using and Discussing the use of Kahoot! with students.

Carefully balance question difficulty with time limits

Explain how Kahoot! works within 'Gamification' and that it aims to increase fun around learning. Discuss novel ways in which to use Kahoot! For example as a group competition. Explain the rationale behind any credit being assigned to Kahoot! scores Discuss the merits and issues involved with naming the winners. Take time to work through why the wrong answers were in fact wrong. Ensure no technical issues exist at the outset. Involve students in the design and choice of questions, background music and other aspects Can it be used collaboratively in groups- not just individually? This would add a pedagogical impact potentially.

Table 2 Correct rate of true-false questions (n=43)

No.	Core concept	Correct rate	True	False	No.	Core concept	Correct rate	True	False
1	Knot	0.70	30	13	12	International Transport Workers Federation	0.70	30	13
2	Hull & Machinery Insurance	0.58	25	18	13	International Chamber of Shipping	0.72	31	12
3	Protection & Indemnity Insurance	0.65	28	15	14	Maritime Security Centre- Horn of Africa	0.77	33	11
4	Ransom	0.74	32	11	15	Customs-Trade Partnership Against Terrorism	0.67	29	14
5	Cruise Lines International Association	0.93	40	3	16	Container Security Initiatives	0.70	30	13
6	General average	0.81	35	8	17	Automatic Identification System	0.88	38	5
7	United Kingdom Marine Trade Operations (UKMTO)	0.70	30	13	18	International Maritime Bureau	0.91	39	4
8	Piracy	0.63	27	16	19	Classification Society	0.72	31	12
9	Detain	0.58	25	18	20	Tokyo MoU	0.74	32	11
10	Baltic and International Maritime Council	0.91	39	4	21	Flag State Control	0.84	36	7
11	No cure No Pay	0.63	27	16					

Table 3 Correct rate of multiple choice quizzes (n=43)

No.	Core concept	Correct rate	No.	Core concept	Correct rate
1	Bill of Lading	0.37	12	Hedge	0.16

2	Shipping strategic alliance	0.47	13	International Convention on Load Lines	0.37
3	Flag of convenience	0.51	14	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers	0.40
4	Hub & spoke	0.35	15	Global Maritime Distress Safety System	0.60
5	Customs, Immigration, Quarantine, Security	0.12	16	International Safety Management Code	0.70
6	Vessel traffic system	0.42	17	Baltic Dry Index	0.35
7	Blockchain in the shipping industry	0.21	18	Cargo claims	0.26
8	Lien	0.12	19	International Ship and Port Facility Security Code	0.26
9	Port state control	0.16	20	Bareboat Charter	0.12
10	International Convention for the Safety of Life at Sea	0.19	21	Freight Futures	0.19
11	International Convention for the Prevention of Pollution from Ships	0.35			

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Collision Risk Assessment in Ship Navigation with Extended Kalman Filter Trajectory Prediction and Fuzzy Logic

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Abstract

Collision accidents account for approximately 60% of maritime accidents, which ranks first among all types of maritime accident. Therefore, in order to enhance the function of ship navigation, the safety problem of ship collision during navigation needs to be solved, and the identification and evaluation of ship collision risk is essential. This paper utilizes an extended Kalman filter(EKF) and fuzzy logic to estimate the risk of collision. The proposed assessment process can be developed as a part of the intelligent navigation system that makes decisions under multi-vessel collision situations. The kernel of this proposed method is first identify information on own ship(OS) and target ship(TS) navigation behavior to establish ships navigational parameters through Automatic Identification System(AIS) and the Long-Range Identification and Tracking(LRIT) system, to predict ship velocity and acceleration components and navigational trajectories are estimated by an extended Kalman filter(EKF), to obtain the collision risk degree through fuzzy logic. The merit of the developed model is can improve the visibility of the collision risk in a close encounter situation. Finally, the model is applied to a typical collision accident in the Yangtze River, the simulation prediction results are very close to the actual navigation conditions. Consequently, the findings are beneficial for the maritime authorities to take countermeasures for navigational accidents prevention.

Keywords: Collision accident; Extended Kalman filter; Fuzzy logic; Risk assessment; Maritime transportation

1. Introduction

Collision accidents are the most frequently occurring type of maritime accidents, which accounts for approximately 60%(Uğurlu, *et al.*, 2016, Wu, *et al.*, 2021, Zhang, *et al.*, 2016). Furthermore, according to historical statistics, the human error is the major causes of maritime accidents(Luo and Shin, 2019, Wu, *et al.*, 2017). In the waters of the Gulf of Finland, 55.5% of maritime accidents were due to human factors, of which collisions were 52.6%(Kujala, *et al.*, 2009). Therefore, the capabilities of intelligent risk assessment in the navigation system will limit the subjective factors of humans in navigation, which can increase the safety and security of maritime transportation.

Owing to the high occurrence probability and serious consequence, many studies have focused on the risk assessment of collision accidents. The most used parameters for collision risk assessment in previous studies were distance to closest point(DCPA)(Kang, *et al.*, 2019) and distance to closest point(TCPA)(Zhen, *et al.*, 2022), which were analyzed to reduce the occurrence of ship-ship collisions. Pedersen used a mathematical model to estimate geometric collision probabilities by introducing a stochastic process model(Pedersen, 1995). In addition, some quantitative methods like fuzzy logic(Wu, *et al.*, 2020), evidence reasoning(Li and Pang, 2013), Bayesian Networks(Wu, *et al.*, 2019), econometrics(Yip, *et al.*, 2015), and combinations of these methods(Wang, *et al.*, 2013) are used to solve the risk assessment problem. Previous studies have mainly focused on the static assessment of ships, and only a few studies have used trajectory prediction methods for dynamic assessment of ship collisions.

Fuzzy logic is widely used in quantitative risk assessment because it is close to the human type of thinking and handles uncertainty well(Wu, *et al.*, 2018, Wu, *et al.*, 2019). Based on these advantages, it is used for the quantitative assessment of collision risk. Moreover, as the extended Kalman filter can predict the ship trajectory well(Perera and Guedes Soares, 2015), the Kalman filter is introduced to predict the dynamic ship trajectory as well as the ship navigation parameters.

2. Development of the EKF-Fuzzy logic based collision risk assessment model

2.1 Establishing a collision accident risk assessment framework

The proposed risk assessment model for collision accidents is shown in Figure 1. The modelling process can be summarized in the following three steps.

The first step is to identify information on own ship(OS) and target ship(TS) navigation behavior to establish ships navigational parameters through Automatic Identification System(AIS) and the Long-Range Identification and Tracking(LRIT) system.

The second step is to predict ship velocity and acceleration components and navigational trajectories are estimated by an extended Kalman filter(EKF), and perform collision risk identification by observing whether there is an intersection of OS and TS trajectories.

The third step is to obtain the risk degree by fuzzy logic, and perform a collision risk assessment.

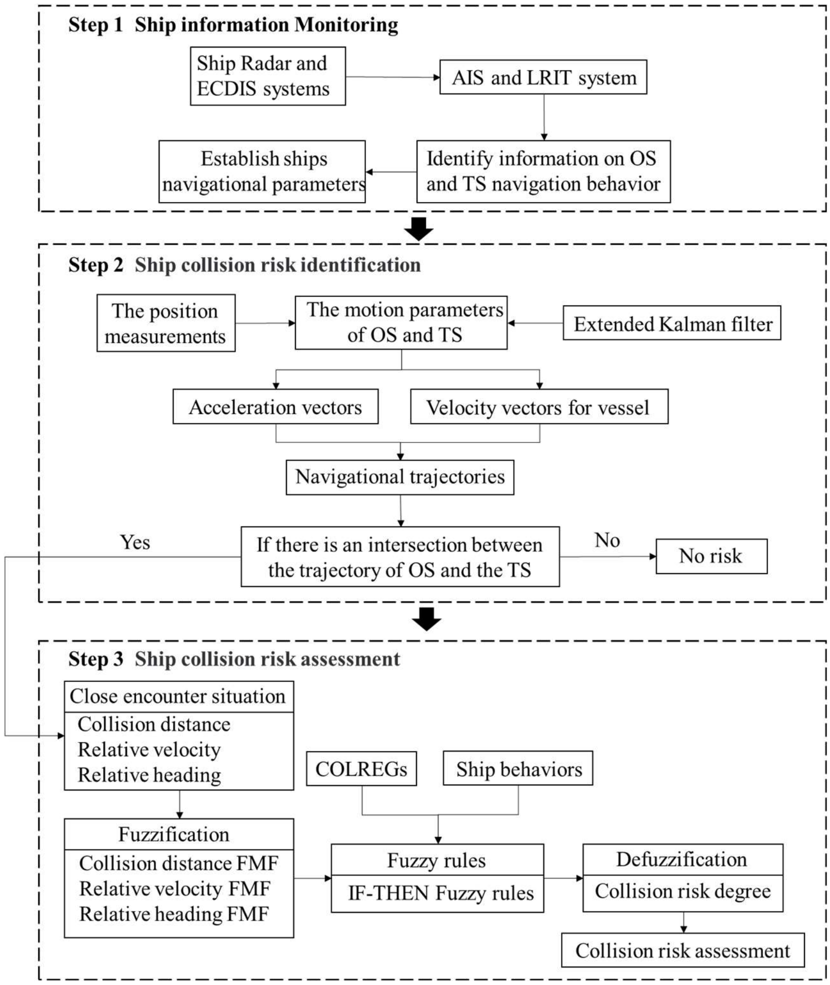

Figure 1: Risk assessment model framework for collision

2.2 Establish ships navigational parameters by AIS and LRIT system

Ship radar and Electronic Chart Display and Information System have been widely used to detect the risk of collisions between ships. The radar and Electronic Chart Display and Information System is facilitated by an accredited AIS and LRIT system, both of which are capable of identifying ship navigational information. Therefore, the ships' navigation parameters can be established.

A two-ships close encounter situation is constructed shown in Figure 2: own ship is located in $O(X_O, Y_O)$ and target ship is located in $T(X_T, Y_T)$. OS and TS course and speed values are V_O, α and V_O, β, respectively. The X and Y velocity vectors of OS and TS are V_{ox}, V_{oy} and V_{Tx}, V_{Ty} .The acceleration of OS and TS are a_O, a_T respectively.

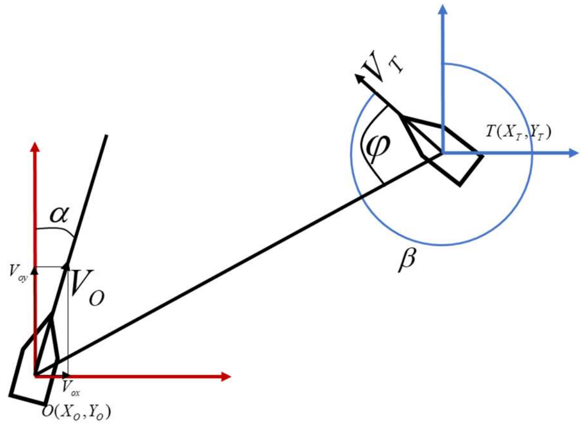

Figure 2: Ship encounter situation

2.3 Introduce EKF to predict velocity and acceleration components and navigational trajectories

The navigational states of the two ships are estimated from position measurements by introducing an extended Kalman filtering algorithm. The estimated ship's navigational state is used to derive the relative heading velocity vector and relative bearing vector of one ship relative to another ship, and to simulate the trajectories of own ship and target ship, and to identify the ship's navigational risk by observing whether the trajectories of own ship and target ship have an intersected point. Even if the vessel position measurement consists of respective sensor noise, the identification algorithm (i.e., EKF) can accommodate these information to improve the accuracy of the ship's position(Perera and Guedes Soares, 2015). The following gives an overview of a Kalman filtering algorithm and its localization error, ϖ ,and ω is the estimated system state vector, in the ship states estimate can be written as(Gelb and Arthur, 1974)

$$\frac{d}{dt}\omega = f(\omega) \tag{1}$$

The error covariance can be written as:

$$\frac{d}{dt}P = F(\omega)P + PF^T \tag{2}$$

where $F(\omega)$ can be written as

$$F(\omega) = \frac{\partial}{\partial \omega} f(\omega) \tag{3}$$

and the P of function is the update of the estimated error covariance with the state. The ships states updated by respective measurement data.

$$H(\omega) = \frac{\partial}{\partial \omega} h \tag{4}$$

where h is the Jacobian matrix of the measurement function.

So the Kalman gain, K ,can be calculated by

$$K = \frac{PH(\omega)}{H(\omega)PH^T + R} \tag{5}$$

2.4 Use of Fuzzy logic to derive the collision risk degree

It should be noted that the intersection point of two trajectories cannot be considered as a collision point because each ship can pass this point at different time intervals. So the risk identification for ship collision will be full of uncertainty when the ship and the target ship are in a close encounter situation. Therefore, the fuzzy logic is introduced to improve the accuracy.

The whole fuzzy logic-based risk assessment system can be divided into the following four steps:

1) Identification of the input and output fuzzy membership functions(FMFs).

FMFs describes the fuzzy set of a given linguistic expression transformed to a unit interval. This is formally and conceptually different from the basic concept of probability(Perera*, et al.*, 2011). The core of the fuzzy set Z is defined as the set of all elements in the typical universe of Z with affiliation value 1, which can be written as

$$Core(Z) = \{x \in X \,|\, Z(x) = 1\} \tag{6}$$

where x is a generalized variable. The determinacy of the fuzzy set is defined as the set of all elements of X that have non-zero affiliation in A. It can be written as

$$Deter(Z) = \{x \in X \,|\, Z(x) \geq 1\} \tag{7}$$

Owing to the ship's navigation state is influenced by the ship's speed and heading, in addition the distance between ships is also an important factor in ship collision assessment. Therefore, the relative speed $(\bar{V}_T - \bar{V}_O)$, relative heading (θ) and collision distance (R) are determined as input FMFs. For output, the collision risk degree will be determined. Figure 3 shows the relative collision in navigation.

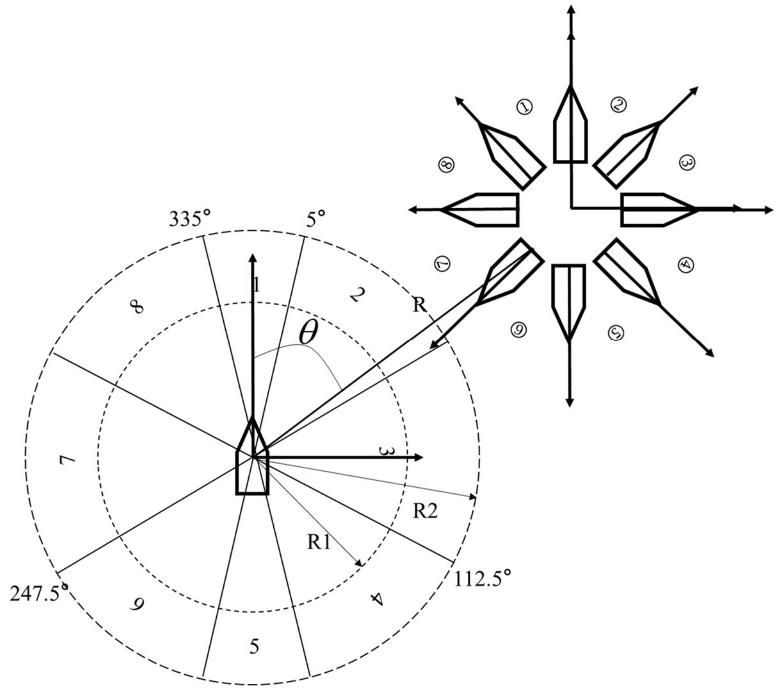

Figure 3: Relative collision situations in navigation

2) Creation of the fuzzy membership function for each set of inputs and outputs.

Based on the ship domain concept and the fact that the ship from the starboard side has a higher navigational priority, the collision distance can be expressed by R1 and R2. The radius R1 indicates the regional extent of the marine ship navigation dynamics. Radius R2 indicates the distance to the target ship when the ship is in the "stand by" state with priority. R3 indicates the distance between OS and the TS. The collision distance can be represented by these radius and coincide with the FMFs. For the relative hearing, in accordance with the OCLREGS, own ship domain is divided action modes into eight regions labeled 1 to 8 and target ship domain is divided action modes into eight equal regions labeled ① to ⑧, so the relative hearing can be represented by θ.The relative velocity condition is denoted by $(\bar{V}_T - \bar{V}_O)$.

The collision risk degree be represented by a 5-point scale{Very Low (VL), Low (L), Average (A), High (H) and Very High (VH)} (Pam, *et al.*, 2013). All the fuzzify the linguistic variables are shown in Table 1.

Table 1: Fuzzify the linguistic variables

Variables	Linguistic term	Fuzzy numbers
Collision distance	Short	$(0, 0, R_1 - \Delta R/2, R_1 + \Delta R/2)$
	Medium	$(R_1 - \Delta R/2, R_1 + \Delta R/2, R_2 - \Delta R/2, R_2 + \Delta R/2)$
	Long	$(R_2 - \Delta R/2, R_2 + \Delta R/2, R_3, R_3)$
Relative velocity	Small	$(0, 0, V_1 - \Delta V/2, V_1 + \Delta V/2)$
	Medium	$(V_1 - \Delta V/2, V_1 + \Delta V/2, V_2 - \Delta V/2, V_2 + \Delta V/2)$
	Big	$(V_2 - \Delta V/2, V_2 + \Delta V/2, V_3, V_3)$
Relative hearing	I	$(0, 0, \theta_1 - \Delta\theta/2, \theta_1 + \Delta\theta/2)$
	II	$(\theta_1 - \Delta\theta/2, \theta_1 + \Delta\theta/2, \theta_2 - \Delta\theta/2, \theta_2 + \Delta\theta/2)$
	III	$(\theta_2 - \Delta\theta/2, \theta_2 + \Delta\theta/2, \theta_3 - \Delta\theta/2, \theta_3 + \Delta\theta/2)$
	IV	$(\theta_3 - \Delta\theta/2, \theta_3 + \Delta\theta/2, \theta_4 - \Delta\theta/2, \theta_4 + \Delta\theta/2)$
	V	$(\theta_4 - \Delta\theta/2, \theta_4 + \Delta\theta/2, \theta_5 - \Delta\theta/2, \theta_5 + \Delta\theta/2)$
	VI	$(\theta_5 - \Delta\theta/2, \theta_5 + \Delta\theta/2, \theta_6 - \Delta\theta/2, \theta_6 + \Delta\theta/2)$
	VII	$(\theta_6 - \Delta\theta/2, \theta_6 + \Delta\theta/2, \theta_7 - \Delta\theta/2, \theta_7 + \Delta\theta/2)$
	VIII	$(\theta_7 - \Delta\theta/2, \theta_7 + \Delta\theta/2, \theta_8 - \Delta\theta/2, \theta_8 + \Delta\theta/2)$
	IX	$(\theta_8 - \Delta\theta/2, \theta_8 + \Delta\theta/2, 2\pi, 2\pi)$
Collision risk degree	Very low (VL)	$(0, a_1, a_2)$
	Low (L)	(a_1, a_2, a_3)
	Average (A)	(a_2, a_3, a_4)
	High (H)	(a_3, a_4, a_5)
	Very high (VH)	$(a_4, a_5, 1)$

3) Construction of if–then fuzzy rules for the overall system.

In rules, a Mamdani type IF < Reasons> THEN < Results> rule has been developed. The IF-THEN Fuzzy rules are proposed in based on COLREGs rules and expert knowledge in navigation(Perera*, et al.*, 2010). Table 2 shows part of the rules.

Table 2 The part of rules for collision risk assessment

Collision distance	Relative velocity	Relative hearing	Collision risk degree
(R_1, R_2)	(0, V_1)	θ_1	L
(R_1, R_2)	(V_1, V_2)	θ_1	A
(R_1, R_2)	(V_1, V)	θ_1	H
(R_1, R_2)	(0, V_1)	θ_2	A
(R_1, R_2)	(V_1, V_2)	θ_2	A
(R_1, R_2)	(V_1, V)	θ_2	H
(R_1, R_2)	(0, V_1)	θ_3	A
(R_1, R_2)	(V_1, V_2)	θ_3	H
(R_1, R_2)	(V_1, V)	θ_3	VH
(R_1, R_2)	(0, V_1)	θ_4	VL
(R_1, R_2)	(V_1, V_2)	θ_4	L
(R_1, R_2)	(V_1, V)	θ_4	A
(R_1, R_2)	(0, V_1)	θ_5	VL
(R_1, R_2)	(V_1, V_2)	θ_5	A
(R_1, R_2)	(V_1, V)	θ_5	H
…	…	…	…

4) Combination of the fuzzy rules to do defuzzification of the output.

In the Defuzzification, the fuzzy risk is defuzzified by the output fuzzy membership function of collision fuzzy membership function to obtain risk degree. The defuzzification was made using the centre of gravity method.

Finally, the ship collision risk is estimated according to the risk degree combined with the ship trajectory.

3. Case study of assessment for collision accidents in Yangtze River

3.1 Scenario description of collision accident

On 26 March 2020, a collision accident close to the Wusongkou Waters in the Yangtze River. The two ships were Hongyun 19 and Huatong 306. Hongyun 19 was on the way from Shanghai to Dalian, Huatong 306 was on the way from Nanjing to Shanghai, and crew and certificates meet the requirements. The accident caused the forepeak damage and flooding of Huatong 306 and about 25.51 tons of light diesel spilled into the river, finally this ship beached close to Wusongkou Waters. The details of this collision accident are shown in Table 3.

Table 3: Details of the collision accident in the Yangtze River

Factor	Information
Collision location	(31°30.96'N,121°32.49'E)
Collision angle	155°
Collision speed of colliding ship	4 kn
Visibility	< 1000M
Navigation environment	Good

3.2 Prediction of navigation trajectory and estimation of relative parameters based on EKF

Through the AIS and LRIT system, it is easy to obtain the ships navigational information. After obtaining the OS and TS navigational parameters, by using the MATLAB software, it is easy to derive the ship velocity and acceleration components and navigational trajectories by EKF.

By adding sensor noise to the actual ship position values, the estimated ship position values are calculated using the EKF algorithm. And this method can create various nonlinear trajectories.

The two ships encounter is presented in Figure 4. The figure consists of the actual and estimated ship navigation trajectories of OS and TS. Figure 5 shows a zoomed in view of the ships trajectory for the same navigational time at the closer encounter position. The actual ship position is simulated by assuming that the derivatives of the ship velocity and acceleration components are white Gaussian processes with zero mean and constant covariance values(Perera*, et al.*, 2012).

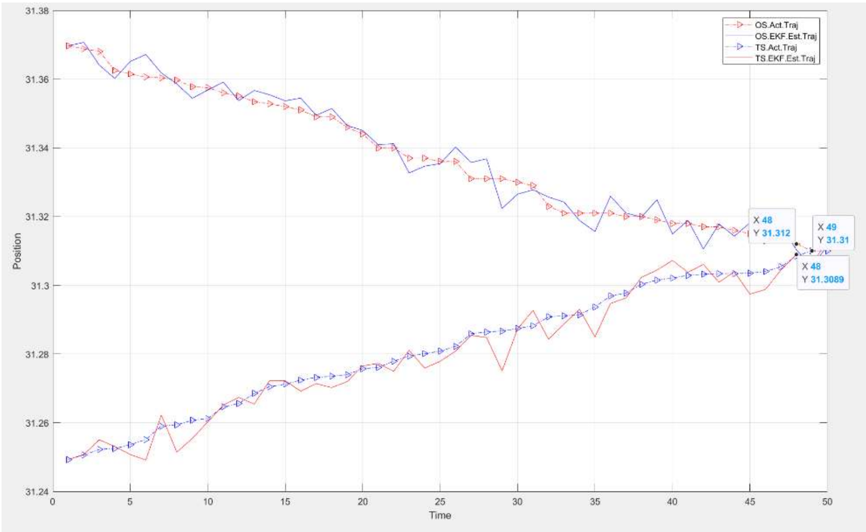

Figure 4: Navigation trajectories ship O and ship T

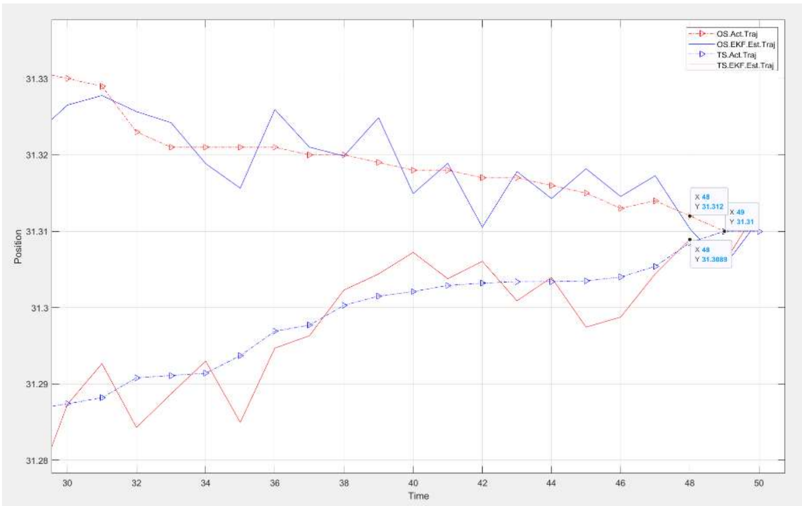

Figure 5: A zoomed in view of the ships trajectory

3.3 Calculation of collision risk degree using fuzzy logic method

From Figure 9, we can see that there is an intersection point between the trajectory of the target ship and this ship. But, one should note that an intersection of two trajectories cannot be concluded as being a collision point because the predicted trajectory will produce an intersection when the ship enters within a certain domain of the encounter ship. Therefore, further risk assessment is required for a close encounter situation.

The Fuzzy logic based collision risk assessment can be implemented on the MATLAB software. For this collision accident, following values can be considered for simulations. The collision distance values are $R_1 \approx 0.6NM, R_2 \approx 6NM, R_3 \approx 10NM$. In the relative hearing, the variables of $\theta_1 = 5^\circ, \theta_2 = 67.5^\circ, \theta_3 = 112.5^\circ, \theta_4 = 175^\circ, \theta_5 = 185^\circ, \theta_6 = 247.5^\circ, \theta_7 = 292.5^\circ, \theta_8 = 355^\circ$ have been considered. The relative speed variables have been assigned $V_1 = 1kn, V_2 = 4kn, V_3 = 5kn$. The output of collision risk degree has been derived to the variables of $a_1 = 0.1, a_2 = 0.3, a_3 = 0.5, a_4 = 0.7, a_5 = 0.9$. Table 4 shows parameters values and result of the risk degree of this collision accident based on fuzzy logic.

Table 4: Parameters values and result based fuzzy logic

Parameters	FMFs values	The collision accident values
Collision distance	$R_1 \approx 0.6NM, R_2 \approx 6NM, R_3 \approx 10NM$	0.54NM
Relative hearing	$\theta_1 = 5^\circ, \theta_2 = 67.5^\circ, \theta_3 = 112.5^\circ, \theta_4 = 175^\circ,$ $\theta_5 = 185^\circ, \theta_6 = 247.5^\circ, \theta_7 = 292.5^\circ, \theta_8 = 355^\circ$	155°
Relative speed	$V_1 = 1kn, V_2 = 4kn, V_3 = 5kn$	4kn
Collision risk degree	$a_1 = 0.1, a_2 = 0.3, a_3 = 0.5, a_4 = 0.7, a_5 = 0.9$	0.75

3.4 Result analysis of the collision risk in the Yangtze River

After obtaining the collision distance, relative hearing and relative speed in Subsection 3.3 and fuzzy rules in Subsection 3.3, the final collision risk degree can be derived. Table 4 reveals that the collision risk degree of this collision accident is 0.75, this is a very high collision risk degree, and this is also consistent with the collision of the two ships.

For the input, we can make some changes to observe the change of the output value. For example, changing the relative velocity from the 4 to 1. In this case, the developed system can also be used to reduce risk. By using the changed information, it can be seen that the collision risk degree is changed. The collision risk degree is changed from 0.75 to 0.5, which has reduced a lot because the condition of relative speed has been changed a lot.

For further analysis, on this basis we also can make changes to the relative angle. For example, changing the relative bearing from the 155° to 120°, it can be seen that the collision risk degree is changed from 0.5 to 0.25. The result of a change in relative speed and relative heading is shown in Table 5.

Table 5: Results after relative speed and relative heading change

Collision distance	Relative hearing	Relative speed	Collision risk degree
0.54NM	155°	4kn	0.75
0.54NM	155°	1kn	0.50
0.54NM	120°	1kn	0.25

It can be seen from Table 5 that the collision risk degree can be reduced by changing the speed and heading. At the same time, it can be found that this model can provide assisted decision-making for ships to achieve collision avoidance.

4. Discussion

In this paper, collision risks related to the relative distances between ships are considered. Moreover, in this study, trajectory predictions based on collision distance, relative velocity, and relative heading are used to represent the corresponding collision risk in order to improve the visibility of ship collision situations. However, this is a novel approach that slightly deviates from the traditional collision risk model. Therefore, in this approach, the corresponding increments and decrements of collision risk are monitored based on the distance, relative velocity, and relative heading between ships.

Furthermore, this method gives a complete picture of the ships encounter situation, in which the collision risk between ships is intuited. Because in some situations, the respective speed and heading vectors of the ships may vary continuously, resulting in a time period before close encounter of the ships that may not be a constant. Therefore, the collision risk degree should be updated by considering the ship navigation trajectory and the corresponding speed vector, and continuously calculating the time period before the possible collision situation. Hence, it is believed that this method can improve the visibility of collision risk in the situation of close collision. The collision risk assessment method proposed in this paper also shows the consistency of collision risk variation in complex ship collisions, which is another advantage that may not be identified by traditional collision risk assessment methods(Perera and Guedes Soares, 2015).

5. Conclusions

In this paper, a novel risk assessment mothed is proposed for collision accidents. The main contribution is to construct an Extended Kalman filter and fuzzy logic model to assess the collision risk. When developing this collision risk assessment model, the Extended Kalman filter method is introduced by predicting the ship velocity and acceleration components and navigational trajectories. The risk of collision between own ship and target ship can be identified visually by the existence of intersection points of trajectories. In addition, the fuzzy logic method overcomes the problem that the risk cannot be accurately assessed in a close encounter situation. The merits of the developed model include the intuitive prediction of the accident development, easy implement and ability to updated information.

Through the case study of the risk assessment of collision accident in Yangtze River, it can be seen that the selected model is unanimous with the actual situation, which indicates that the proposed model has certain reference value for the risk assessment of collision accident. In the future work, the collision avoidance decision-making can be carried out, together with the collision assessment method proposed in this paper for the ship-ship collision avoidance decision-making system. Moreover, the ship-bridge collision should also be considered to obtain a result for maritime formal safety assessment.

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Proposing an Extended Causation Database to Analyse Non-Conformities at Containership Fleet

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Abstract

Investigation of non-conformities, near miss findings, and accidents is the core aspect of ship safety management system. Continuous improvement in ship management can be achieved through effective proactive measures based on accurate root cause identification. Nevertheless, the lack of a comprehensive causation framework is a great challenge in implementation level. The purpose of this study is to develop a non-conformity causation database in order to enable consistent analysis and predictions. The methodology is principally based on benchmarking the prevalent frameworks and concepts (i.e. MSCAT, HFACS, etc.) in different disciplines. Then, relationships among factors cited in different techniques and ship management organization are addressed. The proposed approach is initially tested with a set of non-conformities encountered at container ship fleet in different inspection visits. Furthermore, the findings contribute to systematic analysis of the non-conformities reported in different maritime inspection regimes.

Keywords Safety management system, Non-conformity analysis, Causation database, Container shipping.

1. Motivation

Managing the higher compliance of health, safety, environment, and quality dimensions is a core value of sustainable shipping. In regulation basis, there are various mechanisms, instruments, and procedures are addressed to achieve the standardization. Nevertheless, the international authorities, particularly International Maritime Organization, has underlined the implementation and enforcement problem in different platforms. Flag state control (FSC) and port state control (PSC) are the authorized inspection mechanisms to promote the globally recognized measures in ship operation and management (Fan et al., 2014). Indeed, it is aimed to increase the effectiveness of the control regimes by carrying out joint surveys focused on the thematic issues (fire-safety systems, lifesaving appliances, propulsion and auxiliary machinery system, etc.) under concentrated inspection camping (Akyuz et al., 2016).

Here, it is so critical issue to systematically analyse the inspection records derived from different sources. In this circumstance, the record might include non-conformities, near miss findings, hazardous occurrences, incidents, accidents, and total losses. It is so clear that detailed investigation of these records has vital importance to maintain continuous improvement. In addition to PSC findings, the scope of records can be extended to different inspection mechanisms, conducted by recognized organizations, such as vetting authorities, classification societies, and insurance companies. The implementation of internal audit mechanisms, especially covering requirements of ISM, ISPS, MLC and other regulations, derives a great amount of record. The valuable contributions from the top researchers to develop consistent algorithms on statistical analysis of such kind of records in detail (Fu et al., 2020; Yang et al., 2020; Hänninen and Kujala 2014; Demirci et al., 2022; Bhattacharya, 2012).

However, data scarcity is still a common barrier to diversify the deep analysis in regulatory compliance in shipping. It furtherly seems to be the major bottlenecks for researchers, practitioners, and shipping executives as well. This study proposed a methodology to develop an extended database of non-conformities derived from ship inspection reports. This chapter introduces the motivation behind the focused maritime issue. The next chapter reviews the causation frameworks in literature. Then, the relationships among the frameworks and ship management organization particular to container shipping, is conducted in third chapter. The fourth chapter demonstrates a set of non-conformity from container shipping fleet to develop an extended database. The final chapter gives concluding remarks and future issues.

2. Causation Frameworks

Maritime authorities require timely reporting and analysis of accidents, incidents, hazardous incidents and related deficiencies. It is a great necessity for shipping companies to promote corrective and preventive measures in accordance with SMS. In order to proceeded proactive solutions, effective methods need to be developed and followed. Nevertheless, there is no specific methodology defined within any regulatory instrument in order to analysis the mentioned cases. Considering the findings of inspections, the analysis begins with the definition of case. Then, the required information and evidences are collected. Identifying the possible causal factors is the next stage to clarify the situation. Determination of root cause(s) by taking the techniques (i.e. FMEA, 5-whys, etc.) into account. The final stage recommends the preventive actions, timescales, responsibilities, and follow-up plan through the cycle. In this study, a causation framework is developed to perform consistent casual factors identification on which a database is constructed. Considering the sectoral perspective, it can be argued that the use of MSCAT and HFACS techniques is the most appropriate analysis method for the ship management companies. To strength the practical aspect, the relationships among the frameworks and ship management organization is conceptualized. The integrated application of MSCAT-HFACS to structure a database in nonconformity analysis in ship management companies is performed in eight stages given as follows:

i) MSCAT-1: Substandard Acts
ii) MSCAT-2: Substandard Conditions
iii) MSCAT-3: Personal Factors
iv) MSCAT-4: Job/System Factors
v) HFACS-1: Unsafe acts
vi) HFACS-2: Preconditions for unsafe acts
vii) HFACS-3: Unsafe supervision
viii) HFACS-4: Organizational influences

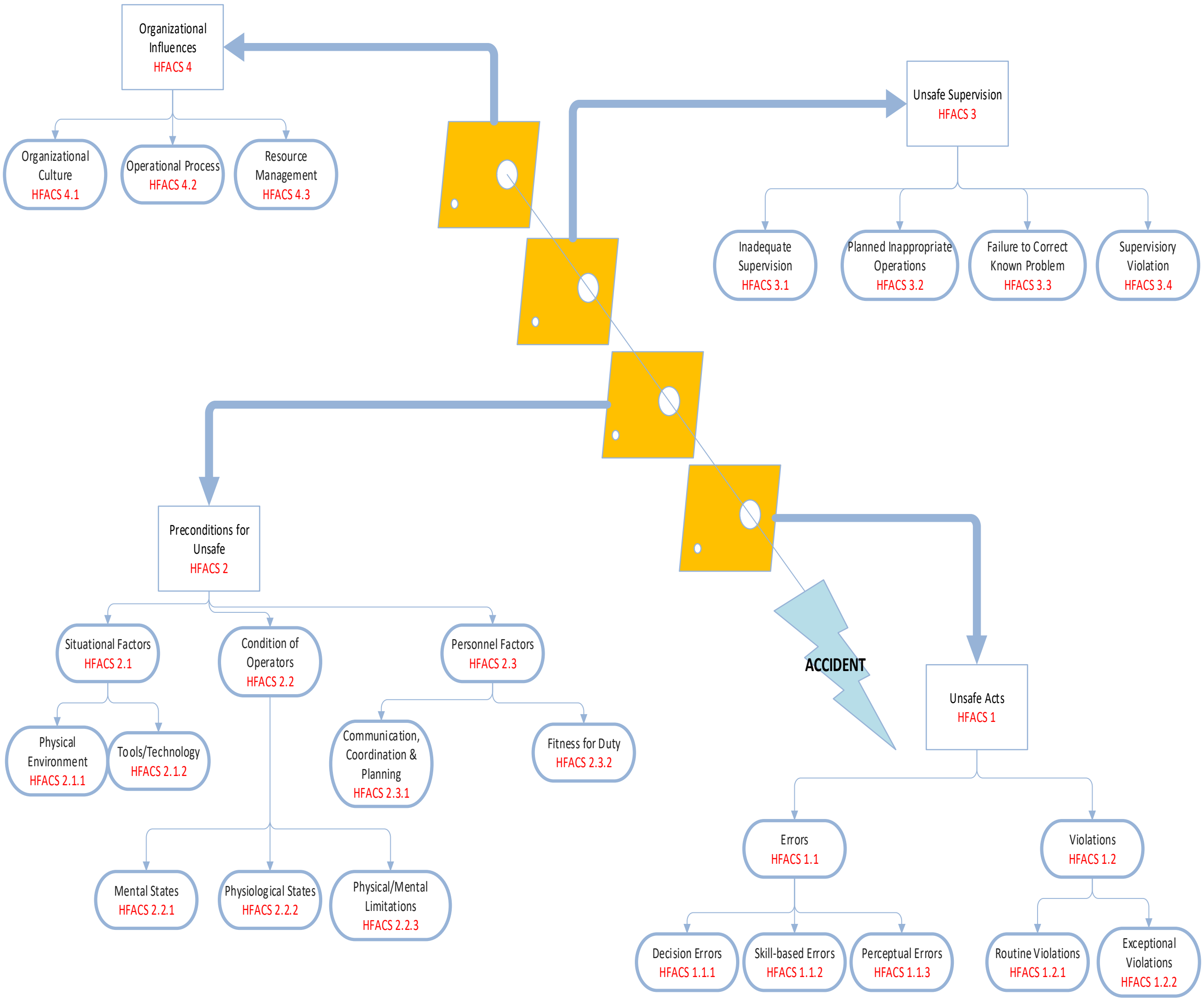
2.1 Marine Systematic Cause Analysis Technique (MSCAT)

Systematic cause analysis technique (SCAT) is a well-known approach to provide accurate evidences in accident analysis in various fields (Ahmadi, Mortazavi & Mahabadi, 2021). Particular to maritime era, MSCAT, developed by DNV-GL (DNV-GL, 2015), is referring as guide to perform comprehensive and rigorous investigations (Murray, 2020 Toz; Biber, & Sakar, 2022; Kececi and Arslan, 2017). The structure of MSCAT involves four distinct levels such as substandard acts, substandard conditions, personal factors, and job/system Factors. MSCAT-Substandard Acts, numbering #1-#22, includes the various factors such as influences of medicine/alcohol/drugs, failure to follow procedure/instruction, failure of secure, failing to use personal protective equipment, etc. MSCAT-Substandard Conditions, numbering #23-#46, includes the following causes; cargo, congestion/restricted space for action, defective tool/equipment, incorrect material, electrical current hazards, exposure to chemicals, etc. On the other hand, MSCAT-Personal Factors, numbering #1-#6.17, involves the subfactors under inadequate physical/physiological capability, inadequate mental/psychological capability, physical/physiological stress, mental/psychological stress, lack of competence, improper motivation, etc. MSCAT- Job/System Factors, numbering #7-#17.9, consists of sub-elements under unclear organizational structure, inadequate leadership, inadequate supervision/coaching, inadequate management of change, inadequate supply chain management, inadequate maintenance/inspection, excessive wear/tear, inadequate planning of use, inadequate tool/equipment/machinery/device, inadequate product/service design, inadequate work/production standards, inadequate communication/information.

2.2 The Human Factors Analysis and Classification System (HFACS)

The HFACS was initiated to support analysis of accident reports in aviation (Wiegmann and Shappell, 2003). Fundamentally, HFACS was structured based on four levels such as unsafe acts, pre-conditions for unsafe acts, unsafe supervision, and organisational influences. The structure of the HFACS method is presented in Fig. 1.

Figure 1: HFACS framework

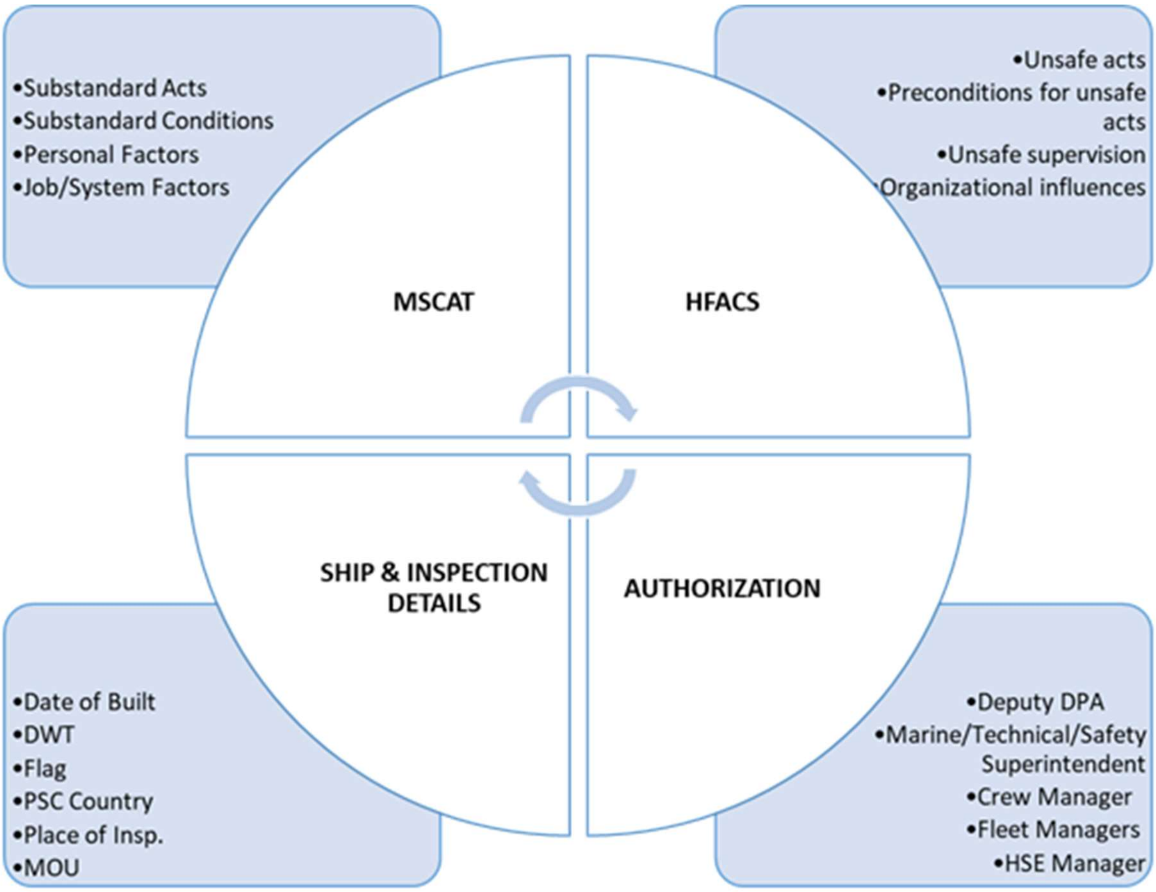


In addition to various application in different fields (Hulme, Stanton, Walker, Waterson, & Salmon, 2019), the HFACS is also extended to maritime safety era (Kaptan, Sarıalioğlu, Uğurlu, Özkan & Wang, 2021; Hasanspahic, Vujicic, Francic & Campara, 2021; Kandemir&Celik, 2021; Celik & Cebi, 2009). In this study, the combination of MSCAT and HFACS is utilized to develop an extended causation database of nonconformities encountered onboard ships.

3. Extended Causation Database

Considering MSCAT and HFACS frameworks, the relationships among the categories/levels and ship management organization are addressed in order to derive an accurate database in fleet level. A conceptual framework of extended causation database development mechanism is given in Fig.2. Besides the division-centred cause identification, the mechanism is also including ship and inspection details. Table.1 addressed the suggested managerial coordination system in nonconformity causation analysis & management in a container shipping company. Considering the managerial roles in company, the responsibilities in causation analysis are identified. The cause selection is proceeded in this order: Deputy DPA, Superintendent(s), Crew Manager, and Fleet Managers. Marine Superintendents, Technical Superintendents and Safety Superintendents will participate according to the subject of nonconformity.

Figure 2: Conceptual framework of extended causation database development approach



For instance, the Fleet Manager is responsible for the causations made with the MSCAT-1-2-3-4 while the Crew Manager is assigned to be responsible for the HFACS-1-2-3-4. The selections are reviewed and verified by HSE Manager. It provides a great flexibly to accurately select the suitable factors in nonconformity analysis process. Indeed, an extended causation database is developed. The verified causes are proceeded by the HSE Manager to circulate the extended database to statistical analysis phase.

Table 1: Managerial coordination system in nonconformity causation

	Deputy DPA	Superintendent(s)	Crew Manager	Fleet Managers	HSE Manager
MSCAT-1	●	○	○	●	●
MSCAT-2	●	○	○	●	●
MSCAT-3	○	●	○	●	●
MSCAT-4	○	●	○	●	●
HFACS-1	○	○	●	○	●
HFACS-2	○	○	●	○	●
HFACS-3	○	○	●	○	●
HFACS-4	○	○	●	○	●

4. Practical Study

The extended causation database development approach is initially tested with a set of non-conformities observed at container ship fleet in different inspection visits. In the practical study, the PSC inspection findings in 2015-2021 period is are investigated. To demonstrate the extended database, causation of 10 sample nonconformities, are studied in detailed. The nonconformities as given as follows;

NC 1: Lack of effectiveness in corrective action was observed.
NC 2: Engine alarm printer was failed.
NC 3: Retro reflective tape of lifeboat was dirty and at poor condition.
NC 4: Original supplement of IOPP certificate (Form A) was missed.
NC 5: Plimsoll marks was illegible.
NC 6: Magnetic compass in lifeboat (portside and starboard side) was not installed correctly.
NC 7: List of coast stations, special service stations and mobile service identities was outdated edition.
NC 8: International tonnage certificate and net tonnage cargo holds frames has incomplete information.
NC 9: Sailing direction and nautical publication were not properly filled in the previous passage plan.
NC 10: There was no identification asked and filled on control access book to inspectors.

Following the extended causation database development approach, Table 2 provides a sample for the nonconformity extended causation database.

Table 2: A sample nonconformity extended causation database

		NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8	NC9	NC10
SHIP & INSPECTION DETAILS	Vessel Name	Vessel A	Vessel B	Vessel C	Vessel D	Vessel D	Vessel E	Vessel F	Vessel G	Vessel H	Vessel I
	Date of Built	2005	2003	2017	2007	2007	1997	2007	2009	2001	2006
	DWT	33796	35971	36974	39257	39257	19325	22014	21988	33894	38133
	Place of Insp.	Novorossiysk	Beirut	Kuching	Beirut	Alexandra	Samsun	Mersin	Poti	Marseille	Algeciras
	MOU	Black sea Mou	Med Mou	Asia – Pacific Region PSC	Med Mou	Med Mou	Black sea Mou	Black sea Mou	Black sea Mou	Paris Mou	Paris Mou
MSCAT	MSCAT-1	#2	#2	#2	#2	#2	#11	#16	#19.5	#2	#2
	MSCAT-2	N/A	#25	#25	#41	#43	#40	#41	#26	#39	N/A
	MSCAT-3	#5.11	#5.1	#5.3	#5.11	#5.8	#5.11	#5.3	#5.1	#5.11	#5.4
	MSCAT-4	#8.7	#12.9	#13.2	#9.3	#12.6	#12.8	#16.11	#14.4	#9.1	#16.11
HFACS	HFACS-1	#1.1.1	#1.2.1	#1.2.2	#1.1.1	#1.2.2	#1.2.2	#1.2.2	#1.2.2	#1.1.2	#1.2.2
	HFACS-2	#2.3.1	#2.3.1	#2.3.1	#2.1.2	#2.3.1	#2.1.2	#2.3.1	#2.3.1	#2.3.2	#2.3.1
	HFACS-3	#3.4	#3.3	#3.2	#3.1	#3.2	#3.1	#3.4	#3.4	#3.1	#3.1
	HFACS-4	#4.2	#4.2	#4.2	#4.1	#4.2	#4.2	#4.3	#4.3	#4.3	#4.1

5. Conclusion & Discussion

This study focused on the first phase towards the management of nonconformities encountered onboard ships. The motivation behind the study is to overcome the challenges with the data scarcity in regulatory compliance monitoring. In this process, it brings added value to the process with its extended database approach. In this way, it will be ensured that nonconformity analysis is conducted more consistently. Identification of causes sequentially under MSCAT-1 Substandard Acts, MSCAT-2 Substandard Conditions, MSCAT-3 Personal Factors, MSCAT-4 Job System Factors and HFACS-1 Organizational Influences, HFACS-2 Supervisory Factors, HFACS-3 Precautions for Unsafe, HFACS-4 Unsafe Act enables a comprehensive perspective. The integration of MSCAT and HFACS frameworks will support consistency in cause identification, while linking with the ship management organization will provide practicality in implementation. Referring the 8 stages causation framework and managerial coordination system, a set of non-conformities observed at container ship fleet in different inspection visits is demonstrated. Consequently, the findings of this study encourage the researchers to conduct statistical analysis on non-conformities encountered in ship fleets. In addition to finding in PSC, the extended causation database might be applied to findings from different maritime inspection regimes.

Acknowledgements

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SWOT Analysis of Offshore Wind Power Development in Taiwan

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Abstract

Purpose – This paper aims to explore offshore wind power development and uses Taiwan to illustrate the main challenges involved and provides strategies to mitigate these challenges.

Design/methodology/approach – Strength, Weakness, Opportunities and Threat (SWOT) is used to analyze the strategic management issues (e.g. feasibility evaluation, construction technique, sailing safety, cost, terminal layout, crew, work ship, etc.) based on comprehensive literature review.

Findings – Taiwan has abundant advantages with wind resources although offshore wind power is still in the early stages. Taiwan's weakness is that it still relies on international support (e.g. Europe, U.S.) for the core know-how. It needs to make more efforts to develop local production. The opportunity is that Taiwan's geographic location is suitable for being a supply chain center for global materials, logistics distribution, work vessels, crew training center for the industry. Currently the governmental subsidy and administrative resource integration have gradually brought opportunities to promote this industry. The threat is negotiation and collaboration with stakeholders (e.g. shipping, fishing operators, and others) for improving environment and ecological impacts (e.g. sailing channel safety regulation, noise pollution white dolphin, fishing compensation, etc.).

Research limitations/implications – Research findings of SWOT application should be further revised based on other regions' characteristics in the future.

Practical implications – This paper provides strategic implications for the stakeholders (e.g. government, investors) who have interests in offshore wind power and help decision-making for feasibility evaluation.

Social implications – This paper studies how to balance the economic (e.g. investment profitability) and environmental (e.g. noise for white dolphin) interests and provides suggestions to mitigate negative effects.

Originality/value – Existing studies on offshore wind power has seldom focused on a strategic context. This paper adopts SWOT analysis to contribute original insights to industry development.

Keywords: SWOT analysis, Offshore wind power, Port, Maritime

1. Introduction

Climate change has led to a paradigm shift in the maritime and electricity sector (Koecklin et al., 2021). Due to negative public perceptions of fossil-fuel-based power generation, offshore wind power has been a renewable energy source in Europe for more than 20 years, e.g. in the Northern Sea. (Akhtar et al., 2021). Currently the costs of offshore wind power production have gradually declined, and received considerable public support through subsidies in many countries (such as in European countries, and Taiwan). These new development trends attracted many offshore wind power related entities (e.g. port authorities, manufacturers, electricity firms, supply chain operators, insurance firms, ship building manufacturers, consultants, shipping companies, crew training centers, etc.) to invest in this renewable energy market. It also involves many engineering and

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managerial skills, such as wind speed monitoring, construction, turbine technology, turbine foundation, turbine installation, grid connection, subsea cables, and regulatory regime. Offshore wind power industries have rapidly grown in many countries, including in Europe and China (Lin and Wu, 2021). Recent studies on offshore wind power have emphasized technology policy (Zhang et al., 2018), resource assessment (Ranthodsang et al., 2020), investment (Liu et al., 2021), regulation (Gonzalez et al., 2020), trend investigation (Soares-Ramos et al., 2020), policy and planning (Soderholm and Pettersson, 2011), economic feasibility assessment (Huang et al., 2022), offshore and onshore wind power comparison (Gao et al., 2021). Research focusing on strategic analysis is limited. This paper aims to fill this gap using Taiwan's empirical survey through SWOT analysis.

Taiwan has been viewed as a leading offshore wind power market in the world due to its suitable geographic location and strong wind conditions[1]. The governmental authorities (e.g. Maritime and Port Bureau[2], Taiwan International Port Corporation[3], and Ministry of Economic Affairs) and related port operators (e.g. shipping agents) have started to develop various investment projects in recent years. However, electricity volume, balancing potential risk (e.g. investment, policy, cost burden) and other factors (e.g. public acceptance and policy implementation commitment) need to be seriously considered when determining investing in offshore wind power since it might affect profitability (Sendstad et al., 2022).

In this paper, we aim to contribute to the offshore wind power literature, by using Taiwan as a case study to examine the potential challenges through SWOT analysis. The rest of the paper is organized as follows. Section 2 reviews past literature related to offshore wind power and development in Taiwan. Section 3 describes the SWOT analysis method. Strategic analysis for Taiwan's case is illustrated in Section 4. Finally, Section 5 offers a discussion and conclusions, as well as prospects for future research.

2. Literature Review

This section outlines the role of the offshore wind power in the maritime supply chain, Taiwan's development situation, and reviewed past related studies.

2.1 Brief review of offshore wind power

In recent years, offshore wind power has become an important global energy policy, port logistics and supply chain topic in the world, including in Taiwan. (Akhtar et al., 2021; Liu et al., 2021; Loos et al., 2022). Europe and the U.S. have plenty of offshore wind power experiences and know-how for more than 20 years. In Asia, China, South Korea, Japan, and Taiwan have started to invest in offshore wind power infrastructure in the past 10 years. Offshore wind power facilities generally are installed near the coast in order to reduce deployment cost and reduce the impacts on residents near the coast. However, such man-made structures at sea might affect the sailing operation of shipping/fishing operators. Related navigation standard should be further established in order to maintain regular sailing operation safety.

In general, a feasibility analysis of offshore wind power is a necessary procedure in the planning stage (e.g. wind speed monitoring, seabed foundation situation, construction and operation safety, finance load, politics, economic, policy commitment, engineering, operation period, environment impact evaluation, human training, public acceptance, etc.). It involves many types of vessels to monitor and construct the infrastructure for offshore wind power, such as geotechnical survey vessels, geophysical survey vessels, multi-purpose survey vessels, jack up barge/vessels, heavy lift vessels, construction support vessels, inter-array cable installation vessels, export cable installation vessels, diving support vessels, tug boats, service crew vessels, safety vessels, multi-purpose project vessels, tailor made operation and maintenance vessels, accommodation vessels, and multi-purpose cargo vessels. The life cycle of offshore wind power includes exploration and appraisal, drilling, offshore development, life to field, and decommissioning.

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[1] Ministry of Economic Affairs. https://www.trade.gov.tw/English/Pages/Detail.aspx?nodeID=855&pid=687967

[2] Maritime and Port Bureau. https://www.motcmpb.gov.tw/Home/Node?nodeId=10078&siteId=1

[3] Taiwan International Ports Corporation.
https://www.twport.com.tw/chinese/News_Content.aspx?s=85B3B5BAAFA54130

The main components of offshore wind power include hub, blade, nacelle, tower, boat landing, platform, transition piece, foundation, scur protection, and others. This industry also involves structures of artificial islands, sub-sea cable, fishing and mining right, uses of vessel, flights, and military consideration. From a maritime supply chain perspective, the stakeholders (e.g. surveyors, designers, manufacturers, banks, information service providers, logistics operators, crew, terminal operators, hinterland truckers, policy makers, environmental and ecological groups, etc.) in the offshore wind power industries (both upstream and downstream) need close long-term collaboration in order to reduce potential operational risk (e.g. finance or bank loan problems, transportation delays, government commitment, operational risks, natural disaster prevention, etc.) Also, many uncertain factors (e.g. construction and maintenance cost, technique, external environment, geography, governmental policy, crew, work ship, etc.) might affect the difficulties and cost for the installation and maintenance operations (e.g. wind turbines and foundation structures). In Taiwan, from a logistics management perspective, industry participants include offshore wind power manufacturers, including material providers (e.g. China Steel Corporation[1], Formosa Plastics Corporation[2]), assembly and system providers (e.g. blade, nacelle, tower, and transition piece, wind power machine manufacture, lift installation, pile installation, etc.), offshore wind power service providers (e.g. offshore wind power planning, operation, and maintenance, shipping operators, terminal operators, warehouse operators, inland trucker, etc.), offshore wind power electricity producer (e.g. Taipower in Taiwan[3]). In fact, offshore wind power is a cross-countries project and needs extensive collaboration, including communication. If any of the industry participants incurs delay or related problems that might bring big economic losses to others, and affect the operational efficiency. Related transportation and logistics activities include “offshore wind turbine and heavy material movements”, “work ship building (including barge, tugboat, survey ship, crane barge, etc.), purchasing and transportation”, “recruiting crew, training, and assignment”, “heavy wharf construction and the hinterland transportation”.

In the COVID-19 era, ship utilization and crew exchanges (e.g. renewing contract, crew rotation) are also critical issues facing the offshore wind power industry since they might affect shipping operators’ schedules and material supply chain distribution problems. The hiring costs of crews have become more expensive due to the impact of COVID-19 and have resulted in a higher cost burden for offshore wind power operators. Offshore wind power involves different field stakeholders, such as industrial and financial investors, governmental authorities, facilities and ocean engineering operators, etc. There is a key role for the government to play to close the gaps between the interests of all stakeholders.

From a port management perspective, a suitable port should be equipped with specific quays/facilities, and be able to provide logistics support, such as stevedoring, tower/ wind turbine assembly on the dock surface. These activities are not without operational risks. For example, operation and maintenance of offshore wind power are affected by ocean conditions (e.g. typhoon waves, earthquakes, etc.). Under extreme situations, it might cause seabed soil liquefaction and consequently lead to submarine cable damage. In the operation environment, wind speed deficits are highest during March-April and lowest during November-December in Taiwan.

Offshore wind power can bring both positive effects (e.g. economic benefits and job opportunities) and also negative effects (e.g. ecological impact on dolphins due to ship’s noise) (Hung, 2020). Thus, the environmental impact evaluation for offshore wind power and related regulations are important to regulate these negative impacts on the port environment. In addition, the installation of offshore wind turbines affects shipping sailing routes (e.g. commercial ships, fishing ships).

2.2 Brief introduction to offshore wind power in Taiwan

In order to decarbonise, the government in Taiwan has set a goal for renewable energy use to increase from 5% in 2016 to 20% in 2025 (Gao et al., 2021). Taiwan has been recognized as one key area to develop offshore wind power in the world[4] (Gao et al., 2021; Huang et al., 2022). According to the Bureau of Energy, Ministry

[1] China Steel Corporation. https://www.csc.com.tw/csc_e/ch/ifo/ifo.html
[2] Formosa Plastics Corporation. http://www.fpc.com.tw/fpcw/index.php
[3] Taipower, Taiwan. https://www.taipower.com.tw/en/index.aspx#
[4] Global News and Intelligence for the Energy Transition. https://www.rechargenews.com/energy-transition/cop26-taiwans-offshore-wind-dilemma-holds-lessons-for-the-world/2-1-1079736

of Economic Affairs, Taiwan's government will establish 600 offshore wind turbines before 2030[1]. A suitable offshore wind power port should be equipped with qualified terminal length, water depth, bearing capacity, and hinterland area.

The Western coast of Taiwan has substantial wind resources and rich potential but has not yet been developed for offshore wind power. It is argued that Taiwan can play a key role in regional offshore wind power supply chains, offering everything from foundations and transition pieces to turbine electronic components and blades[2]. Considering Taiwan's geographic location with strong and stable wind resource areas, most wind farms are concentrated in Changhua offshore[3] and geographically close to Taichung port. The Taiwan government has chosen Taichung port as the home port for offshore wind power that serves as the foundation of turbine pre-assembly (Figure 1), domestic manufacturing, maintenance and operation, and staff training.

Transition piece

Working vessel and transition piece load out operation

Figure 1: Offshore wind power assembly terminal in Taiwan
Source: Uni-Freight Logistics Cor., Ltd. Taiwan

In Taiwan, due to limitations in technology and resources, there is a reliance on European countries (e.g. Germany, Denmark, UK, etc.). Some international firms (and Taiwan's domestic firms) still hesitate investing in projects involving offshore wind power due to the potential risks (e.g. uncertain cost burden, time-consuming tending procedure, negative external environment factor due to typhoon in summer, fishing group compensation problems). It is also difficult to estimate the profitability. It is argued that long-term government commitment with sufficient support (e.g. subsidy and feed-in tariff mechanism) may be necessary to induce more investments in this industry.

In early 2017, the Taiwan government has started to execute the selection and tendering scheme. Investors and governmental units (Fishery Agency, Maritime Port Bureau and local governments) have continuously negotiated purchase agreements and other issues (e.g. sailing channel planning, investors must meet the requirements for the bidding documents for offshore wind turbines). In November 2019, the first offshore wind power facility (Formosa 1) has officially started operation in Miaoli. However, many uncertain risks (e.g. typhoon in summer) and disputes between stakeholders (e.g. fishing compensation, public acceptance) affected the interest in investing into offshore wind power for related operators. On 19 May 2021, the sailing direction for the Changhua farm channel was announced by Maritime Port Bureau (Figure 2). Port operation ships (including work vessel, commercial ship, fishing ship, etc.) must obey the sailing regulation and ensure safe regulation for entry/exit offshore wind power ship and navigation control operation in the port in order avoid potential collision risks.

[1] Bureau of Energy, Ministry of Economic Affairs, Taiwan. https://www.moeaboe.gov.tw/ECW/english/home/English.aspx

[2] https://www.rechargenews.com/energy-transition/cop26-taiwans-offshore-wind-dilemma-holds-lessons-for-the-world/2-1-1079736

[3] Hsinchu, Miaoli, Taichung, Changhua, Yunlin and Chiayi in Western coast of Taiwan are also potential development areas of offshore wind power.

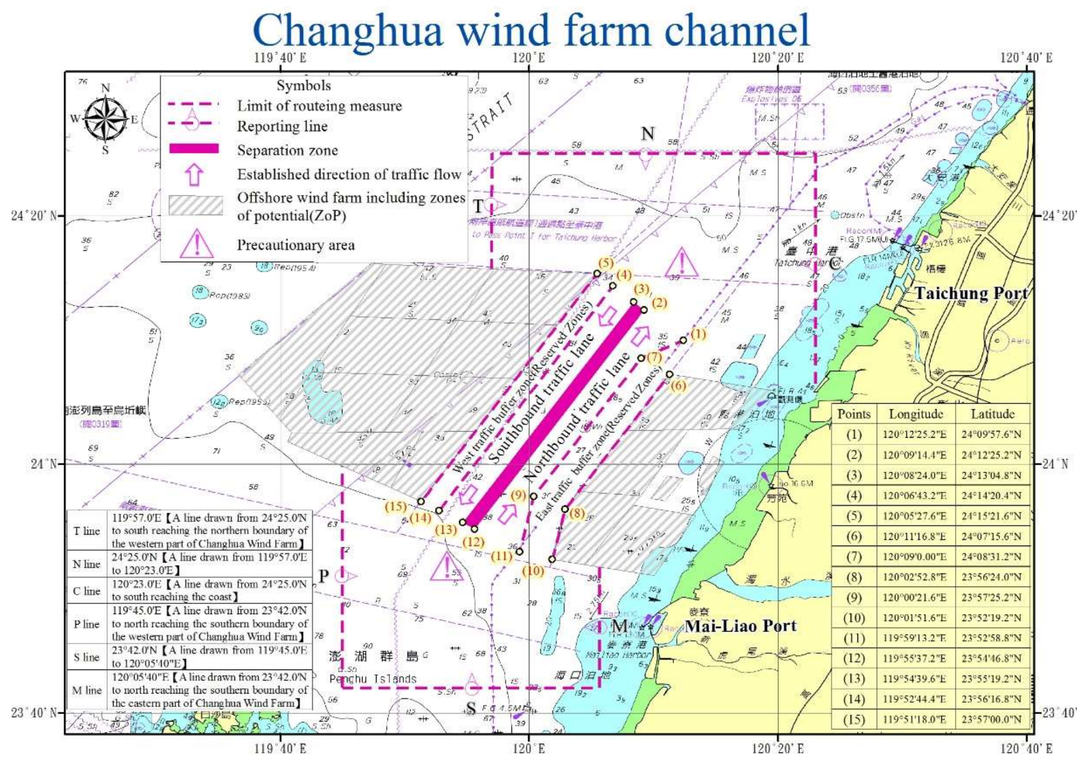

Figure 2: Changhua wind farm channel
Source: Maritime Port Bureau, Taiwan. https://en.motcmpb.gov.tw/

In Taiwan, the main pre-assembly area is Taichung port and its service contents include turbine pre-assembly, home port services for working boats, stevedoring, warehousing, transportation & logistics service. Local turbine manufacturing areas are Taichung (turbine manufacture area) and Taipei port (foundation manufacture area). A training center is located at Taichung port (providing global wind organization and customized courses). Operation and Maintenance (O&M) services are located at Taipei, Taichung and Pudai port (land based and water based O&M base, ship repairing works, and maritime transportation services). Regarding past research issues, Hung (2020) explored the relationship between conserving the oyster farming landscape, protecting an endangered species, and developing offshore wind power. Further, Huang et al. (2022) adopted economic feasibility to evaluate offshore wind power in the Changhua area in Taiwan. Cost-benefit analysis of 16 cages during five-year production showed that the breakeven point can be achieved at a survival rate of 50% and a purchasing price of 235 NT dollar/kg.

2.3 Review of offshore wind power issues in past studies

Past research has adopted various methods to study offshore wind power issues. For example, Zhang et al. (2018) explored selection of key technology policies for offshore wind power in China. South Korea has started to provide offshore wind power supplies since 2017 (Park and Kim, 2017). It is argued that public preference on energy infrastructure might affect renewable energy policies development (Koecklin et al., 2021). In order to explore public acceptance of offshore wind power in South Korea, Kim et al. (2020) used an ordered probit model to analyze the determinants of pros and cons of the offshore wind power project in July 2019. A total of 1,000 research respondents indicated that 43.3% agreed to the project and 23.8% disagreed. People who live in the Seoul Metropolitan area are more likely to accept the project than others areas. In Thailand, Ranthodsang et al. (2020) evaluated and conducted feasibility analysis for offshore wind power. Results show that offshore wind power plants with 3.3 MW wind turbine generators could produce over 13 GWh of electricity per year. In Brazil, Gonzalez et al. (2020) proposed a regulatory framework for development of offshore wind power development and related issues are discussed (e.g. tariff, licenses, marine and air collision, cable laying, construction and operation, and pre-decommission). In Taiwan, Gao et al. (2021) reviewed recent offshore wind power strategy. Based on 69 papers and 12 countries (including China, other European countries, UK, Spain, Norway, Denmark, Germany, USA, Korea, Iran, Brazil, Austria), Liu et al. (2021) reviewed decision-making methodologies (e.g. AHP, ANP, DEMATEL, ELECTRE, PROMETHEE, TOPSIS, VIKOR, TODIM, Fuzzy measure, interval type-2 fuzzy sets) in offshore wind power investments and mapped appropriate analytical techniques to specific investment applications and presented possible research gap.

In general, from the perspective of technology, wind turbine size and capacity, turbine model, distance to shore, water depth, investment cost, type of foundation, transmission technology, and voltage array systems are important consideration factors when evaluating offshore wind power (Soares-Ramos et al., 2020). Crew transfer vessel should pass the certificate mechanism by Classification Societies and confirm its seaworthiness. Schedules arrangement between barge, tugboat, survey ship, and crane barge also affect the port operation efficiency.

3. SWOT Analysis

In the early 1980s, Werwick, proposed the SWOT analysis method to solve various business management problems (Dyson, 2004). Up to now, SWOT analysis has been widely used in many fields (Arslan and Er, 2008; Miroslav et al., 2015; Ibrahim et al., 2019; Penco et al., 2019; Chandrachud and Venkataganesh, 2019), such as One Belt and One Road strategy in Jilin Province, China (Cui, 2019). In the port literature, Christodoulou and Cullinane (2019) studied the impact of the internal and external environment of the port for policy formulation via SWOT. Based on expert interviews and literature review, Tseng and Pilcher (2021) used PESTELE (Political, Economic, Social, Technological, Environmental, Legal, and Ethical)/SWOT analysis to explore the opportunities and challenges of the Kra Canal. Results revealed that huge challenges exist related to the construction and possibility of the Kra canal being built, such as its impact on the political balance within the ASEAN region. Also, the potential of the Kra canal for maritime business is significant, and that the Strengths and Opportunities of increased route possibilities and reduced sailing times outweigh any Weaknesses and Threats.

Based on SWOT results, a TOWS matrix analysis can be further applied to develop strategic planning for matching the environmental threat and opportunities with the organizational weakness and strengths (Weihcrich, 1982). Table 1 shows the TOWS matrix to improve potential internal and external problems and enhance the competitiveness and reduce potential barriers when conducting offshore wind power policies. Such a strategic analysis method has also been applied in other fields (Weihcrich, 1999; Gottfried et al., 2018).

Table 1: TOWS Matrix Analysis

		Internal	
		Strength (S)	Weakness (W)
External	Opportunities (O)	SO strategy: Give full play to internal advantages; Take advantage of external opportunities.	WO strategy: Take advantage of external opportunities; Overcome internal disadvantages.
	Threats (T)	ST strategy: Strengthen internal advantages; Avoid external threats.	WT strategy: Reduce internal disadvantages; Avoid external threats.

4. Results

4.1 SWOT Analysis Result

4.1.1 Strength

(1) Taiwan is located in a monsoon zone and surrounded by ocean, substantial and stable wind resource. Taiwan has a niche market to establish a hub of offshore wind power industry.

(2) Many large Taiwanese engineering companies (e.g. China Steel Corporation[1]) and marine companies (e.g. China Shipbuilding Corporation[2]) have started to invest in supply chain services of offshore wind power and provide necessary resources to develop localized offshore wind power.

(3) Taiwan has good onshore wind power experiences and has a capability to deal with the challenges of offshore wind power and respond to potential operational problems.

(4) Offshore wind power is clean and which aims at fighting climate change. Facilities/materials can be recycled during the end of life cycle.

4.1.2 Weakness

(1) Taiwan's offshore wind power is in the early stages and has lacked critical technologies. Most equipment of offshore wind power still relies on foreign imports and need the technical support from foreign engineers (e.g. Germany, Denmark, UK, US, etc.) to improve system integration problems. Also, the offshore wind power operators lack a maritime logistics capability and knowledge sharing mechanism.

(2) Taiwan currently lacks qualified wind testing and verification units.

(3) Sea operation during maintenance is dangerous (especially in winter) and adds to the difficulties when developing offshore wind power.

(4) Typhoon and earthquake in Taiwan might destroy the construction of offshore wind power, especially in geographical environment of offshore wind farm.

(5) Wind power in summer is smaller compared to winter. However, electricity usage is huge during summer period.

(6) Huge investment is needed when developing offshore wind power and it would be a challenge when competing with international companies.

4.1.3 Opportunity

(1) Taiwan's government authorities (e.g. Maritime Port Bureau, Fishing Agency) have continuously supported green energy policies and provided incentives (e.g. subsidy and fishing compensation) to promote the offshore wind power development policies, such as sailing area management, consulting services, crew training.

(2) Currently, Taiwan has spent lots of money to purchase material and hire professional engineers and consultants in Taiwan. When local supply for materials of offshore wind power becomes available in Taiwan, this will reduce transportation and maintenance cost.

(3) Most of other countries in Asia has less experience with offshore wind power. Taiwan has a great opportunity to develop a niche market based on abundant monsoon advantage and geographic characteristics.

4.1.4 Threat

(1) Political stakeholder influence is another risk, such as uncertain feed-in tariff of government, government intervention in provider choice.

(2) Developing offshore wind power might bring negative impacts on migratory bird and white dolphin. It might bring potential disputes from ecological groups and other stakeholders in the future. Related operation rules might be further revised in order to fit ecological conservation rules.

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[1] China Steel Corporation. https://www.csc.com.tw/indexe.html
[2] China Shipbuilding Corporation. https://www.csbcnet.com.tw/English/

(3) Public participation for offshore wind power is the future trend. Their opinions might positively or negatively affect the operation and procedures of offshore wind power. For example, stakeholders are concerned that offshore wind power might bring negative substances into the ocean, such as oil, chemicals, waste dumping from shore, atmosphere, ships, and dumping. Also, marine noise pollution with suitable sound exposure level will be regulated when constructing offshore wind power. These environmental issues should be gradually solved in the future. Necessary consultation and negotiation with these stakeholders will be necessary before official permitting the operation of offshore wind power.

(4) Offshore wind power might shrink fishing areas of offshore fishermen and damage the fishing right. The fishermen will strive their right to obtain satisfying government subsidy or compensation mechanism.

(5) Offshore wind power inevitably bring impacts, or even conflicts, to existing ocean utilizations, such as shipping, ecology, fishery, and the traditional uses of coastal communities.

4.2 TOWS strategy analysis results

4.2.1 Strength-Opportunity strategy

Taiwan's government has encouraged investors to develop offshore wind power since renewable energy is an important governmental commitment for its green energy policy. Taiwan has sufficient business information capabilities and R&D resources and thus has a great opportunity to play. The authorities could refer international organizations and advanced countries' experiences to develop Taiwan's offshore wind policies. The government authorities (e.g. Ministry of Economic Affairs) should provide an efficient licensing and consenting process to solve potential barriers and prevent potential conflicts. In addition, it is suggested that the government should develop transparency and open competition market to attract investors' intention for investing the construction and development of offshore wind power.

4.2.2 Strength-Threat strategy

Taiwan has a good investment environment with transparent government policies and it can effectively attract foreign investors to collaborate with the offshore wind power industry through reward and incentives strategies. During the feasibility evaluation stage, well organized environmental impact assessment with various fields experts' opinions (e.g. maritime, port, ecology, environment, finance, engineering, business, fishing, crew, manufacturing, noise, etc.) should be implemented and investigate potential adverse effects on the environment and human health. The authorities should develop resource and knowledge sharing platform to create opportunities for offshore wind power industries. For port authorities, it should formulate safe regulations on the entry and exit of offshore wind power vessels and navigation control operations in the port. Operators in vessel traffic center can prioritize berthing of offshore wind power work vessels.

4.2.3 Weakness-Opportunity strategy

The authorities could provide continuous incentives to attract international professional teams (e.g. Norway, Denmark, Germany, UK, US) and collaborate in Taiwan. According to experts and seabed geological hazard case studies, scientific teams could use advanced technologies (e.g. geographic information system, global position system) to identify potential development areas (with appropriate terminal sites) and construct risk evaluation mechanism and mitigation strategies to prevent potential losses (including natural disaster). Related authorities (e.g. Taiwan International Ports Corporation, Maritime Port Bureau, Coast Guard Administration unit) can help provide operational procedures for search and rescue operations in the future.

It is suggested that the government provides financial support when developing offshore wind power and consequently reduce potential investment risk. The authorities should establish well organized feed-in tariff mechanism and government commitment to attract more investors' intention and support more technique resources and achieve win-win goals.

4.2.4 Weakness-Threat strategy

Currently, environmental and ecological impacts still affect the operation of offshore wind power. It is believed that a good environmental impact evaluation (e.g. monitoring soft seabed soil and slope stability) can identify potential of soil liquefaction caused by earthquake and typhoon waves. Also, professional human training with certificates is necessary during the development and operation stages. It is suggested that the working operators should assign dolphin observer(s) to identify if any dolphin exist around the operation site (within 750-1500 m) (Rankin et al., 2020) and use bubble curtains to reduce the noise pollution (Figure 3) and construct piling engineering with gentle noise to improve the impact of environment and ecology. Finally, it is suggested to invite citizen and related stakeholders to participate and understand the development of offshore wind power through various marketing and promotion activities, such regular open meeting and school education. Communication between stakeholders could reduce disputes or barriers in the future.

Figure 3 Monopile installation vessel
Source: Uni-Freight Logistics Cor., Ltd. Taiwan

5. Discussion and Conclusion

Global environmental awareness has increased the focus on renewable energy, and a variety of countries have focused on the development of offshore wind power. The offshore wind power industry is closely related to the maritime industry and it involves design, engineering and fabrication, transportation and installation, and commission professions. This industry needs to integrate various knowledge areas, such as maritime, electricity, system control, civil engineering, structure, mechanic engineering, underwater engineering, noise monitoring, ecology and environment, ship building, business management, finance and insurance, safety, stakeholder management, etc. Taiwan has abundant wind resources around western Taiwan and offer many potential economic markets. Based on relevant literature, this paper used Taiwan with SWOT and TWOS analysis to explore its development challenges and present strategic implications. The research findings can help to establish operational guideline of offshore wind power development for the authorities (e.g. Maritime Port Bureau, Taiwan International Ports Corporation, Fishing Agency, etc.), shipping and terminal operators, and other stakeholders in the future.

Future research could benefit from our research findings. Further study topics can include quantitative (e.g. statistical or modelling analysis) and qualitative (e.g. expert interview) approaches, such as operation safety, insurance, purchasing and logistics, environment and ecology (e.g. noise influence for white dolphin), operator training, localized turbine manufacturing production, electricity production, feed-in tariff, human training and occupational safety (e.g. mechanic, electric, hydraulic training, sea survival, working at heights, fire awareness, first aid, manual handling, helicopter underwater escape training, customized wind turbine maintenance, cable maintenance, life cycle), cost-benefit analysis, stakeholder concern, etc.

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Gaming for Green Port Management as a Learning Tool: a Case Study of Green PorTech

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Abstract

Purpose – Constructing Green Port is a novel port management direction prevailing among the globe to realize carbon reduction in the context of ports developments. This study developed a 2D RPG game "Green PorTech" which mainly disseminates the professional knowledge of green port in simple and intriguing way. The main purpose of this study is to gather reflections of "Green PorTech" for improvements and verify university students' learning effects of this game.

Design/methodology/approach – Summarized relevant literature review of green port management and related practices to provide justifications for game setting basis. We further introduced current trend of Climate Change Education (CCE) and Digital game-based learning (DGBL) as guidelines to develop the game. This study used face-to-face feedbacks and questionnaire to empirically analyze four dimensions-learning, engagement, usability and user experience and satisfaction of the Green PorTech game.

Findings – The results shown that Green PorTech provides fine user experiences and satisfaction therefore raise the overall learning performance of the game. This research proved that Green PorTech can become a brand-new model of learning and discussion-facilitating tool in terms of introducing the idea of green port management and related climate change mitigation knowledge.

Originality/value – This study created the first 2D RPG game-Green PorTech based on implementing the idea of climate change mitigation measures on green port management strategies. Players are given chances to immerse themselves in the simulated port management scenarios and implicated green port management measures at first hand. In the hope of motivating the public of all ages enjoying the knowledge of green port by extracting pleasure from the game, in the meantime raise their green port awareness and core sustainability competencies.

Keywords: Green Port, Eco-Port, Climate Change education (CCE), Digital game-based learning (DGBL)

1. Introduction

Under the context of globalization, Ports is no doubt one of the most significant catalysts connecting the invisible linkages between ocean and land (Ningrum and Schuylenburg, 2020). Ports' flourishing transportation activities contributed enormous environmental pollutions especially greenhouse gas (GHG) emissions (Kaya., et al, 2017). Therefore, it's critical to find the solutions to strike a balance between Economic development and Environment protection.

The importance of Climate change education (CCE) has been specified for its educational purpose of educating learners of fundamental climate change knowledge and resilient action plans to cultivate their life with sustainability. The idea of Game-based learning (GBL) is proposed to improve learners' critical thinking, problem solving, and teamwork abilities to cooperate with others and adapt to the dynamically-changing world. In this paper, we practically simulated the idea of incorporating the Climate Change literacy education of Green Port into the innovative video game Green PorTech to educate the public with the carbon reduction measures that are adopted in Green Port management.

The paper proceeds as follows. We will first provide a brief literature review of Green Port management, certifications of Taiwan International Port Corporation (TIPC), and the CCE. Then clarified the need to build Green Port games as a learning tool for CCE games. Described the game basis of Green Port management practices and entire designing process of game are proposed, and the performance evaluation methods of Green PorTech is discussed. In last, the game users' feedbacks and statistics analysis would be analyzed as reference for future research and game developments.

2. Literature

2.1 The overview of Green Port Management

Green port development is about long-term plans, strategies and initiatives that make the port become sustainable and climate-friendly (Lam & Notteboom, 2012, Pavlic et al., 2014; Davarzani et al. 2016). Facing with the challenges of sustainability and environmental, numerous developed economies have initiate actions to implement green port policies and legislation in their countries and the term "green port " has become as a new paradigm within the field of port competition (Lawer et al., 2019). Woo et al. (2018) also indicated the rising public environmental awareness and timely evolves environmental legislation have brought ports to the forefront on sustainability issues. Besides, international institutes and organizations such as International Maritime Organization (IMO)'s MARPOL Convention, the European Sea Ports Organization (ESPO), the APEC Port Services Network (APSN) and International Association of Ports and Harbors (IAPH)'s World Ports Sustainability Program (WSPS) etc. all have set clearly principles and guidelines which connected UN's SDGs for the growth of green ports.

Therefore, in the past decade, many ports positively invested themselves into adopting green port policy and won certificated, labeled or conceived as green ports (Acciaro et al., 2014; Gonzalez et al, 2018). Be certificated or labeled as a green port has been proved to be positively related to higher port performance and economic benefits, and also enjoyed better corporate reputation and attracting climate and green funds and trading partners (Moon et al., 2018). As the pioneer in environment commitment to green port, TIPC has taken measures to promote the European Ecoports Certification and become the first port in Asia to receive the EcoPorts Certificate (PERS) in 2013, and continues to obtain renewed in 2015, 2017, 2019. In 2021, Port of Kaohsiung has been named the honored recipient of IAPH for Best Resilient Physical Infrastructure in World Ports Sustainability Program Awards. Green port policies created positive effects by improved environmental performance of the port and urban areas and vitalized the port industrial cluster (Woo et al., 2018). That is why ports need to implement green policies more actively. Green PorTech set its example point at the location of Port of Taipei to demonstrate the idea above in first step.

2.2 Climate Change Education via Game Development

Climate change education (CCE) is defined as education that implements and develops effective climate change strategies. The educational purpose of climate change education is to educate learners of among all ages understand the causes and effects of climate change, so that they can adopt appropriate action strategies such as prevention, mitigation and adaptation in the era of climate change, and cultivate their life with sustainability (UNESCO, 2022). Innovative and non-conventional teaching and education methods combined with multimedia and the Internet are encouraged to adopt under any climate change education contexts to transmit climate change knowledge directly to the public (UNESCO, 2019).

The usage of Digital game-based learning (DGBL) has been proven to be a feasible tool to alter students' attitudes and behaviors towards executing sustainability measures on Climate Changing issues (Janakiraman et al., 2018). Its advantage has also been verified, including raising public awareness on specific social engagement topics, altering players' attitudes toward climate change and sustainable development related themes and measures, and nurturing interdisciplinary and novel learning environments (Ho et al., 2022). Our game content and design are thus guided by the combination framework of Climate change education (CCE) and DGBL to design Green PorTech as a new learning tool for Green port education.

2.3 Gaming Education

The position of universities is critical in climate change education (CCE) if the global warming and resource depletion challenges the world confronts are to be met. Ouariachi et al. (2018) also mentioned universities are an efficient channel to engage young people in the key issues associated with climate change.

Consequently, to engage the public for green port idea, this study has chosen the universities as the first target audience to disseminate the fundamental knowledge of green port. However, the engagement of universities students has always been an insurmountable challenge for the higher education institutions. Given the urgency required to communicate and engage the public, new methods are being employed to convey environmentally conscious messages, gamification is one of popular and effective methods (Wu and Lee, 2015; Ouariachi et al., 2018; Fernández and Hamari, 2021). Games are identified as a natural and effective tool to communicate climate change education because of immersing players and place them in climate change scenarios (Janakiraman et al. 2018). Compare with acquiring green port knowledge from traditional reading and lecturing, games provide designed scenario experiences where players can learn and enjoy by being and doing (Gris and Bengtson, 2021). This study aims to fill this gap and select a Taipei port as a demonstration site. This study used questionnaire to empirically analyze four dimensions-learning, engagement, usability and user experience and satisfaction of Green PorTech game (Gris and Bengtson, 2021).

2.4 Competitive Games Analysis

The existing competitive games analysis of Green PorTech can be categorized into three types ——Eco Ports and Port Education, Climate Change Education, and Port operation and management. The types of Eco Ports and Port Education games are manual web browser games and board games. In Green PorTech, we input the fundamental infrastructures and different scenarios of port management process with originality in our games and added exclusive experiences (like the players' own green port certificate) to create resonances for players. Next, the types of Climate Change Education games are usually role-playing, decision-making and resource-allocating board games. In Green PorTech, we adopted the element of role-playing, introducing players' different professional positions (Captain, dock worker, and custom) in port management practices and emphasizing the importance of cooperating with each other on managing green port to combat the climate change phenomena. Last, the types of Port operation and management games are mainly video games which focused more on the techniques of effectively operating ports on economic aspects, in our game, we not only place emphasis on the interconnection of climate change and green port management, the economic concerns regarding carbon trade are also demonstrated and applied in the game.

3. Research Approach

3.1 Emergence of Green PorTech

Green PorTech is an unprecedent 2D pixel Role-Playing Game (RPG) developed to immerse the public with professional carbon reduction knowledge of Green Port in unique and innovative ways, with a view to raising public awareness of professional knowledge of green port management issues, improving national climate change literacy, and promoting Taiwan's ports contributions and efforts in green port managements. The naming of Green PorTech originated from the combination of Green Port and Technology, which elaborated our theme of promoting Climate Changing knowledge under Green Port context utilizing the technology of Unity Engine. Moreover, the pronunciation of "PorTech" resembles the word "Protect", which in line with our vision of protecting the entire global village from the harm of hazardous disasters bring about by Climate Change phenomena.

3.2 Complete Game sessions analysis

3.2.1 Game sessions

Figure 1 presented the complete gaming workflow of Green PorTech, the game is divided into four main sections: Firstly, initial game stage that shows the main gain scene to introduce the coming of players into the virtual game world of Green PorTech by customizing the users' name, with a view to increasing their sense of Engagements. In first section, the coastal activities are stressed, including the idea of ship slowing-down practices and the realization of connecting shore power through built-in gaming instructions, anticipating to increase the participants' willingness to learn by enjoying the unique gaming experiences. For the second sections, the game content shifted to the off-shore tasks especially focused on the arrangements and comprehensions for dangerous goods, providing users with the precautions of unpredictable disasters caused by dangerous goods accidents. As for the last section, we collaborated the professional knowledges of green port management policies and measures with Climate change education into brain twister along with a number of fun facts quizzes to remain vivid impressions for players to review main concepts.

Figure 1: Green PorTech game sessions design workflow

3.2.2 Layout Design Analysis

Based on the game flow of Green PorTech (shown in figure 1), the section of layout design analysis elaborated the two essential gaming components – game characters and the gaming scenes.

In Green PorTech, there are four main characters created in line with the four levels (figure 2). With the mysterious man acting as the game guide, it leads the player to accomplish all the game sessions. Players are given opportunities to play the three other roles – Pilot, docker worker, and custom. As for the gaming scenes, there are also six main corresponding scenes for four levels, listed as the child items in figure 1.

Figure 2: The four main characters in Green PorTech

3.3 Game Validation and Evaluation Approach

The corroboration of Green PorTech as effective learning tool facilitating interaction and communications on green port management issues has been implemented through two main experiences: (1) The Engagement and recognition in 2021 National Climate Change creative implementation competition and (2) assisted in arranging Climate change education exhibitions displaying Green PorTech to the in 2021 Climate Change forum. Along with the objective method of acquiring feedbacks for future modifications.

3.3.1 Climate change Competition and Climate Change forum curation

Green PorTech is rewarded as national top 7 championship out of 89 teams in Engagement of in the 2021 Climate change creative implementation competition. The award is recognized by the experts from the eight domains of Climate change mitigation and adaption. In the process of curation, we presented our complete Green PorTech models, and acted as the guidance to assist the players obtaining more pleasing gaming experience. Our players' age ranging from child to elderly, proving its flexibility and futuristic developments as a learning toolkit with no age barriers.

3.3.2 Evaluation Approach

The evaluation approach mainly contains two parts: (1) The instant oral feedbacks, (2) The statistical analysis of online questionnaire both after the comprehensive gameplay sessions of Green PorTech. In order to corroborate the learning effects of Green PorTech, the instant feedbacks after the complete game experiences from the players are also included into result analysis phases to provide concrete and specific suggestions and directions for future research. Then, a comprehensive online questionnaire designed with Likert five-point scale has been distributed to the players to better understand their learning performances on green port management and related climate change mitigation knowledge and user experiences for Green PorTech.

4. Results and Analysis

In the section of results and analysis, the content is mainly divided into three parts: firstly, the profiles of respondents, then evaluating the game using both qualitative method and quantitative methods.

4.1 Data Collection and Profile Analysis

A total of 35 students with 19 males and 16 females, with their age mainly ranged from 19~29 years old. On education background aspect, we focused on college students as our research targets, with undergraduate students composed of two-thirds and postgraduate students for remaining parts. The data collection duration was accomplished from 30 March 2022 to 2 April 2022.

4.2 Results of Feedbacks analysis

On the qualitative feedback session, respondents either directly give their suggestions to our team members face-to-face or by filling out the survey questionnaire after the gameplay process. The overall results would be categorized based on the four dimensions of assessment measures of game-based learning.

4.2.1 Sense of Engagement

Sense of engagement emphasizes on ensure if the game sessions is well-organized that assisted players to mentally immerse themselves in the game scenes and feel intensively related to the main theme this game tried to express, therefore leave strong impressions in their mind. Some positive feedbacks and suggestions regarding are listed:

"I think the background music in Green PorTech introduce me in indulging myself in the game sessions, which is very satisfying."

"The knowledge cards in the game can be integrated into game dialogues, which can introduce the players in a dynamic way, also provides more story background to deepen players' impressions."

4.2.2 Usability

For the dimension of Usability, we hope to acquire concrete suggestions and improving directions especially focused on the gaming interaction systems in Green PorTech including gaming instructions, design of interfaces, and other gaming mechanisms. The suggestions are listed as follows:

"The game instructions in first sessions are suggested to demonstrate in a clearer way."

"It's suggested to accelerate the walking speed of the player in Green PorTech for better control over the game."

4.2.3 Learning Performance

For the dimension of Learning Performance, we hope to evaluate the physical enhancements and improvements of Green PorTech as an effective learning tool for introducing green port management policy and its applications on greenhouse gas mitigation scenarios to our audiences. Some positive feedbacks are listed as follows:

"Green PorTech is certainly a meaningful educational game that introduced me professional green port management knowledge, which also reminds me of concerning related environmental issues."

"Every ports has their own environmental issues to deal with, and will therefore develop various characteristic measures to adopt. I hope one day, there would be a series of Green Port games for the public to get to know more about professional green port management knowledge!"

4.2.4 User Experience and Satisfaction

For the dimension of User Experience and Satisfaction, we hope to evaluate players' user experiences and degree of their satisfaction after the complete gaming experience of Green PorTech. Some feedbacks shown the audiences' affections for the overall art design of the game:

"Green PorTech is a cute retro game."

"The overall art design and the settings for characters are very adorable."

4.3 Results of questionnaires analysis

Based on the questionnaires data, the overall mean ranges from 3.97 to 4.69, representing most players' perception over the four dimensions. Table 1 shows the statistical results of descriptive analysis of the survey questionnaire. In first dimension -- Sense of Engagements, the mean scores of its four items ranging from 3.97 to 4.34, with the item "Strongly relevant to the main theme" obtained highest score, representing that the players felt the sense of Engagements during their gaming process since the game is prominently aligned with its main theme. For the dimension of Usability, the mean scores of its five items ranging from 4.14 to 4.34, with the item "Quickly get the tips to accomplish" obtained highest score, indicating that most players agree that the design of gaming instructions, interface, and interactive mechanisms systems in Green PorTech are well-designed that allowing them to find the knacks to accomplish the game. As for the dimension of Learning Performance, the mean scores of its four items ranging from 4.54 to 4.69, which has best performance among all the dimensions. The item "Learn green port management policy" obtained highest score, elaborating players acquired broader visions and are evidently more interested in Green port management policy and measures after playing Green PorTech. Lastly, for the dimension of User Experience and Satisfaction, the mean scores of its four items ranging from 4.23 to 4.49, with the item "Helpful of raising sense of identification." obtained the highest score, highlighting the effectiveness of Green PorTech on constructing players' sense of identification for Green port management policies and issues by providing them pleasing gaming user experiences. As the statistics shown, the mean scores for all items and dimensions mainly exceeds 4, representing the players giving recognitions to Green PorTech as a pioneering learning tool for future educational promotions for Green port management policy and issues developments.

Table 1: Results of descriptive analysis of the survey questionnaire

Dimensions	Measurements	Mean	SD
Sense of Engagements	An intriguing game.	4.26	0.817
	Strongly relevant to the main theme.	4.34	0.873
	Indulged in the game scenes.	4.20	0.833
	Game sessions connected logically.	3.97	1.043
Usability	Instructions was logical and easy	4.14	0.974
	Interact smoothly with gaming mechanisms	4.20	0.868
	Manual interface is user-friendly and well-designed.	4.23	0.877
	Game playing process is straightforward.	4.23	0.808
	Quickly get the tips to accomplish	4.34	0.938
Learning Performance	Learn green port management policy.	4.69	0.583
	Learn GHG mitigation policy.	4.57	0.655
	Learn green port applications on GHG mitigation scenarios.	4.54	0.657
	An effective tool for deepening knowledge for green port management policies.	4.57	0.739
User Experience and Satisfaction	I enjoyed the game experiences.	4.23	0.877
	Satisfied with game design.	4.40	0.812
	A sense of achievement after accomplishing.	4.23	0.877
	Helpful of raising sense of identification.	4.49	0.702

We conducted difference analysis based on different gender and education background of the respondents. As Table 2 shown, there were no statistically significant gender differences for Sense of Engagements, Usability, and Learning Performance, with women's mean scores are performed slightly higher, indicating indifferent perceptions between gender. In contrast, statistically significant differences have demonstrated in dimension of User Experience and Satisfaction, with $t(35) = -2.428$, $p = 0.022$, representing remarkable difference that women has significantly more pleasing user experiences and satisfaction for the game.

Table 2: Results of difference analysis by gender

Dimension	Gender	N	Mean	t-value	Significance
Sense of Engagements	Male	19	16.1053	-1.428	.163
	Female	16	17.5625		
Usability	Male	19	20.3158	-1.391	.174
	Female	16	22.1250		
Learning Performance	Male	19	17.8421	-1.477	.149
	Female	16	19.0000		
User Experience and Satisfaction	Male	19	16.3684	**-2.428**	**.022**
	Female	16	18.5000		

As for the difference analysis on respondents' education background, the dimension of Sense of Engagements, Usability, and User Experience and Satisfaction shown insignificantly difference, with undergraduate's mean scores performed averagely higher (shown in Table 3). However, on the dimension of Learning Performance, undergraduate performed conspicuously better than postgraduates, with $t(35) = 2.665$, $p = 0.019$, indicating that Green PorTech shown prominent learning effects on Green port management policies and issues for undergraduate students.

Table 3: Results of difference analysis by education background

Dimension	Education	N	Mean	t-value	Significance
Sense of Engagements	Undergraduate	23	17.1739	0.887	.389
	Postgraduate	12	16.0000		
Usability	Undergraduate	23	21.8261	1.174	.259
	Postgraduate	12	19.8333		

Learning Performance	Undergraduate	23	19.2174	**2.665**	**.019**
	Postgraduate	12	16.7500		
User Experience and Satisfaction	Undergraduate	23	18.0000	1.626	.126
	Postgraduate	12	16.0833		

5. Conclusions and Future Outlook

5.1 Conclusions and Discussion

The commitment of the world ports to sustainability has evolved from the concept of "green ports" and "eco-ports" to aligning with the United Nations Sustainable Development Goals (SDGs). That means the port sector has transformed from passive pollution and conflict resolution to proactive sustainability. The cooperative alliances of port clusters also extend to integrated the ports, industrial networks, and the neighboring cities in order to meet the challenges of global climate and become sustainable and resilient ports. In order to implement the concept of green port, the main actions taken by the TIPC include the green port policy, eco-port certifications, and the commitment to connect with the United Nations for sustainability. TIPC only fulfills its corporate responsibility, but also increases the environmental competitiveness of the Taiwan Port cluster and actively becomes a member of the world sustainable ports (TIPC websites).

Green port is still an emerging topic that needs to place more emphasis on in the field of Climate Change Education. In this paper, we summarized the possibilities of video games with application in Climate Change Education (CCE) on Green port carbon reduction aspects. We further produced and demonstrated the game Green PorTech incorporating professional Green Port management knowledge especially regarding Carbon Reduction aspects to exemplify the opportunities of utilizing video games as a learning tool to engage people in paying attention to Green Port management topics. The ultimate goal is to amplify the power of game-based learning to invoke players' internal motivation of learning and observing more about Green port developments. Through accomplishing the intriguing challenges in games, their understanding of Green port developments towards economic, social, and environmental aspects are improved to possibly change their attitudes toward Green port management issues.

Taiwan as an island country surrounded with Pacific Ocean, its ports act as the bridge between Taiwan's land to the entire global village, which can massively affect surrounding areas due to the hustle and bustle shipping and maritime economic activities; not to mention the direct and indirect environmental pollution impacts on surrounding ecosystems and environmental systems. Therefore, the dilemma of economic and environmental aspects needs to be carefully reconsidered in cooperation of all the stakeholders. In addition to the geographical relationship, the Green Port is actually one of the environmental indicators that the international community pays great attention to.

The results collected from feedback analysis can be summarized as follows: Some players responded with positive feedbacks, others provided practical game mechanism and design suggestions, still others are amazed and approved the idea of incorporating hard-core climate change education with the use of multimedia. For quantitative analysis aspect, by creating connections between audiences and Green port management themes using attractive game sessions, combined with the detailed design of gaming interaction systems (from gaming instructions, interface, to mechanisms), Green PorTech provides fine user experiences and satisfaction therefore raise the overall learning performance of the game. In conclusion, based on the results analysis, this research believe that Green PorTech can become a brand-new example of handy learning and discussion-facilitating tool in terms of introducing the idea of green port management and related climate change mitigation knowledge to players among all educational level, ages, gender.

We look forward to creating Green PorTech as a stepping stone for future education and promotion of Green Port management measures towards Climate Change Education (CCE). Exploiting the internal motivation of playing games as a driving force, the public are more willing to discuss and begin to pay close attention to Green port managements and developments.

5.2 Research limitations Future Outlook

Ultimately, we organize the future improvement directions and suggestions of the works into the following context for future research and game developments of Green PorTech, and the suggestions are divided mainly into two main aspects: game content and advancement of game development technologies.

On game content aspect, Taipei port is set as the first game demonstration target, it is expected that different green ports or eco-ports in Taiwan or ports around the globe can also be added as the displaying points based on their respective traits. Additionally, as our respondents suggested, more novel contents and difficult gaming interactive mechanisms can be included to enrich the game thus attracting more players to concern about green port management issues. Last but not least, as Taiwan and other countries continuously pursuing been rewarded for eco-port recognition, the realistic complete recognition process are suggested to be visualized.

On game development technologies aspect, the idea of Virtual Reality Learning Environments (VRLEs) has been proposed to adopt as avant-garde technologies for its features of providing users the opportunities to immerse themselves in the simulated physical environments under preset scenarios in computer systems (Stavroulia et al., 2019). Ports are often the area with constraints, which is not easily accessible for the public. Therefore, with the assistance of Virtual Reality Learning Environments (VRLEs) constructed based on actual port structures and activities would help increase players' engagement for Ports related and Green Port management issues, visualizing their imagination and improve their learning interests and efficiency compared to concentrating on routine activities in traditional paperwork education.

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Air Passenger Data Protection: The Case of China

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Abstract

Purpose – The development of civil aviation sector necessitates the enactment of laws and regulations on air passenger data protection. This article analyzes challenges in protecting air passenger data in China after the adoption of the Personal Information Protection Law of the People's Republic of China and gives corresponding suggestions.

Approach – Based on the analysis of Chinese laws and regulations regarding air passenger data protection, this article examines the new challenges in air passenger data protection. These challenges include the definition ambiguity of personal information, dilemmas on the application of informed consent rule, improprieties on the burden of proof in air passenger data leakage disputes and difficulties in regulating transborder air passenger data flows.

Findings – This article explores a set of suggestions for legislators, air passenger data processors and data subjects respectively: firstly, it is helpful to clarify the definition and scope of sensitive personal information, private information and right to privacy; secondly, air passenger data processors should simplify the privacy policies and display the policies on the website in a reader-friendly visual format; thirdly, the aviation industry is encouraged to launch a self-discipline work to develop industry self-regulation; last but not least, setting up a global regulatory framework in the form of international treaties or aviation industry sector instruments can help to standardize the transborder air passenger data processing activities.

Value – This article put forward strategies and suggestions to strengthen air passenger data protection in the digital era.

Keywords – Air passenger, digital era, data flow, data protection, Personal Information Protection Law

1. Introduction: the relevance of protecting air passenger data in China

In the digital era, rapid developments in information technology have brought new challenges to personal information protection (Lord, 2019). To start with the most obvious, when the data processors collect personal information, the right to data protection is at stake (Oostveen, 2018). Making a balance between data protection and data flow is of great importance. Suppose the protection of personal information is too strong. In that case, it will constitute an obstacle to the sharing and flowing of personal information and data mining, and therefore may hinder the economic value realization of personal information (Lieshout, 2016). If the protection of personal information is too weak, however, it will lead to the abuse or leakage of personal information. The development of big data analysis outpaces the existing legal frameworks, thus reconciling the societal benefits of big data with the increased risks to personal information protection through laws and regulations is just around the corner (Tene and Polonetsky, 2013). To increase its level of personal information protection, China is speeding up the promulgation of laws and regulations on personal information protection.

Data protection law is omnibus regulation. The data processing activities in civil aviation sector are more complex (Abeyratne, 2010b), and the risk of personal information leakage in such sector is higher. The protection of air passenger data thus can be regulated through sector-specific regulations. Air passenger data protection is becoming more and more critical as airlines collect and use air passengers' personal information, such as name, date of birth, and frequent flyer number in the course of business. The new challenges in civil aviation sector necessitate adequate laws and regulations, specifically in air passenger data protection (Zadura, 2017). This article will focus on air passenger data protection in China. It will discuss the difficulties in air passenger data protection, including the unclarity of the scope of sensitive air passengers' personal information, the absence of informed consent for entrusting a third party to process data, the improprieties on the burden of proof in data leakage disputes, and airlines' compliance dilemmas on transborder air passenger data flows. Then it will put forward corresponding suggestions to strengthen the protection of air passengers' personal information.

2. Chinese legislations in re air passenger data protection

2.1 Overview: the Chinese legal framework of data protection

In recent years, with the increasing attention to personal information protection, the Chinese legal framework has been continuously improved (Han, 2018). China's development of personal information protection laws and regulations has experienced bottom-up processing (Feng, 2019). With decades of effort, China has established a comprehensive personal information protection legal framework based on the long-awaited Personal Information Protection Law, which took effect on November 1st, 2021.

Vertically, China's legal framework of data protection is based on the following three levels' law-making: national laws, national administrative laws and regulations, and department regulations. Firstly, national laws include Criminal Law, Civil Code, National Security Law, Cybersecurity Law, Data Security Law, Personal Information Protection Law and Law on the Protection of Consumer Rights and Interests. For example, In 2009, Amendment VII to the Criminal Law added the crimes of selling or illegally providing and illegally obtaining personal information. Under Article 253, any staff member of a state organ or an entity sells or illegally provides personal information which is obtained during the organ's or entity's performance of duties or provision of services in violation of the state provisions, if the circumstances are serious, shall be sentenced to imprisonment. Such entity, however, is limited to the field of finance, telecommunications, transportation, education or medical treatment. In 2015, Amendment IX to the Criminal Law broadened the criminal subject in Article 253 to whoever is selling or providing personal information in violation of the relevant provisions. Civil Code grants natural persons the interest of personal information protection. Cybersecurity Law regulated that no individual or organization may obtain personal information by stealing or any other illegal means, or illegally selling or providing personal information to any other person. Law on the Protection of Consumer Rights and Interests stipulated the business operators' obligation to protect consumers' personal information, that is, business operators and their employees must strictly keep confidential the collected personal information of consumers, and may not divulge, sell, or illegally provide such information to others. Secondly, national administrative laws and regulations that govern the personal information protection affairs issued by State Council, such as Telecommunication Regulation and Administrative Measures for Internet Information Services. Thirdly, department regulations protect telecommunications and internet users' legitimate rights and interests and maintain online information security. These department regulations include Provisions on Protecting the Personal Information of Telecommunications and Internet Users issued by the Ministry of Industry and Information Technology, Provisions on the Cyber Protection of Children's Personal Information issued by Cyberspace Administration of China, and some other regulations.

In addition, other documents concerning personal information protection, including national standards and trade standards, also guide the standardization management of personal information. These standards, such as Information Security Technology – Personal Information Security Specification (GB/T 35273 – 2020), stipulate stricter and more specific personal information protection requirements than laws and regulations, even though they are not mandatory.

Most of the air passenger data protection regulations are at the third level, the department regulations. They are usually called guidance, norms, and suggestions. These regulations include Regulations on Passenger Service Management by Public Air Transport, Rules for Aviation Safety Protection by Public Air Transport Enterprises and Implementation Guide to Information System Security Classified Protection of Civil Aviation.

2.2 Legal bases: from the cybersecurity law to the Civil Code

Adopted by the Standing Committee of the National People's Congress on November 7th, 2016, Cybersecurity Law of the People's Republic of China (hereinafter referred to as 'Cybersecurity Law') entered into force on June 1st, 2017. As China's first and the most critical legislation on cybersecurity, Cybersecurity Law has played an essential role in personal information protection (Yin, 2017). To guarantee cybersecurity and promote the sound development of economic and social informatization, Chapter IV 'Network Information Security' of the Cybersecurity Law regulates the principles of collecting personal information. The Law confirms that network operators are obliged to protect users' personal information and establish and improve the protection system. When collecting and using personal information, network operators shall follow the principles of legality, rightfulness and necessity. The Law defines personal information as all kinds of information recorded in electronic or other forms, which can be used independently or in combination with other information, to identify a natural person's personal identity. The personal information includes but is not limited to the natural person's name, date of birth, identity certificate number, biology-identified personal information, address and telephone number. Such definition, however, has been expanded by Civil Code of the People's Republic of China (hereinafter referred to as 'Civil Code') in 2020.

Civil Code, which was adopted by the 3rd Session of the Thirteenth National People's Congress of the People's Republic of China on May 28th, 2020 and came into force on January 1st, 2021, is the first-ever Civil Code in China. It covers most civil activities in a person's life, including property, contracts, personality rights, marriage and family, inheritance and tort liability. Civil Code strengthens the protection of personal information and marks a significant step forward in respect of data protection (Cheng, 2020). Civil Code Article 1034 adds three types of personal information to the definition in Cybersecurity Law: e-mail address, health information, and whereabouts information. Chapter VI 'Right of Privacy and Protection of Personal Information' of Civil Code regulates that laws and regulations protect natural persons' privacy right and personal information. The Code reconfirms the principles of lawfulness, justification and necessity when processing personal information. It also regulates that data processors shall not excessively process personal information.

2.3 Sector-specific regulations: from data protection to air passenger data protection

Compared with ordinary personal information, air passenger data are more sensitive since the leakage or illegal use of air passenger data could easily harm the air passengers' personal or property safety (Enerstvedt, 2017). Furthermore, the processing of air passenger data is usually complex because multiple data processors will be involved (Abeyratne, 2010a). Given the inherent nature of civil aviation, cross-border flow of air passenger data is inevitable. Considering the characteristics of air passenger data, the Ministry of Transport of the People's Republic of China and the Civil Aviation Administration of China have issued regulations on personal information protection in the civil aviation industry.

These regulations are drawn up to ensure air passenger data security. For instance, the Implementation Guide to Information System Security Classified Protection of Civil Aviation regulates the object, purpose and process of the classified security protection of civil aviation data system. Guidance on Further Improving the Quality of Civil Aviation Service underlines the secrecy of air passenger data. Regulations on Passenger Service Management by Public Air Transport, which came into force on September 1st, 2021, stipulate that data processors shall not disclose, sell or illegally use or provide air passenger data. Such data processors are carriers, airport authorities, ground service agents, air transport sales agents, network platform operators and aviation data companies

2.4 Liability fixation: from fault liability to presumption of fault liability

On April 29th, 2021, China issued a second version of the draft Personal Information Protection Law. Under Article 68, in cases of harm to personal information interests, if the data processor cannot prove that it is not at fault, the processor will be liable for a tort and the relevant compensation. Compared with the regulation in the first version, this provision shifts the burden of proof for the parties in a tort legal action against personal information infringement. The second version clearly defines the doctrine of liability fixation of personal information infringement as a presumption of fault liability, which greatly lightens the data subjects' burden of proof (Cheng, 2021b). On August 20th, 2021, the officially passed Personal Information Protection Law adopted this regulation. Compared with the principle of 'who claims, who provides evidence' in previous judicial practice, the inversion of the burden of proof helps to solve the difficulties of proof by the data subjects.

3. Definition ambiguity of personal information

3.1 The boundary of personal information vis-a-vis right to privacy under the Civil Code

Chapter VI of the Civil Code distinguishes the right to privacy and protection of personal information. Articles 1032 and 1033 stipulate the concept of privacy and the situations of infringement of right to privacy. Articles 1034 to 1038 stipulate the protection of personal information. Under these Articles, privacy is the undisturbed private life of a natural person, and the private space, private activities, and private information that he is unwilling to be known to others. Private information is one kind of privacy, so the rules of privacy shall apply. Data subjects thus have the right to request the protection of personality rights and have the right to apply to the people's court to order the infringer to cease the relevant behavior. If there are no corresponding provisions, the provisions on personal information protection shall apply. Civil Code, however, has no provisions on what kind of personal information belongs to private information, leaving room for the identification of private information in judicial practice.

Although, to some extent, the right to privacy and personal information overlap, they are different in the following aspects. Firstly, privacy is one kind of 'personality rights', and specifically, it is a spiritual-moral personality right. Personal information, however, is a kind of comprehensive 'legal interest' that involves both mental interests and property interests (Ritter and Mayer, 2017). Personal information has not been protected as a 'right' in the Civil Code and Personal Information Protection Law. Secondly, personal information is an interest that can be actively exercised or used, while the right to privacy is passive and negative. A person cannot permit others to use his privacy. With his consent, however, data processors can process his personal information (Wang, 2021). Thirdly, personal information focuses on identification, while right to privacy focuses on confidentiality (Zhou, 2021). Privacy is the private space, private activities, and private information that a person is unwilling to be known by others. As for personal information, the key point is that it can be used to identify a specific natural person separately or in combination with other information.

3.2 Unclarity of the scope of sensitive personal information in aviation sector

Sensitive personal information is another classification of personal information regulated in Section 2 of the Personal Information Protection Law. Sensitive personal information can be divided into three categories: firstly, static information, which includes biometric information to identify a natural person uniquely, information concerning religious beliefs, identity, health care and financial accounts; secondly, dynamic information like information concerning personal whereabouts; and thirdly, personal information of minors under the age of fourteen. The leakage or illegal use of sensitive personal information could easily violate the natural person's dignity or harm personal or property safety. Sensitive personal information is subject to stricter rules than other personal information to give sensitive personal information a higher level of protection. The Law regulated the data processors' behaviors in processing sensitive personal information. For instance, data processors can only process sensitive personal information with specific purposes and sufficient necessity, and the processors must take strict protection measures. Data processors must also obtain the data subjects' separate consent for processing their sensitive personal information.

In civil aviation sector, the scope of sensitive personal information remains unclear. Air passengers' flight information shows their tracks; therefore, such information concerning personal whereabouts belongs to sensitive personal information. Minors' personal information also belongs to sensitive personal information. It is controversial whether the air passengers' reservation record information, personal passport information and purchase preference information belong to sensitive personal information. Furthermore, the Frequent Flyer Program includes passenger payment, boarding, beneficiary, and purchase preference which are of great economic value (Air China, 2021). The leakage or illegal use of Frequent Flyer Program information may harm air passengers' property safety. Airlines, however, have not agreed on what information is sensitive personal information or have not published stricter regulations to protect air passengers' sensitive personal information. It is also controversial whether sensitive personal information is equated with private information in Civil Code (Cheng, 2021a). If there is some overlap between sensitive personal information and private information, the rules of privacy will prevail, then comes the provisions on personal information protection.

3.3 Suggestions and prospects

It is helpful to clarify the definition and scope of sensitive personal information, private information and right to privacy. On this basis, different regulations and protection measures shall apply. As for sensitive personal information, if the scope is too broad, it will hinder the flow of personal information. The sentence 'the leakage or illegal use could easily lead to the violation of the natural person's dignity or harm to personal or property safety' in Personal Information Protection Law Article 28 shall be narrowly interpreted. The categories of sensitive personal information shall be listed explicitly.

Airlines shall conduct air passengers' data protection impact evaluation in advance and record the processing information. The evaluation must include the purposes of processing, the security risks and the corresponding protection measures. Listing sensitive air passengers' information in the Laws and Privacy Policy is a good way to remind air passengers. For instance, China Eastern Airlines Corporation Limited (hereinafter referred to as 'China Eastern') specifies that sensitive personal information includes: identity card, passport, permanent residence booklet and telephone numbers, online identification information, bank account numbers, itinerary information, and webpage browsing records. Airlines can learn from China Eastern's practice and reach a consensus in aviation sector.

4. Dilemmas on the application of informed consent rule

4.1 The informed consent rule under Chinese laws and regulations

As a significant rule on personal information protection, the informed consent rule regulates that data processors shall explicitly indicate the purposes, means and scope of collecting and using personal information. Data processors shall obtain the consent of the data subjects (Chalton and Gaskill, 1988). The informed consent rule has been stipulated in Chinese laws and regulations on personal information protection, such as Cybersecurity Law, Civil Code, Personal Information Protection Law and Decision of the Standing Committee of the National People's Congress on Strengthening Information Protection on Networks. The core of the informed consent rule is to respect and carry out the data subjects' will in data processing (Van Caeneghem, 2019). In this rule, making data subjects informed is the precondition; otherwise, the subjects cannot make a strategic decision (Thouvenin *et al*., 2021).

Under Article 41 of the Cybersecurity Law, informed consent is the only legal basis for processing personal information. Without the consent of data subjects, data processors shall not collect any personal information. Unlike Cybersecurity Law, Personal Information Protection Law provides exceptions for the informed consent rule, including (1) The data processing is necessary for the conclusion or performance of a contract to which the individual is a contracting party or for conducting human resource management under the labor rules and regulations, and a collective contract signed in accordance with the law; (2) The data processing is necessary to fulfill statutory responsibilities or obligations; (3) The personal information is processed within a reasonable scope to conduct news reporting, public opinion-based supervision, or other activities in the public interest; (4) The personal information that has been disclosed by the data subjects themselves or has been legally disclosed; and (5) Any other circumstance as provided by any law or administrative regulation. Under these circumstances, the data processors do not have to obtain the consent of data subjects.

4.2 Difficulties in the application of informed consent rule in aviation sector

Lack of technical knowledge and skills, data subjects are usually vulnerable vis à vis the data processors (Malgieri and Niklas, 2020). Airlines' Laws and Privacy Policies are usually long-winded and not reader-friendly (Gindin, 2009). Air passengers, however, can only passively receive the data policies provided by the airlines. Air passengers may get lost in the vast amount of information, thus the the valid information, such as the purposes, means and scope of collecting and using air passengers' personal information, may be ignored. The defects in the process of informing will affect the effectiveness of the application of the informed consent rule to a great extent (Asay, 2013). The air passengers may make an incorrect assessment of the security risks, therefore it is difficult for them to freely exercise their right to self-determination in the process of consenting.

When air passengers book tickets, airlines are just one process of the data flow. Online Travel Agency, Passenger Service Systems, airports and other aviation entities are also the data processors and take part in the data processing. Under the Personal Information Protection Law, all air passenger data processors have to inform the air passengers and obtain their consent if no 'exceptions for the informed consent rule' happen. Article 23 of the Personal Information Protection Law regulates that when providing any other data processor with personal information, the data processor shall notify the data subjects of the recipient's name, contact information, purposes and methods of processing, and categories of personal information. The data processor must also obtain the data subjects' separate consent. But whether the data processor shall obtain the data subjects' consent when commissioning the processing of personal information to another data processor is unclear. Article 21 of the Law only stipulates the data processors' supervision duty to oversee the personal information processing activities of the commissioned party. The data subjects' right to be informed and right to consent to the commission have not been confirmed. Whether the air passengers' consent should be obtained is controversial when one air passenger data processor commissions another air passenger data processor.

4.3 Suggestions and prospects

To prevent air passengers from getting lost in the verbose privacy policies, airlines and other data processors can simplify the privacy policies on the website, by summarizing the notices and displaying the descriptions in a reader-friendly visual format (Rao *et al.*, 2016). Completing the privacy policies with short-form notices tailored to the air passengers is also a good way to make them clear of the policies. As for sensitive personal information, only obtaining the data subjects' consent to the whole privacy policy is not enough, because this does not mean that the data subjects agree with the processing of sensitive personal information. The data processors shall obtain the data subject's separate consent for processing (Greenleaf, 2014). In addition, the data processors shall limit the collection to the minimum scope necessary for achieving the processing purpose (Burdon, 2020). If the data processors do not obtain the air passengers' consent, they may process the data beyond the minimum scope. Air passenger data processors shall abide by the 'minimum necessary standard' in the Information Security Technology – Personal Information Security Specification, which regulates that data processors must make reasonable efforts to use, disclose, and request only the minimum amount of personal information needed to accomplish the intended purpose.

The data subjects should have a close relationship with the commissioned party. As stipulated in the Information Security Technology – Guidance for Personal Information Protection within Information System for Public and Commercial Services (GB/Z 28828-2012), the airlines shall inform the air passengers of the commissioned party, the purposes and period of the commissioned processing, the processing methods, the categories of personal information and the corresponding protection measures. The triple authorization principle, first raised in Sina Weibo vs. Maimai, also guides data processors to use the informed consent rule properly. Under this principle, the first data processor shall obtain the data subject's consent. The third party shall obtain the consent of the first data processor when collecting personal information on the open platform. The third party also needs the consent of the data subject. This principle can help regulate the data flow and disclose personal information in a necessary scope.

5. Improprieties on the burden of proof in air passenger data leakage disputes

5.1 Recent cases on the distribution of the burden of proof

Pang Lipeng Case and Fang Yueming Case are the two typical cases concerning air passenger data protection in China. Both plaintiffs in these two cases believed that China Eastern leaked their personal information and filed lawsuits with the court to request compensation. The judge's logic of the two cases, however, is different.

On January 20th, 2016, Beijing Haidian Primary People's Court made the first-instance judgment of the Pang Case. The court denied that the two companies, China Eastern and Beijing Qunar Information Technology Co., Ltd. (hereinafter referred to as 'Qunar'), leaked Pang's personal information. The reason was that the evidence provided by Pang Lipeng could not prove that China Eastern and Qunar had infringed upon his personal information. Qunar is one of the Chinese tourism services providers from which air passengers can book tickets. On March 27th, 2017, however, Beijing No. 1 Intermediate People's Court made the final civil judgment in which the court revoked the first instance judgment. In the final judgment, the court held that the plaintiff should prove that the defendant has a high possibility of infringement. Then the defendant, in this case, China Eastern and Qunar, needs to prove that they have fully fulfilled their obligation of personal information protection. The Pang Case specifies that the standard of proof used to determine personal information leakage should be the 'high probability' for civil evidence. According to the standard of high probability, the plaintiff should prove that the personal information leakage was highly possibly caused by the defendant (The Supreme People's Court of the People's Republic of China, 2019). The defendant should prove that they are innocent of the leakage and have taken appropriate measures to protect the plaintiff's personal information. Before the Pang Case, there were other air passenger data protection cases, but most of the plaintiffs lost the cases. In these cases, the plaintiffs had the burden of proving the data processors leaked their personal information. In the Zhao Junyan Case, the court held that Zhao Junyan, the plaintiff, lost the lawsuit because she could not prove that the defendant did not take measures to protect her personal information and caused the leakage. Compared with other cases, such a shift in the Pang Case lightens the plaintiffs' burden of proof to some extent.

In the Fang Case, however, the court adopted the evidence rule of 'who claims, who provides evidence to support the claim'. The plaintiff needed to prove that the defendant leaked his personal information. The defendant should prove that it has taken adequate measures to protect the plaintiff's personal information. In this case, China Eastern won the lawsuits both in the first and final instances. China Eastern submitted a series of evidence to prove that it has set up the data desensitization system and formulated a strict data security management system. On this basis, the court held that China Eastern did not disclose Fang's personal information.

Under the standard of 'high probability' specified by the Pang Case, the proof requirement for the data processors is high. The Fang Case then helps to overcome the adversity faced by the airlines in the air passenger data protection cases.

5.2 Air passengers' disadvantages in gathering evidence

Data subjects are somehow weak on proof, since they usually have limited means to gather evidence. There are many air passenger data processors such as Online Travel Agency, Passenger Service Systems, airports and some other aviation entities. The numerous data processors may result in the plaintiffs' difficulty in identifying the infringer. It is difficult for the plaintiff to prove that the defendant is the only data processor who processes his personal information, therefore the plaintiff can hardly prove that the defendant causes the personal information leakage (Buttrick *et al.*, 2016). Some data subjects may not tend to file a complaint since they cannot figure out who infringes their personal information. To a certain extent, the power imbalances between air passengers and air passenger data processors increase the possibility of the plaintiff losing the lawsuit.

Personal Information Protection Law shifts the burden of proof. Rather than the plaintiff having to demonstrate justified grounds for claiming, the defendant, i.e., the data processors, must prove that they are not at fault, otherwise they shall assume liability for damage and other tort liability. Although such a shift makes it easier for data subjects to assert their rights, the data processors are under a heavy burden to prove no fault.

5.3 Suggestions and prospects

Airlines and other air passenger data processors need to prove that they fully comply with the Personal Information Protection Law. The different decisions in the Pang Case and the Fang Case reflect the importance of gathering evidence in the data processors' business. It is helpful for the airlines and other air passenger data processors to maintain a record of their processing activities. The data processors can ask the third party for a confidential assessment of the potential legal ramifications of the process activities (Cleland and Bidanda, 2000), and maintain the assessment report just in case. The aviation industry is also encouraged to launch air passenger data protection self-discipline work to develop industry self-regulation.

6. Difficulties in regulating transborder air passenger data flows

6.1 Rules on the transborder data flows under the personal information protection law

The transfer of personal information between states is necessary to expand international trade (Lloyd, 2020), whereas such cross-border flows put forward higher requirements for laws and regulations. Transborder data flows are closely related to national interests, so one frequent justification of countries for restrictions on transborder data flows is national security (Burri, 2021). The growth in transborder data flows has been accompanied by a growth in countries' laws and regulations of data protection to explicitly regulate the transfer of personal data outside the geographical boundaries of the country of data collection and processing (Kuner, 2013). In China, Measures for the Security Assessment for Cross-border Transfer of Personal Information (Exposure Draft) points out that the purpose of the measures was to guarantee personal information security, safeguard cyberspace sovereignty, national security, and social public interests, and protect the legitimate rights and interests of citizens and legal persons.

The draft Personal Information Protection Law regulates the transborder data flows in Chapter III – Rules on the Cross-Border Provision of Personal Information. The official version of the Personal Information Protection Law also takes the rules on transborder data flows as an essential chapter and further improves the regulations. Under the Personal Information Protection Law, personal information may not be transferred to any party outside the territory of China without meeting specific conditions. As for the informed consent rule, the Law regulates that the transborder data processors shall notify the data subjects of the overseas recipient's name and contact information, processing purposes, processing methods, categories of personal information, the methods in which the data subjects exercise the rights provided in this Law over the overseas recipient, and other matters. Such transborder flows shall obtain the data subjects' separate consent. The highlight of the official version is that it adds the provisions concerning the international treaty, i.e., if there is any international treaty or agreement concluded or acceded to by China provides for the conditions on the provision of personal information to any party outside the territory of China, such provisions may apply. The data processor shall take necessary measures to ensure that the personal information processing activities of the overseas recipient meet the personal information protection standards provided in the Personal Information Protection Law. The rules in the Personal Information Protection Law thus are the baseline of China's transborder data flows. The protection measures taken by the data processors shall not be inferior to the standards in this baseline.

6.2 Airlines' compliance dilemmas on transborder data flows

The tension between the free flow of data and precise regulation of transborder data flows takes place between different countries. Some countries favor little or no restriction to promote the free data flow, while others find it necessary to regulate transborder data flows precisely. The Chicago Convention confronted the international potential of civil aviation (Milde, 2016). The transborder air passenger data flows have accompanied the growth of the global aviation industry. Regretfully, there is no unified international regulatory framework on air passenger data flow at present.

Airlines operating internationally will process the worldwide air passengers' personal information. From the international perspective, the airlines must obey different laws and regulations of other countries (Walsh, 2009). For example, EU General Data Protection Regulation (hereinafter referred to as 'GDPR'), the California Consumer Privacy Act of 2018 (hereinafter referred to as 'CCPA') and China's Personal Information Protection have different regulations on minors' personal information. EU and China's regulations are stricter. The GDPR's parental consent requirement applies to all data processing, while the CCPA only requires parental consent for minors' data sales. The GDPR regulates that all data processing activities concerning minors below 16 years old shall be authorized by their parents. The CCPA regulation prohibits selling a consumer's personal information under 16 years old without consent. Minors aged 13 to 16 years old can directly provide consent. As for minors under 13 years old, parental consent is required. China's regulation is more similar to the GDPR. Under China's Personal Information Protection Law, data processors must obtain the consent of the minor's parents or other guardians when processing the personal information of a minor under 14 years old.

In addition, some countries' laws even have an extra-territorial effect. Take GDPR as an example. Article 3 of the GDPR regulates that GDPR applies to 'the processing of personal data of data subjects who are in the Union by a controller or processor not established in the Union, where the processing activities are related to the offering of goods or services, irrespective of whether a payment of the data subject is required, to such data subjects in the Union'. Many Chinese airlines have to update their privacy policies after the enaction of GDPR. In the United States, without a single principal data protection legislation in the United States, a jumble of hundreds of laws both on the federal and state levels play a role (ICLG, 2021). So Chinese airlines may also be subject to both federal and numerous state data protection laws for activities impacting United States residents whose information they collect, hold, transmit or process. Furthermore, the airlines must renew their privacy policies again after China's Personal Information Protection Law took effect. This may increase the airlines' compliance costs.

6.3 Suggestions and prospects

The existing aviation law bases seem insufficient to cope with the growing complexity of transborder air passenger data flows (Abeyratne, 2020). Setting up a global regulatory framework for transborder air passenger data flows can help to standardize the transborder data processing activities. Such regulations can be in the form of international treaties or aviation industry sector instruments. It is suggested that states work together to promote international cooperation concerning transborder air passenger data flows. It would be better if ICAO can draft a global treaty on transborder air passenger data flows. In addition, IATA can take measures to support airline ownership on data protection and look to establish a global industry-wide position on air passenger data protection (IATA, 2018). As for industries, airlines should try to ensure that their internal rules and regulations on air passenger data processing are complied with the governments' regulations.

7. Conclusions

The Chinese Personal Information Protection Law entered into force on November 1st, 2021, which was a milestone in China's data protection legal landscape. The sector-specific regulations in relation to air passenger data protection have also developed in recent years. Airlines can reach a consensus on the scope of air passengers' sensitive personal information to protect air passengers' personal information more effectively. Simplifying the privacy policies and tailoring them to suit air passengers' needs can help make the privacy policies more reader-friendly to meet the requirement of informed consent rule. Airlines and other data processors should maintain a record of their processing activities in case of air passenger data leakage disputes. Finally, states must work together to promote an international cooperation concerning transborder air passenger data flows.

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Analysis of PM10 Concentration Changes and Influencing Factors in Coal Port Area Based on K-means Clustering

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Abstract

Purpose – The purpose of this study is to analyze the change characteristics and influencing factors of PM_{10} concentration in the coal port area.

Methodology – The daily change of PM_{10} concentration was analyzed based on the K-means clustering method by using the 2020 annual monitoring data of a typical coal port area; the correlation between the PM_{10} pollutant concentration and humidity and wind speed was analyzed by combining the meteorological environmental characteristics of the port area.

Findings – The results showed that the PM_{10} concentration in the port area was positively correlated with humidity and negatively with wind speed, and the daily change trend was in the form of "single peak and single valley", with peak values obtained at 5:00-7:00 and alley values at 17:00-18:00. In addition, the PM_{10} mass concentration was prone to abnormal fluctuations in summer and winter, and showed six different clustering characteristics of hourly change patterns.

Value – The results of the study can provide theoretical support for the prevention and control of particulate matter pollution in coal port areas.

Keywords: coal port area; PM_{10}; K-means clustering; mass concentration change

1. Introduction

The loading, unloading, transportation and storage of coal in the port areas will generate a large amount of particulate matter, which not only pollutes the port environment, but also seriously affects the air quality of nearby cities (Tolis *et al.*, 2015) and the health of residents(Priyankara *et al.*, 2021; Xu *et al.*, 2018), and constrains the sustainability of the port. The prevention and control of particulate matter in coal port areas has become an important task for the construction of green port.

The PM_{10} concentration in the coal port area (particles with aerodynamic equivalent diameter ≤10 μm suspended in the atmosphere) is an important indicator for judging the extent of port dust pollution. Domestic and international studies on PM_{10} in ports mainly involve dust generation mechanisms(Wang, 2021), spatial and temporal variation patterns(Žibert and Pražnikar, 2012; Shen *et al.*, 2019; Diao *et al.*, 2020), and dust suppression measures (Hong *et al.*, 2021), with the conclusions indicating that PM_{10} concentration changes involve many factors such as meteorological conditions and human activities, with complex long-term persistence and nonlinear chaotic characteristics(Xie and He., 2019). The research of dust in dry bulk port areas in China started relatively late, but there have been abundant results on the time-frequency evolution of dust in recent years. For example, Wang *et al*.(2020) analyzed the time-frequency of atmospheric TSP concentration in dry bulk port area by using Hilbert-Yellow transform and elucidated the multi-scale characteristics of atmospheric particulate matter pollution in port area by combining the characteristic modal function; Feng *et al*.(2020) analyzed the atmospheric PM_{10} concentration in dry bulk port area in time-frequency by using Hilbert-Yellow transform, and pointed out that there were long-term and short-term influencing factors for the changes of PM_{10} concentration, the former influencing the overall change of pollution concentration and the latter influencing the difference of pollution concentration in different areas of the port area. In general, most of the current studies on PM_{10} time-frequency patterns have focused on the overall daily, monthly, seasonal, and annual variability patterns(Happy *et al.*, 2018; Gupta *et al.*, 2004), and there is a lack of attention to disobeying the overall patterns and a lack of in-depth studies on the time-varying characteristic patterns.

Clustering algorithm is an unsupervised learning algorithm, which combines data with the same or similar attributes to form a cluster data set. It will be a good clustering if the condition of low intra-set dissimilarity and high inter-set dissimilarity can be achieved (Yao and Yang., 2019). Clustering has a certain grouping effect (Tian *et al.*, 2021) and can provide insight into various relationships hidden in the data (Wang *et al.*, 2020). K-means algorithm, as the most typical and common kind of clustering algorithm, has the advantages of simplicity and ease of operation (Deng, 2020), and is also widely used in air pollution research. For example, Wang *et al.*(2016) performed K-means clustering of six basic air pollutants including PM_{10} to determine the pollutant sources.

There are few research results on the time-varying pattern of PM_{10} in the port area, and the K-means clustering method can ensure to achieve the advantage of high data similarity within the same cluster. In this paper, based on the online monitoring data of port dust in 2020, the PM_{10} data of Changshu FD port area of Suzhou port were clustered and analyzed to investigate the time-varying pattern of PM_{10} average concentration and its correlation with meteorological factors.

2. Technical solutions

2.1 Location

This paper takes the Changshu FD port area of Suzhou Port in Jiangsu Province as the research object, which is located in the lower reaches of the Yangtze River, and the main operating cargo is coal. The location of the monitoring points in the port area is shown in Figure 1.

Fig.1 FD port area and monitoring point
Source: Authors original

2.2 PM_{10} measurements

The PM_{10} data acquisition instrument is H6 particle particulate matter monitor, which emits laser light from inside the instrument to produce scattered light on the air pollutant sample collected by the instrument. Under certain conditions of particulate matter nature, the intensity of scattered light of particulate matter is proportional to its mass concentration, thus obtaining the concentration of atmospheric particulate matter, and then deriving the corresponding data through the sensor.

The detection data were recorded every minute at the monitoring point, which worked continuously for 24 hours. The detection data were for the whole year from January 1, 2020 to December 31, 2020 and included PM_{10} concentration values and real-time meteorological values of five parameters (wind speed, wind direction, temperature, humidity and barometric pressure).

2.3 Data processing

In order to ensure the accuracy and reliability of the data, data cleaning, including the identification and reduction of errors, is the first step in analyzing the data. Data cleaning for PM_{10} mainly included the processing of three types of data: vacancy data, error data and abnormal data. For the first two types of data, the main manifestations were: data loss due to weather, equipment, etc.; wind direction range not between 0 and 360°, PM_{10} mass concentration equal to the detector extremes (300000 μg/m^3) and other apparently unrealistic very few data, the processing of these two types of data corresponding to the time period would be deleted without analysis; for the remaining abnormal data, the triple standard deviation method was selected to cycle through the data set to eliminate the outliers, and the adopted outlier judgment (Huang *et al.*, 2006) formula is (1).

$$\left|x_i - \bar{x}\right| \ge 3 \times \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} \left(x_i - \bar{x}\right)^2} \qquad (1)$$

Wherein x_i is the i-th data in each group, $\bar{x}$ is the mean of the data in the group, and N is the total number of data in the group. x_i conforming to inequality (1) are regarded as outliers.

In order to reduce the complexity of data calculation, the K-means algorithm clustering of PM_{10} was performed with 25 eigenvalues for one day's data for input (the similarity between days was compared by 25 eigenvalues), where 24 eigenvalues were the PM_{10} mass concentration data corresponding to 24 hours of each day, and the 25th eigenvalue was the day's PM_{10} arithmetic mean concentration. In order to meet the needs of the first 24 characteristic values, the data were processed by the triple standard deviation method in a group of one hour data, and the outliers were eliminated through the cycle of inequation (1), and the remaining data in the group were taken as the arithmetic mean of a characteristic value. When there were less than 25 eigenvalues for a particular day, the deletion process was done because it was impossible to compare with other days, and a total of 36 days were deleted.

3. K-means clustering method

The core idea of the K-means algorithm is to randomly select k initial cluster centers from all the sample data sets, calculate the similarity between the remaining data objects and the cluster centers, and then assign these data objects to the cluster corresponding to the cluster center with the highest similarity. Then the new cluster center in each cluster is found, and the next iteration is performed until the cluster center no longer changes or stops when the maximum number of iterations is reached. According to the testing of three different similarity measures of PM10 in ports: a squared Euclidean distance, a city-block distance and a cross-correlation(Žibert and Pražnikar, 2012), this paper uses the Euclidean distance between the input feature values as the basis for judging the similarity, the greater the similarity is, the smaller the distance is.

In K-means clustering, determining the number of clusters is the most critical part of the K-means algorithm. In this paper, the problem was solved by combining the "inflection point method" and the "average contour coefficient method"(Kaufman and Rousseeuw, 2005). Firstly, the "inflection point method" was used to calculate the index for evaluating the effectiveness of the clustering quality: the Sum of the Squared Errors (SSE) was calculated by Equation (2).

$$SSE = \sum_{i=1}^{k} \sum_{P \in C_i} \left(P - m_i\right)^2 \qquad (2)$$

Wherein i represents the type i-th cluster in the clustering result, k is the number of clusters clustered, C_i is all the data sets of the i-th type cluster, P is any data element in C_i, and m_i represents the data center of the i-th type cluster.

The closer the value of SSE is to 0, the better the classification effect of the sample. When the value of k is less than the optimal number of clusters, the differences within the clusters are large, and the value of k increases, the aggregation degree of each cluster will increase significantly, while SSE will decrease rapidly. When the k value is greater than the optimal number of clusters, the difference within the cluster is small, the increase rate of the aggregation degree of each cluster will slow down, and the decline of SSE will tend to be gentle, but it is meaningless to choose a cluster with a large k value. Therefore, it is possible to draw a graph of (SSE) and the corresponding number of clusters (k) to find a point with a larger rate of change ("inflection point"), and the value corresponding to this point is the optimal number of clusters.

In the case where there is an insignificant shift in the decreasing trend of SSE, another index is introduced to determine the validity of the clustering quality: the average silhouette coefficient(SC). The average silhouette coefficient is calculated by the "average contour coefficient method" for different numbers of clusters, and the formulae are given in (3) and (4).

$$S(i)=\frac{b(i)-a(i)}{\max\{a(i),b(i)\}} \quad (3)$$

$$SC=\frac{1}{m}\sum_{i=1}^{m}S(i) \quad (4)$$

Wherein $a(i)$ is the average distance from the sample i to other sample points in the same cluster, indicating the dissimilarity of the sample within the cluster; $b(i)$ is the average distance from sample i to all points in other clusters, indicating the dissimilarity between clusters; $S(i)$ is the silhouette coefficient of sample i; m is the total number of samples; SC is the silhouette coefficient of the entire sample set, the value range is [-1, 1], and the closer SC is to 1, the better the clustering effect is.

The calculation results of the above two methods were shown in Figure 2. From the SSE curve in Figure 2, it could be seen that when $k < 4$, the decreasing trend of SSE was obvious; when $k > 4$, the decreasing trend of SSE slowed down, but the effect of the two changes was not obvious. Therefore, continuing to observe the SC curve in Figure 2, it could be seen that when $k=2$, the SC had a maximum value, but the clustering into 2 clusters couldn't well show the diverse change pattern of PM_{10}, and the large value of SSE was not good. Considering, $k=6$.

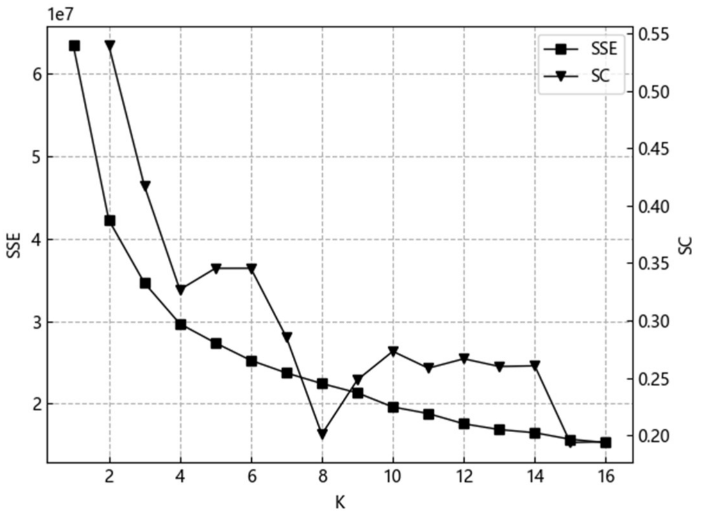

Fig.2 *SSE* 、 *SC* with cluster number *k*
Source: Authors original

4. Results and Discussion

4.1 Statistical analysis of PM_{10} annual average hourly concentration

The hourly average PM_{10} concentrations for 330 days in 2020, after excluding 36 days, were calculated and the results expressed by quartiles are shown in Figure 3. From the trend of the mean value, the daily trend of PM_{10} concentration shows a "single peak and single valley". The concentration peaks at 5:00~7:00 each day, then starts to decline rapidly, then reaches a valley at 17:00~18:00, and rises again at night. The possible reason for the overall low dust concentration in the morning when the operation intensity in the port area increases is related to the detector deployment at a height of 3m from the ground. In the morning, the Brownian motion of particulate matter is gradually stronger when the temperature rises, which drives the diffusion of pollutants to the upper atmosphere, thus making the dust concentration near the surface appear lower (Chen *et al.*, 2012; Gao *et al.*, 2020), and at the same time, as the artificial dust reduction measures such as spraying are turned on around 7:00~8:00 in the port area with the daytime operation, the PM_{10} concentration further decreases and reaches the valley value around 18:00; at night, although the intensity of operation in the port area becomes low, the closing of some artificial dust reduction measures such as spraying, along with the gradual reduction of temperature leads to the weakening of the Brownian motion of particles, which makes the PM_{10} concentration detected near the ground gradually rise to a peak around 7:00 the next day.

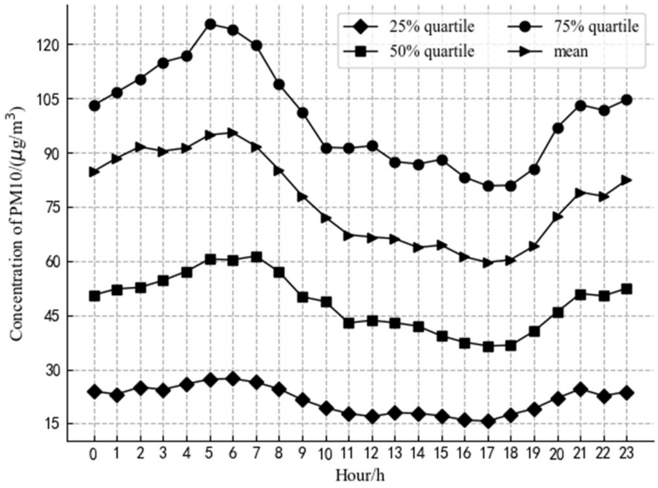

Fig.3 PM_{10} mass concentration change diagram at each time
Source: Authors original

4.2 Clustering results and analysis of PM_{10}

The data intervals between the 25% quantile and 75% quartile in Figure 3 are wide, and the fluctuation range of PM_{10} is 63-98 μg/m^3. This indicates that the intra-day variability of hourly concentration values is large, and further analysis by clustering is necessary. The clustering was performed by the aforementioned method, and the results are shown in Table 1 and Figure 4. For the convenience of description, the set consisting of all samples of class *x* (*x* taken 0-5) of PM_{10} in the clustering results is called cluster *x*, denoted as P*x*. Table 1 shows the specific monthly distribution of the number of days in each cluster. Figure 4 shows the daily variation of PM_{10} for cluster 0 to 5, and the data at each moment are the mean values of all days within each cluster at that moment in the clustering results.

Table 1 PM_{10} cluster classes correspond to the number of days per month

month\cluster	0	1	2	3	4	5	Total
January	4	8	8	0	4	0	24
February	0	19	5	0	2	0	26
March	0	26	3	0	2	0	31
April	0	24	5	0	1	0	30
May	1	16	3	1	5	0	26
June	2	12	7	0	9	0	30
July	1	17	2	7	2	2	31
August	0	12	7	5	7	0	31
September	2	2	5	3	4	0	16
October	0	23	3	0	3	0	29
November	1	14	11	1	3	0	30
December	3	13	4	0	6	0	26
Total	14	186	63	17	48	2	330

Source: Authors original

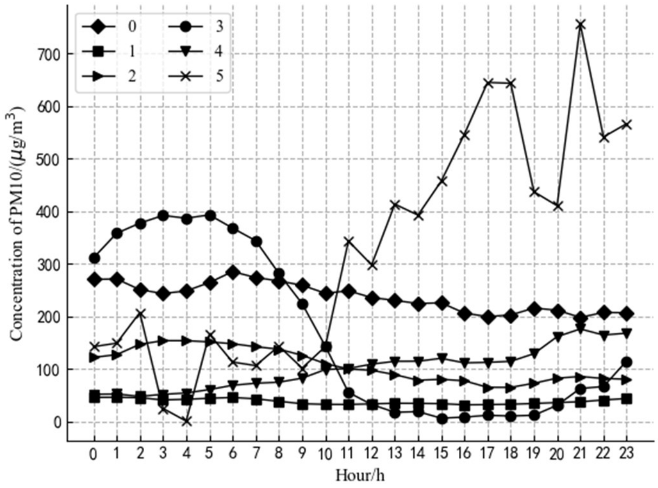

Fig.4 PM_{10} changes in average intraday hours per cluster
Source: Authors original

4.2.1 Analysis of the overall situation of PM_{10}

As can be seen from Figure 4, the P3 and P5 curves fluctuate greatly, with P3 fluctuating from 6 μg/m^3 to 393 μg/m^3, showing high pollution from 0:00 to 8:00; P5 fluctuates from 1 μg/m^3 to 756 μg/m^3, showing high pollution from 10:00 to 23:00. The remaining clusters have a relatively smooth change in curve, among which the intra-day change in mass concentration of P1 does not exceed 16 μg/m^3, and the maximum value of mass concentration does not exceed 50 μg/m^3 in the whole day, with significant effect of dust prevention and control; the fluctuation range of mass concentration of P0 is 198-285 μg/m^3, showing a continuous decreasing change in the whole day, but PM_{10} does not reach the annual average value of Ambient Air Quality Standard (GB 3095-2012) annual average value of secondary standard (70 μg/m^3), which is worth focusing on; P4 mass concentration fluctuates from 47 μg/m^3 to 176 μg/m^3, showing a continuous increase throughout the day; P2 mass concentration fluctuates from 65 μg/m^3 to 154 μg/m^3, with the same trend as the annual daily average change in Figure 3. In summary, the future dust suppression work in this port area should focus on the key hours including: ① the change of P3 at 0:00~8:00; ② the daytime change of P5, especially at 10:00~23:00 hours; ③ the whole day change of P0; ④ the continuous growth trend of P4; ⑤ the continuous use of the reasonable dust suppression measures of P1.

Table 2 shows the percentage of days each cluster in each season (spring in March, April, and May, summer in June, July, and August, autumn in September, October, and November, and winter in January, February, and December). The number of days in each season is more balanced in P1, P2 and P4, while the proportion of winter in P0 is nearly 50% and the proportion of summer in P3 and P5 is 68%, indicating that this port area is more prone to dust pollution in summer and winter seasons, with summer being particularly prominent. The above findings are different from those found by (Žibert and Pražnikar, 2012) based on Koper port that pollution is more likely to fluctuate in winter and spring, probably due firstly to the differences in climate and loading and unloading of cargoes in the two port areas, and secondly to the fact that the greater fluctuation in summer than winter is related to the significant reduction in port operations in January and February 2020, which coincided with the outbreak of COVID-19 epidemic in the country.

Table 2 Percentage of seasonal days in each PM_{10} cluster

cluster/season	Spring	Summer	Autumn	Winter	Total
0	7.14%	21.43%	21.43%	50.00%	100.00%
1	35.48%	22.04%	20.97%	21.51%	100.00%
2	17.46%	25.40%	30.16%	26.98%	100.00%

3	5.88%	70.59%	23.53%	0.00%	100.00%
4	16.67%	37.50%	20.83%	25.00%	100.00%
5	0.00%	100.00%	0.00%	0.00%	100.00%

Source: Authors original

4.2.2 Reasons for the variation of various clusters of PM_{10}

In order to further analyze the reasons for the changes of various clusters, the daily average changes of humidity and wind speed, which have more significant effects, are selected and the hourly averages of the corresponding time are drawn as shown in Figs. 5 and 6. As can be seen from Fig. 5, except for cluster 5, which consists of a few days, the humidity variation trends of all clusters show a "single peak and single valley" pattern of rising, then falling, and then rising again, which is basically the same as the hourly average variation trends and peak and valley arrival times throughout the year in Fig. 3, This indicates that the PM_{10} mass concentration has a positive correlation with the humidity distribution (the calculated Pearson coefficient is 0.173), which is the same as the conclusion reached by Zhang *et al.*(2021) through gray correlation analysis. When the relative humidity of air increases, water vapor is more likely to condense with particles as condensation nuclei, thus causing pollutants to accumulate and leading to an increase in PM_{10} concentration. The overall trend of P3 in Figure 4 is also similar to that of Figure 3 for each moment of the annual average, excluding the same reasons that caused the annual average trend in Figure 3, and considering the severe pollution in the early morning hours, which may be caused by the significantly higher average humidity (in Figure 5) from 0:00 to 7:00 than the other clusters (Pearson coefficient of 0.483), where the high humidity hinders the diffusion of PM_{10}.

Comparing Fig. 6 and Fig. 4, it can be found that the changes of P2 and P0 corresponding concentrations are obviously opposite to the changes of wind speed, indicating that these two changes are mainly influenced by wind speed (the calculated Pearson coefficients of P2 and P0 are -0.109 and -0.115, respectively). The Pearson coefficient calculated for the relationship between PM_{10} mass concentration and wind speed for all clusters is -0.145, indicating a negative correlation between PM_{10} mass concentration and wind speed. The possible reason is that an increase in wind speed tends to reduce surface concentrations by diffusing PM_{10} to the atmosphere, which is consistent with the conclusion reached by a regression model by Zhang *et al.*(2021).

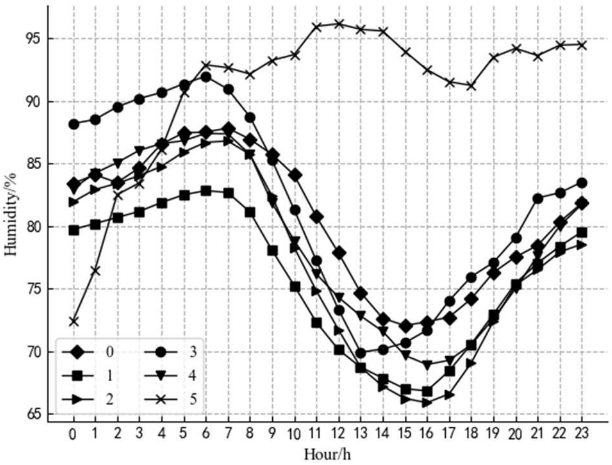

Fig.5 PM_{10} each cluster (0-5) correspond to changes in average daily humidity

Source: Authors original

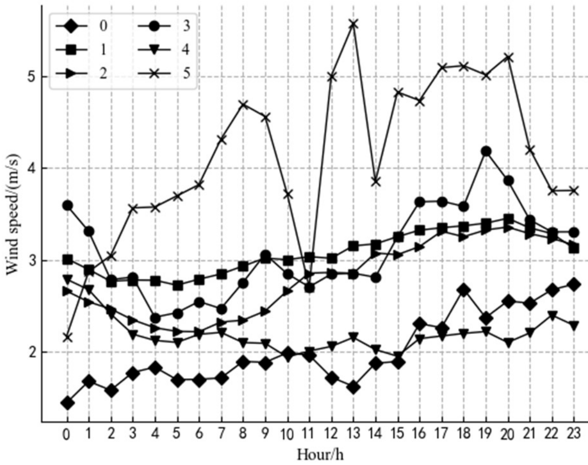

Fig.6 PM_{10} each cluster (0-5) correspond to changes in average daily wind speed

Source: Authors original

Comparing Figs. 4, 5, and 6, it is found that there is no significant correlation between the concentration changes and the changes in humidity and wind speed for both trends of P4 and P1, indicating that humidity and wind speed had different extents of influence on PM_{10} pollution concentrations in different clusters. It is consistent with the judgment of Ma *et al.* (2021) that wind speed and relative humidity with different ranges of values have different variation relationships with PM concentrations. In addition to the effects of humidity and wind speed, fluctuating changes in barometric pressure will lead to a continuous increase in PM (Hua *et al.*, 2015). 79% of the days in February and March 2020 are in P1, and during this period, due to the outbreak of the COVID-19, the pollution source intensity was reduced by the sudden decrease in the port area operations, and the PM_{10} pollution concentration decreased at all moments throughout the day. This leads to lower and more stable concentrations at all moments of P1, indicating that changes in port operations are also an important factor influencing PM_{10} concentration changes (Pérez *et al.*, 2016).

P5 can only last two days, corresponding to the time concentration in July. From the intra-day hourly variation in Fig. 4, it can be found that the intra-day variation trend is an overall increase from morning to evening, but there are substantial up and down fluctuations in the process, showing great differences from other clusters, which can be regarded as a special cluster. As can be seen in Figures 4 and 5, the humidity corresponding to this cluster is generally high, and the wind speed is chaotic and high, indicating that the reasons for the appearance of this particular cluster may be: the fact that the high temperature in July leads to easy dust generation of PM_{10}; at the same time, the relatively high humidity makes it easy to form haze pollution after dust generation; the chaotic change in wind speed leads to sharp fluctuations in pollution concentration. The dust starts to rise sharply during the 9:00~10:00 period and is associated with more commuter and logistics vehicle exhaust emissions near the port area, peak loading and unloading operations in the port area and special climate change.

5. Conclusions and recommendations

This paper analyzes the PM_{10} online monitoring data of Changshu FD port area in Suzhou Port in 2020 by clustering and combining with real-time humidity and wind speed data, the main conclusions are as follows.

(1) The annual average intra-day changes of the FD port area, where coal is the main cargo, can be described as follows: the annual average PM_{10} data show a "single peak and single valley" within a day, with the peak and valley mass concentration values occurring from 5:00 to 7:00 and 17:00 to 18:00 daily, respectively, which are mainly affected by the placement of detectors, temperature and dust suppression measures. From the seasonal performance, PM_{10} concentration values tend to fluctuate abnormally in summer and winter, and the performance is most dramatic in summer.

(2) Based on the K-means clustering method, the number of clusters was determined by combining the "inflection point method" and the "average contour coefficient method" with six categories. The analysis of the intra-day variation of PM_{10} in the port area shows that: P3 and P5 curves change intensely, while the remaining clusters are relatively stable, with P3 showing high pollution from 0:00 to 8:00 and relative humidity as the main influencing factor; P5 showing high pollution from 10:00 to 23:00, caused by the combined effect of various meteorological factors and port activities; P1 shows a concentration change of no more than 16 $\mu g/m^3$ in a day, and the daily average value of each moment does not exceed 50 $\mu g/m^3$, with significant effect of dust prevention and control; P0 shows a continuous decreasing change, but the PM_{10} mass concentration is naturally higher than the standard value, and wind speed is the main influencing factor of this cluster; P4 shows an overall continuous increasing trend.

(3) In general, PM_{10} mass concentration is positively correlated with atmospheric humidity and negatively correlated with wind speed, and the fluctuation of air pressure and the intensity of operation in the port area also have certain influence on it; however, the extent of influence of humidity and wind speed on it has great variability in different clusters.

Based on the above conclusions, the following recommendations are made for the study and management of PM_{10} in dry bulk port areas.

(1) 5:00-7:00 in FD port area, where coal is the main operating cargo, should be the key time period for daily monitoring and taking dust suppression measures; based on the seasonal changes of PM_{10} concentration and the relationship with humidity and wind speed, the port pollution prevention and control department needs to enhance dust suppression in summer and winter, and at the same time, pay more attention to the meteorological situation in the port area and take targeted dust suppression measures in advance according to the meteorological forecast.

(2) The results of this study show that: the COVID-19 leads to lower pollution in winter, and the proportion of normal winter in each cluster is somewhat in error with the study of this paper, but it's still necessary to focus on monitoring in winter; the port operations decreases abruptly during the epidemic, which leads to a great increase in the number of days to reach the standard, and the port operation intensity can be controlled appropriately under the demand of environmental protection.

(3) The changing patterns of each cluster is different. The monitoring system of PM concentration should be improved to distinguish each cluster to which they belong in time according to the change of concentration and take appropriate dust suppression measures accordingly. The particularly valuable law found in this study is: the dust suppression measures are reasonable in the case of P1 and should be kept in use. For the high concentration changes that still occur: in P3 case at 0:00~8:00, measures such as sprinkling and spraying should be taken to affect relative humidity; in P0 case, measures such as thatching of stacks should be taken to affect wind speed; meanwhile, in the port area, dust suppression measures should be increased and dust suppression efficiency should be improved to solve the high pollution of P5 and control the growth trend of P4. Different dust suppression measures should be taken for different situations to reduce the waste of resources based on effective reduction of PM_{10} concentration.

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An Overview through Start-up Initiatives on HRTech in Maritime and Offshore Industries

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Abstract

Human resources technologies (HRTech) has become an emerging field of digital transformation. It principally combines software and hardware units to automate the various functions of human resources activities in organizations. The purpose of this study is to overview the start-up initiatives on HRTech solutions particularly in maritime and offshore industries. Besides the functional achievements (recruitment, talent development, performance management, etc.), the methodologies behind the featured solutions are addressed and classified. In addition, the requirements of HR Tech in the future talent acquisition is extensively discussed. The findings point out the potential of HR Tech market to clarify future challenges and opportunities in maritime and offshore industries.

Purpose - The purpose of this study is to overview the start-up initiatives on HRTech solutions particularly in maritime and offshore industries. Besides the functional achievements (recruitment, talent development, performance management, etc.), the methodologies behind the featured solutions are addressed and classified.

Design/methodology/approach - A benchmarking approach is adapted to identify and classify the startups eligible in providing HRTech solutions in maritime and other disciplines.

Findings - The findings point out the potential of HR Tech market to clarify future challenges and opportunities in maritime and offshore industries.

Research limitations/implications - In the research, the number of startups is limited to those that are very visible in the market.

Originality/value - This study contributes to identifying the need for a holistic model through HR Tech functions to produce consistent, reliable and cross-industry solutions.

Keywords - Human resources management, HR technologies, maritime start-ups

1. Introduction

Globalization benefits global awareness and cross-border technology distribution in two ways: it allows countries to easily acquire foreign expertise and increases international rivalry by increasing the number of emerging market enterprises as well as innovation and the entrance of new technologies from other countries (Aslam et al., 2018). While this situation increases the number of candidates that human resources can reach and enables talents from various parts of the world to be brought into industries, it also complicates the task of human resources (Johnson and Stone, 2019). Some of these challenges are: Investing a significant amount of effort in communicating with individuals, reviewing and confirming their resumes, doing credentials verifications, and completing background checks. Carrying out all these processes causes the recruitment processes to prolong and increases the resource use of the workplace, resulting in cost loss (Kristof-Brown, 2000). In order to prevent this situation, employers have adopted human resources technology (HR tech), especially in recent years. HR tech is a broad phrase that refers to software and hardware used to automate the human resources function in businesses (Johnson et al., 2016). Payroll and remuneration for employees, diversity, talent acquisition and management, workforce analytics, performance management, and benefits administration are all covered. Although technology facilitates recruitment processes, a bridge is needed between workplaces and candidates due to the large number of job applicants and the use of a lot of data. In this case, human resources startups emerged. Startups are organizations that operate independently of companies (Kavanagh and Johnson, 2018). It examines job applications from all over the world and filters them according to the profiles of the candidates. It then brings together companies that are hiring and job applicants. Thus, the recruitment process of companies becomes considerably shorter and more efficient. In all these processes, startups use HR tech.

The number of people working in the maritime field is increasing every year, as it is an international sector, the most important transportation route in world trade and the effect of the growth of trade every year. Therefore, the number of startups using HR tech in this field is increasing. Finding personnel to work on ships, recruitment processes in the offshore sector, selection of cadets and meeting with companies can be given as examples of the work of these startups.

The goal of this study is to provide an overview of HRTech start-up projects, notably in the marine and offshore industries. The approaches underlying the presented solutions are addressed and categorized, in addition to the functional successes (recruitment, talent development, performance management, and so on).

2. Literature Review

It is not a relatively new notion to use technology in the job. HR procedures were well-integrated with ERPs during the 1990s. Payroll, training, recruiting, and attendance, among other processes, were handled, significantly decreasing the transactional aspect on professionals. Over the last few years, the HR Technology area has changed dramatically. New classifications continue to develop. HR tech's main categories in 2012 were HRIS, talent acquisition, performance management, benefits and compensation, learning and development, and job portals. New categories in 2016 included onboarding, recruitment tools such as video interviews and exams, and collaboration/communication technologies. In 2017, the most powerful categories were HR analytics, engagement/experience technologies, automation, and artificial intelligence (Madhvapaty and Rajesh, 2018). The HR industry is $54bn worldwide (Everest Group, 2017). Out of this, HR Tech is $14bn. HR technology has the potential to save Indian businesses a lot of money. HR Technology is expected to save Indian firms at least $600 million per year by 2021, according to estimates (PeopleStrong, 2017). HR Tech start-ups saw funding of $49m in 2015 (Tracxn, 2016) and $16m in 2016 (PeopleMatters, 2017). Globally, this figure was $1.968bn (Everest Group,2017). The majority of expenditures are made in areas such as job-talent matching, employee retention, gamification, and employee experience, among others. Also, The Japanese government's activities boosted the HR market significantly, and the HRTech industry has grown at annual rates of 40 to 50 percent since 2016 (Iwamoto, 2019). Bogers et al., (2021), they aimed to produce ideas, present new studies and develop them together with the opinions of experts in the field by convening a committee on HR and holding a workshop with experts in their fields. In addition, technological developments such as vacancy prediction software, job description optimization software, multi-database candidate sourcing-CV screening software by AI programs, how they are received by large companies (Intel, eBay, IBM, LinkedIn, Amazon etc.), how they are implemented, adaptations and outputs were investigated. As a result, it includes advice on how to use them, how things work for HR managers, and how they can be achieved (Albert, 2019). Srivastava and Bhatnagar, (2010), they studied talent acquisition, data storage, data analysis, and various other situations. In their study, they examined various academic publications by scanning the literature and determined what the concept of talent acquisition covers and how it finds application areas. In addition, a situation specific to India was examined in the study and its findings were given. Johnson et al., (2021), they examined the recruitment processes in the tourism industry, discussed the recruitment processes applied in the tourism industry and the use of AI. They explained the concept of e-HRM (electronic human resource management) and gave examples in detail. The use of AI and e-HRM reduces costs, enables them to reach more candidates in a shorter time, enables HR managers to use their time more efficiently, and by this means, workplaces can achieve a much more effective recruitment. have worked through the process. They concluded their studies by revealing the data in the field of hospitality and tourism. Wright and Jackson, (2018), says that with the development of technology, it will be more important than ever to find, measure and bring in talents to the company. He made evaluations in terms of various features such as that most companies are still not ready for this, measuring the performance of their employees, that they do not have ATS (applicant tracking system), and their engagement structure is not sufficient. In addition, the examination of automatic and manual recruitment processes has also addressed the problems in the processes that companies will do.

In the maritime field, studies have been carried out in terms of HRTech. M. Safa et al., (2017), they investigated about the importance of talent by talking about the features and capabilities required when operating a port and the features that will be required when running these new generation businesses. They gave examples by talking about the applications in the Texas Port, the importance of bringing talents to the company and the importance of HR in port management. Here, too, the importance of HR tech was mentioned. STCW requirements, distance learning, digitalization, the features of talents and the needs of the new generation seafarers examined. It was mentioned about the acquisition of talent in maritime, the importance of the HR market, the ever-increasing workforce requirements, performance management and compensation management. Improvement of recruitment processes, necessary digitalization and features were mentioned. Features such as human resources competitiveness, cadet programme, leadership were mentioned (Barsan et al., 2016). Issues such as cross-cultural competency, diversity, performance management and engagement are very important for maritime companies. Therefore, necessity of increasing the duties required of human resources managers, the necessity of adding items related to diversity to company policies, and the necessity of promoting diversity more both to improve company performance and to bring international maritime to better levels mentioned. In addition, the necessity and importance of digital execution of this and similar processes using HR tech was mentioned (Progoulak and Theotokas, 2016).

This research helps to establish the need for a holistic model involving HR Tech functions in order to generate consistent, dependable, and cross-industry solutions. To discover and qualify the companies suitable to provide HRTech solutions in marine and other disciplines, a benchmarking technique is used.

3. Human Resources Technology (HR Tech)

HR tech (Human Resources Technology) is a wide phrase that refers to the software and hardware used to automate a number of key HR operations (Hendrickson and Anthony R., 2003). Assuming the position of HR's co-pilot, HR tech makes use of digitalization and automation to complete the time-consuming activities of:

HRT1- Payroll and compensation management
HRT2- Travel and expense management
HRT3- Talent management
HRT4- Performance management
HRT5- Employee engagement
HRT6- Benefits administration
HRT7- Learning and development
HRT8- Talent acquisition
HRT9- Data storage and analytics
HRT10- Diversity and inclusion
HRT11- Redeployment and career coaching

HR technology services have effectively changed paper-clogged, noisy HR departments into simpler, calmer work spaces in the past (Ashbaugh and Miranda, 2002). HR professionals can now focus on hiring great personnel, engaging and keeping them, and increasing their productivity thanks to technological advancements that have relieved them of their organizational and administrative duties. HR technology is critical to the existing work culture's sustainability. HR technology, despite its drawbacks, provides a framework for employees to preserve a feeling of community and allows managers to manage onsite and remote teams. It has also relieved HR professionals of administrative duties, allowing them to focus on enhancing the employee experience, increasing engagement, and cultivating a positive business culture. Project management is becoming a significantly more valuable ability as a result of HR technology. Senior executives are expected to spend 60% of their time selecting and driving initiatives by 2025. Project managers should be adaptable and comfortable working with freelancers. It's critical to have a firm grasp on the reality of employees and the economy, as well as how to engage them via preferred channels. It's also critical to articulate the company's mission in order to maintain a healthy culture for both contingent and salaried employees. HR directors must be ready to adapt gracefully to new technological advancements that are constantly altering the working environment.

Embracing new HR technologies gracefully needs preparation. In a sink-or-swim work environment, the following suggestions can help HR executives make the most of the IT services they use on a regular basis:

- Improved employee performance,
- Healthy workplace culture,
- Optimized talent acquisition with right hires for all positions,
- Reduced retention rates,
- Improved workplace diversity and inclusion at local and global offices,
- Optimized performance management systems and metrics,
- Happier high-performing employees,
- Sustained talent pipeline for succession planning,
- Seamless inclusion of women and minorities.

4. HR Tech Startups

This section will provide examples of startups utilizing human resources technology that have been formed in various regions of the world. The table below displays the name, its location, the year it was created, the amount of funding, the technologies it uses, and its growth over the last five years. The technologies under the table are represented by the numbers mentioned in the HR Tech services portion of the table. Payroll and salary administration, for example, is represented by HRT1, while employee engagement technology is represented by HRT5.

Table 1: HR Tech startups in different industry fields

Company	Location	Year Founded	HR Tech Service	Funding	5-year search growth
Company A	France	2018	HRT3-4-5-8-9-11	$65.7M (Series B)	5200%
Company B	USA	2017	HRT3-4-5-8-9-10	$188.6M (Series C)	3000%
Company C	France	2015	HRT1-2-3-4-7-8-9	$495.8M (Series E)	900%
Company D	England	2018	HRT1-2-4-5-6-8-9	$12.4M (Series A)	14%
Company E	Singapore	2013	HRT3-4-5-8-9-10	$32.2M (Series C)	691%
Company F	Germany	2015	HRT3-8-9-10-11	$524M (Series E)	230%
Company G	Denmark	2014	HRT2-5-6-7-8-9	$68M (Series B)	7600%
Company H	England	2018	HRT3-5-8-9-11	$1.3M (Seed)	9%
Company J	USA	2013	HRT1-2-3-5-9-11	$569.8M (Series E)	400%
Company K	USA	2016	HRT4-6-9-10-11	$4M (Seed)	0%
Company L	USA	2016	HRT1-2-4-5-8-9-10-11	$145.9M (Series C)	-15%
Company M	USA	2010	HRT3-8-9-10-11	$161.4M (Series D)	0%
Company N	USA	2011	HRT1-2-4-5-6-9-10-11	$56.6M (Series B)	152%
Company O	England	2013	HRT3-4-5-6-7-8-9-10-11	$173M (Series C)	2100%
Company P	USA	2016	HRT1-2-4-9-11	$444.5M (Series D)	-100%
Company R	Germany	2014	HRT1-2-5-8-9-10	$190.8M (Series D)	4800%
Company S	Germany	2015	HRT3-5-8-9-11	$18.1M (Series B)	-26%
Company T	Austria	2013	HRT3-5-8-9-11	$6.8M (Non-Equity A.)	-100%
Company U	USA	2016	HRT1-2-3-5-8-9-10	$396.8M (Series E)	-62%
Company Y	India	2015	HRT4-7-8-9-10-11	$670K (Seed)	0%

Source: Howarth, 2022

Information on 20 startups is given in the table. Some of these companies work in the automotive, service, tourism, pet services areas, while others do human resources work for the software, information systems and remote working industries.

For instance, Company F is a German-based HR software startup that caters to small and medium-sized businesses. Their software helps with simplified hiring, unified HR document and data management, and payroll processes. In January 2021, Company F received a $125 million Series D investment and announced that it had surpassed 3,500 users. The firm is presently valued at $6.3 billion, making it one of Europe's most valuable startups. Thanks to software technologies, the information of the members who use it is taken into the system. this information is processed and made available by data analysts working within the company. Then, a detailed profile of the person is created in line with his/her abilities and experiences. In line with all the determined characteristics and job preferences of the person, a company that is hiring at that time is determined and the person's information is presented to this company. Companies that work with Company F can easily identify candidates who are more suitable for them, thus making their recruitment processes much faster and more reliable. In line with all these features, the company has been given the HRT3-8-9-10-11 features shown in the Table 1.

Another example, Company L provides digital solutions to organizations and individuals to help them combat the emergence of an overworked, stressed-out workforce. Their "behavioural transformation platform" blends current research and narrative in an interface that gives workers small nudges to help them better their lives. Working with a world-renowned company, Company L also supports remote working thanks to the technologies they use. The company, which introduces the applicants to large companies by passing them through certain processes, also provides consultancy to companies. It also performs operations such as the processing of financial data related to the expenditures of companies, performance management, employees' salaries and expenses. The company, which helps them find the most suitable roles by making analyses about people who have left the company or who want to change positions, also undertakes diversity and career coaching. Accordingly, the numbers HRT1-2-4-5-9-10-11 for the technologies used by the company are given in the Table 1.

Table 2: HR Tech startups in maritime field

Company	**Location**	**Year**	**HR Tech Service**
Company	USA, Greece, Ukraine, Germany, Philippines	2020	HRT3-4-5-8-9-10-11
Company	England	2021	HRT3-4-8-9-10
Company	England	2014	HRT1-2-3-4-8-9
Company	Singapore	2017	HRT3-4-5-8-9-10
Company	-	2010	HRT3-5-8-9-10
Company	Netherlands	2017	HRT3-4-7-8-9-10
Company	UAE	2018	HRT1-2-3-5-8-9-10-11
Company	-	2012	HRT3-4-6-7-8-9-10
Company	Lithuania	2016	HRT1-2-4-5-8-9-10-11
Company	Canada	2017	HRT1-2-5-6-10-11

Company I, a maritime tech startup, has raised $5.7 million in a round headed by General Catalyst. Company I, which began operations in late 2020, has already attracted a number of paying customers, including a top-100 shipping firm in the world. The firm has five operational locations: New York City (USA), Berlin (Germany), Athens (Greece), Odessa (Ukraine), and Manila (Philippines), however the majority of its workers work remotely, which is a culture that the company intends to keep post-COVID. The organization works hard to create a diverse, inclusive, and transparent culture. Everyone at Company I, for example, is aware of each team member's compensation system. The new funding will enable Company I to grow into new and existing areas such as Western and Eastern Europe, the Philippines, and the United States, as well as develop new technologies for seafarer vetting. Company I delivers openness and innovation to the $60 billion worldwide marine recruiting industry. The firm offers a digital platform for connecting seafarers with shipping companies, as well as software for vetting, managing, and retaining seafarers. Company I collects data about seafarer histories, talents, and performance onboard a vessel using its software and proprietary technologies, which are then utilized as inputs in its matching algorithm, allowing shipping firms to match them to the most suitable vacancy. The company's mission is to use data to assist maritime businesses better understand how to make sailors more productive in their daily work.

Another HR tech startup is Company IV. It has functions such as finding suppliers, introducing candidates to companies, and providing career mentorship to them. It provides source candidates, simplify recruitment, manage crew, track applications and transparency. Software is reserved for employers and workers. The data of both categories are taken in line with their requests. then the most appropriate match is made according to certain characteristics such as talent suitability, diversity and location. In addition, there are vacant job postings on their website and anyone who wishes can directly apply for vacant jobs.

In addition startup companies, Company V and Company VIII can be an example of HR Tech websites. These startups, which were opened as a website, offers all kinds of job opportunities from all over the world. They provide the opportunity to apply for a maritime job anywhere in the world by looking at various parameters such as salary, location, tenure and experience.

An example of a venture from the offshore industry is Company IV. Candidates who want to work in this sector are involved in the process by submitting their information. The trainings, certificates and more information they need to receive are given by Company IV consultancy. In line with the agreement with the employer, all road planning, insurance and health-related arrangements are made, thereby reducing a significant burden on the employer. also, if extra training is required, it is arranged and candidates who are fully prepared are presented to the employer.

5. Findings and Results

The use of more than one technology in industries has gained great importance and accelerated especially in recent years. Providing access to people from all over the world is much easier than before. Especially with the increasing remote-working model in recent years, employers can meet and recruit candidates from all over the world. This requires a systematic human resource management, a careful analysis of the applicant's data, and an acceleration of the recruitment process. As this is the case, independent startups that perform the human resources task have emerged. Startups, which provide a link between employer and employee, use human resources technologies very effectively to help companies and enable them to identify the right candidate. Along with HR tech, topics such as performance management, diversity and inclusion, talent acquisition, data analytics can be used systematically and appropriately. This enables companies to reduce costs, use time more efficiently and recruit quickly while finding the right candidate. HR tech are also used in the maritime field and startups are opened in this field, especially since it is an international business and the world trade is growing rapidly.

Among the 20 startups established in other sectors, examined in the study, the least use of human resources technologies is 5 out of 11 technologies. In addition, the most used HR techs are : Talent management, performance management, talent acquisition and diversity and inclusion. The reason for this is talent hunting and data expertise, which has gained acceptance especially in recent years. In addition, although it is a company that was founded in 2018 (Company A), when the growth volume and the funds it receives are considered, it is observed that its volumes have increased very quickly. Therefore, the importance of the use of human resources technologies and the need in this field emerge. In addition, it is seen that 16 startups out of 20 start-ups use talent acquisition technology. That is, 80% of talent acquisition is used, and this shows that this technology is very important for the future in identifying suitable talents and bringing them into the company. Another important parameter is in the talent management section. 60% of the companies in the table use talent management technology, and this shows that it is extremely important for new personnel joining the company with talent acquisition to be assigned tasks in line with their abilities, to be used in appropriate positions and to increase the value of the company.

When looking at the startups in the maritime field, it is seen that most of them are related to crewing and the technologies most used in this direction are talent acquisition, talent management and diversity. Especially due to the increase in new generation technologies, the digitalization of maritime and the need for new generation talents, an extremely important task falls on human resources. Looking at the table, it is seen that the rate of use of talent acquisition technology is 90%. It is seen that this technology is of great importance for companies due to the changing manpower needs of the maritime industry, the new generation of seafarers and its adaptability to technologies. In this direction, while companies that recruit and startup companies need experienced seafarers, another important need will be related to the recruitment of cadets to companies and the selection of new graduate candidates. Therefore, it has been determined from study that HR tech extremely important in the maritime and offshore industries especially talent acquisition, as in other sectors, and will gain even more importance in the coming years.

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The Future of Aviation Industry – A Public Choice Perspective

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Abstract

Purpose – This study aims to analyse how public choice theory can be applied to the air transport industry in Hong Kong from an economic and public administration perspective. The scope of this study focuses on whether existing bureaucratic structure and rent-seeking phenomenon has impacts on the entire industry and to what extent.

Design/methodology/approach – Case studies approach is employed for qualitative review in respect of public choice theory, specifically in its sub-field of bureaucracy and rent-seeking. The case of the Civil Aviation Department (CAD) new headquarters and the application for licence by Jetstar Hong Kong Airways Limited (JHK) are identified as the relevant cases respectively.

Findings – Although it is not an absolute proof, the construction of the CAD new headquarters reflected the bureaucratic behaviour to a certain level while rent-seeking action was observed in the strong opposition to JHK licence application.

Research limitations/implications – This paper implies that it is necessary to review the existing governance structure to tackle the future challenges and rapid development of the aviation industry. A more detailed quantitative analysis based on budgets and rent-seeking may be further investigated.

Originality/value – A fresh attempt is carried out to explore the aviation industry in the recent two decades by using public choice concept in the Hong Kong context. The preliminary findings may serve as a basic foundation and framework for further discussions on the development of air transport policy and management and aviation market of the world-class aviation hub in future.

Keywords – Aviation, public choice theory, bureaucracy, rent-seeking

1. Introduction: Aviation of Hong Kong

1.1 Aviation history and airport development in Hong Kong

The first powered flight in Hong Kong was flown by a Belgian pilot which took off from a makeshift airstrip in Sha Tin on 18 March 1911 (Airport Authority Hong Kong, 2022b). Hong Kong's original airport, Kai Tak, opened in 1925 and was named after its previous landowners, Ho Kai and Au Tak (Robinson, 2006). With increasing demand of air traffic, Kai Tak Airport underwent a major expansion with the construction of a new runway and a passenger terminal building in 1955 (Airport Authority Hong Kong, 2022b). The airport then became famous globally for its thrilling and dangerous approach - aircrafts would descend over Victoria Harbour and the crowded apartments of Kowloon City before turning 47 degrees at an altitude of less than 700 feet for landing (Robinson, 2006).

The announcement of the plan to construct Hong Kong's new airport, Chek Lap Kok, was made by Governor David Wilson in 1989 as an urgent replacement for Kai Tak, which was the busiest single-runway airport in the world and it had already played an important role in the air movement of both passengers and freight (Robinson, 2006; Shaw, 1997). Construction work of the Airport Core Programme commenced in 1991, which covered 9 other projects, such as 34 km Airport Express, 1-mile Western Harbour Crossing and Tung Chung new town (Airport Authority Hong Kong, 2022b; McNeill, 2014). In 1998, the Hong Kong International Airport (HKIA) at north Lantau Island opened for commercial operations. Two-runways design and around-the-clock operation are new breakthrough to Hong Kong's airport development. Since November 2019, the extension of Terminal 1 has been completed and under operation, adding a new aisle with 48 check-in counters, two additional baggage reclaim carousels, catering kiosks, offices and other services enhancement (Civil Aviation Department, 2021a).

According to the Civil Aviation Department (2021a), the HKIA serves as one of the busiest airports worldwide, with approximately 120 airlines offering direct flights to over 200 destinations all over the world. Prior to the outbreak of the COVID-19 pandemic, the HKIA recorded continuous growth and handled about 71.5 million passengers, 4.8 million tonnes of air cargo and around 420,000 air traffic movements in 2019. Unfortunately, due to the impact of cities lockdown under the COVID-19 pandemic, the HKIA suffered a decrease in traffic and only recorded 4.5 million tonnes of air cargos in 2020 (Civil Aviation Department, 2021a).

Despite the negative impact caused by the pandemic, the HKIA three-runway system (3RS) project is progressing well. With the aim of meeting long-term air traffic demand and strengthening Hong Kong's status as a leading international aviation hub, transforming the HKIA from a city airport into an Airport City is also an integral part of long-term vision (Airport Authority Hong Kong, 2022d). The size of the project is similar to the size of the existing airport, and it involves seven key parts including a 3,800-metre-long runway, a new Terminal 2 Concourse and Automated People Mover (APM) system etc. The third runway is expected to be completed in 2022, and the entire 3RS is expected to be finished in 2024 (Airport Authority Hong Kong, 2022d).

1.2 Administration and management of aviation industry

Basically, there are three major organisations managing and governing the aviation industry in Hong Kong – the Civil Aviation Department (CAD), the Airport Authority Hong Kong (AAHK) and the Air Accident Investigation Authority (AAIA).

The main responsibilities of the CAD include 'the provision of air traffic control services, certification of Hong Kong registered aircraft, monitoring of airlines on their compliance with bilateral Air Services Agreements, the regulation of general civil aviation activities and overseeing the safety and security of airport operations' (Civil Aviation Department, 2021a). In addition to the regulatory role in aviation safety, air navigation services for the flights at the HKIA and in the Hong Kong Flight Information Region are also provided by the CAD (Civil Aviation Department, 2021e). In its official website, it is noted that 'the CAD moves with the times and unswervingly strives to maintain a safe, efficient and sustainable air transportation system over some 70 years' since its establishment in 1946 (Civil Aviation Department, 2021e). Obviously, the CAD under the Transport and Housing Bureau (THB) plays a critical role in monitoring the aviation safety in Hong Kong.

For the operation and development of the HKIA, the AAHK has taken the responsibility. The AAHK, started to function in 1995, is a statutory body wholly owned by the Hong Kong SAR Government (Airport Authority Hong Kong, 2022b). The AAHK is governed by the Airport Authority Ordinance (Chapter 483, The Laws of Hong Kong) and is required to ensure the operations of the HKIA comply with the safety and security requirements of CAD in an attempt to obtain an Aerodrome Licence from CAD for operating the Airport (Civil Aviation Department, 2021a). With the management team comprising of experts from different sectors, the board of the AAHK comprises a Chairman, CEO and between 8 to 15 other members. The daily operations and services of the HKIA are contributed by around 2,900 employees of the AAHK (Airport Authority Hong Kong, 2022c).

Recently, an independent authority - the AAIA, was established on 10 September 2018 under the THB for the conduct of aviation safety investigation (Civil Aviation Department, 2021d). The investigation is in accordance with the principles of ICAO Annex 13 to the convention on International Civil Aviation – Aircraft Accident and Incident Investigation as incorporated in Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Chapter 448B) (Air Accident Investigation Authority, 2022). It is a comparatively new restructure of the organisation in aviation public sector.

1.3 The importance of air transport market and aviation sector in Hong Kong

Currently, eight licensed operators (Table 1) holding the Air Operator's Certificate are listed out by the CAD in Hong Kong (Civil Aviation Department, 2021b). Apart from the all-cargo airlines and helicopter providers, there are four local air carriers in Hong Kong. Among them, Hong Kong Express Airways Limited is one of the subsidiaries of Cathay Pacific Airways ('CPA') Limited (Cathy Pacific Airways Limited, 2022). Launched in 1946, Cathay Pacific Airways Limited has become one of the largest and most successful airlines in the world and is regarded as Hong Kong's designated flag-carrier (Malkani, et al., 2005). It is the largest airline in Hong Kong while the company scale of Hong Kong Airlines Limited and Greater Bay Airlines Company Limited is far smaller than CPA. As part of its competitive strategy, CPA acquired several of its competitors. The results of the study done by Liu et al. (2018) show that acquisitions provide positive outcomes which contribute towards success factors. However, there exists unavoidable risks of entering a new market after the acquisition (Liu et al., 2018). Albeit CPA encountered some 'competitions' defined by some scholars, it has maintained its dominant position in the air transport market for decades.

Table 1: List of Air Operator's Certificate (AOC) Holders

No.	Operator	AOC No.	Remarks
1.	Cathay Pacific Airways Limited	1	
2.	Hong Kong Express Airways Limited	7	Subsidiaries of Cathay Pacific
3.	Hong Kong Airlines Limited	15	
4.	Greater Bay Airlines Company Limited	19	
5.	AHK Air Hong Kong Limited	6	All-cargo airline, wholly owned by Cathay Pacific
6.	Hong Kong Air Cargo Carrier Limited	18	All-cargo airline, subsidiaries of Hong Kong Airlines
7.	Heliservices (Hong Kong) Limited	3	Helicopter operator
8.	Sky Shuttle Helicopters Limited	12	Helicopter operator

Source: Civil Aviation Department, 2021b

Since its operation from 1998, the HKIA has been awarded the world's best airport by Skytrax (Year 2001 – 2005, 2007 – 2008, 2011, 2017) together with other international and regional airport awards in recent years (Airport Authority Hong Kong (2022a). The previous awards and recognitions have certainly affirmed the leading position of the HKIA in Asian region and the world. For air cargo, the HKIA ranked the world's busiest airport by cargo traffic with international freight from 2010 to 2021, except 2020, according to the data released by the Airports Council International (ACI) - the trade association of the world's airports (Airports Council International, 2022). The HKIA gained back the top rank in 2021, with 5.0 million metric tonnes cargo, an increase of 12.5% compared to 2020 (Airports Council International, 2022).

The aviation sector is undoubtedly a crucial component of Hong Kong's economy, directly impacting both tourism and commerce. The strategic position of the HKIA in Asia has made it an important regional trans-shipment centre, passenger hub and gateway to other Chinese cities (Civil Aviation Department, 2021a). Hong Kong's four economic pillars are supported by the HKIA – namely financial services, trading and logistics, tourism, and producer and professional services, which totally accounted for around 57% of the city's GDP in 2018 according to government statistics (Airport Authority Hong Kong, 2022d). The estimate of the aviation sector's economic contribution demonstrates that it is a core element and support of Hong Kong's economy (Fung, et al., 2006).

Some researchers performed analysis on airline market structure and airport efficiency of major northeast Asian airports, including the HKIA, which had a high efficiency score and labour productivity (Ha, et al., 2013). Hong Kong has had a successful past and is enjoying a prosperous present, but it should prepare for intense competition to maintain its present position as the foremost aviation hub of the region (Ha, et al., 2013; Robinson, 2006). Threats are inevitably imposed on the Hong Kong's future status as a global hub for Asia due to the impressive growth of Middle East airports including Dubai, Abu Dhabi and their airlines such as Emirates, Etihad (Abu Dhabi), and Qatar Airways respectively (Robinson, 2006). Nevertheless, where there are threats and competitions, there are also opportunities and strengths.

2. Public choice theory and its applications on air transportation

To maintain high efficiency and standards, public sector in the aviation and air transport industry plays an ever-increasing role to regulate the operations and monitor the services provided. This section will introduce the public choice theory and its related literature before applying it to transportation sector.

2.1 Public Choice Theory

Public choice can be viewed as an economic theory that uses modern economic tools to analyse problems that are linked to political science field (Johnson, 1991; Reid, et al., 2008). The behaviour of voters, politicians and public institutions as self-interested agents and their interactions in the social system representative for any form of government can be studied to understand how the government works (Reid, et al., 2008).

When discussing and solving how individual political decision-making results in public policy that opposes to the overall desires of the general public, public choice theory can be referred to (Reid, et al., 2008). This can be considered as one of the important economic postulates from private market analysis to political market analysis (Johnson, 1991). Public choice also explains how bureaucracies tend to grow apparently without limit and without connection to initially promised functions once they are established (Reid, et al., 2008).

Two common subfields will be discussed in this paper – bureaucracy and rent seeking phenomenon.

2.1.1 Bureaucracy

Stigler (1975) and Peltzman (1976) developed public choice's application to government regulation in the early stage (Reid, et al., 2008). After that, Niskanen (1971), who is in general considered the founder of public choice literature on bureaucracy argues that, in his research, bureaucratic entrepreneurs maximize their utility through the pursuit of budget appropriations (Reid, et al., 2008).

Public choice theory tires to investigate governments from the perspective of the bureaucrats and politicians who compose them. The assumption of bureaucracy is that they act based on budget-maximizing model in a self-interested way in order to maximise their own economic benefits (Reid, et al., 2008). The civil service system usually protects the jobs and pays of the civil servants in the government against major changes by their appointed bureau chiefs. Therefore, they are considered as the bulk of bureaucrats (Reid, et al., 2008). Compared to business owners, it has a completely different story. Their profits depend a lot on the production and sales and with the aim at maximising the profit. It is relatively easier for private sector employers to hire and fire employees (Reid, et al., 2008).

The position of the government bureaucrats facilitates budget maximization because first, bureaucrats do not face substantial collective action problems (Pennington, 1997). As monopoly suppliers, bureaux are often the mere source of output or cost data with respect to their services and may easily inflate cost estimates in order to obtain budget increments (Pennington, 1997). Dunleavy (1991) suggests that incentives for budget maximization are strongest in those agencies where the core budget represents a high proportion of the total budget - in delivery agencies (cited in Pennington, 1997).

The degree of professionalisation is the second factor which may influence the tendency toward bureau expansion within different agencies (Pennington, 1997). Breton and Wintrobe (1975) stated that, highly professionalized bureaux often have personnel whose expertise is relatively restricted with possibilities for career advancement residing mainly within the agency.

2.1.2 Rent-seeking

Rent-seeking is another area that is closely related to public choice theory. The term 'rent-seeking' was invented and first-appeared in economic field in 1974 by Anne Krueger in a paper published in the American Economic Review (Kreuger, 1974). Kreuger (1974) commented that 'it focuses attention upon market-orientated economies in which government restrictions upon economic activity are pervasive facts of life.

Such restrictions give rise to rents in a variety of forms; and people often compete for rents. Sometimes such competition is perfectly legal' (Cited in Tullock, 1976). Public choice theorists focus on either individual or group economic behaviour of a rational, self-seeking nature that destroys rather than provides more resources available to society (Tullock, 1976).

This field is a combination of the study of a market economy and government. Both the government agents or parties and self-interested market participants seek these privileges in an attempt to participate in the monopoly rent that they provide (Reid, et al., 2008). Rent seeking adds a third dimension to monopoly analysis and economists are indicating socially bad rent seeking that emerges when government restricts competitions, imposes entry barriers or grants special privileges to certain segments of society but not to others (Johnson, 1991). The efficiency of the economic system may be affected and reduced if such privileges are granted. Furthermore, the rent-seekers use resources that could be used to produce goods that are valued by consumers in other aspects (Reid, et al., 2008). A direct relationship may be established between the overall size of government and the investment in efforts to secure special concessions from government i.e., rent seeking. Some scholars even pointed out that the scope of rent-seeking is broader than public choice (Reid, et al., 2008).

2.2 Public choice theory in air transportation

Corrales (1998) pointed out from a case study that aviation sector and airlines could be largely affected due to policy failure. The privatisation of Aerolineas encountered difficulties due to inefficient policy and conceivable mistakes during the process (Corrales, 1998). In addition, inspired by Olson's (1982) board view of the rent seeking effects on nation's decline, Stockman (1996) centres on the fall of American general aviation industry using a public choice framework with a positive economic viewpoint. The impacts of the General Aviation Product Liability Reform Bill and the General Aviation Revitalisation Act of 1994 were deeply analysed in the aspects of regulations, legislation, taxation, judicial litigation and influence of special interest group (Stockman, 1996). The study shared that those appropriate policies and regulations from public choice solutions might be effective to reverse the aviation industry decline (Stockman, 1996).

Locally, Cheung (2006) examined that the AAHK established under the Airport Authority Ordinance of 1995 has almost full corporate flexibility in operation similar to that of a private company. Moreover, there is complete existing controls and monitor against abusing its monopolistic power or not acting according to government-defined public interests (Cheung, 2006). The author further concluded that the existing kind of fused ''autonomy-control'' mode of organisation is contemplated to be good in administrative and political aspects (Cheung, 2006). However, few research papers discuss the operation and management of the CAD and the airline market in Hong Kong. Thereby, this paper would take the opportunity to fill the research gap.

Public expenditure allocation on infrastructure funding such as airport development is another research area. Atkinson (2020) analysed the Federal Aviation Administration Airport Improvement Programme grant funding grantee characteristics and noted that administrators may be more likely to fund where funding has already taken place and provide token dollars to other airports. The cycle benefitting those that have already been benefitted is vicious (Atkinson, 2020). The efficiency in the broader, service quality provided to commuters, equality in use of public funds for communities are all actively considered criteria beyond enplanements and political demands when making choices in airport funding (Voytek 1991, cited in Atkinson, 2020).

Keeping in pace with the technology development, public choice applications have also been extended to the scope of drone. Hall and Coyne (2014) highlighted the apparent influence by the interest groups or 'Big Players' on the outcomes, having the ability to significantly alter outcomes of drone policies.

3. A case in bureaucracy - Civil Aviation Department new headquarters and its expansion

From workers' view, the ideal director for their agency is 'an aggressive and active leader who is able to convince others of the important mission of their agency and who is able to procure resources and enlarge their agency as well' (Johnson, 1991). Expansion and maximisation will increase employees' own chances of advancement, provide new facilities and equipment, and generally make life more pleasant (Johnson, 1991). Albeit bureaucrats seldom benefit in a direct monetary way from their agency's monopoly position, they can benefit in many indirect ways. The benefits may include redecorated offices for incoming bureaucrats, costly recreational facilities and special restaurants for senior or flag officers (Johnson, 1991).

To house a new air traffic control (ATC) system to meet traffic growth up to 2025 and to concentrate CAD's various operational divisions, an initiative in the 2006-07 Policy Agenda was made for the development of a new CAD headquarters on the Airport Island. Funding was approved by Legislative Council (LegCo) to construct a new headquarters of about 22,775 m^2 net operational floor area (NOFA) (Audit Commission, 2014).

There are three items reflecting the bureaucratic beheviour in the case of the CAD new headquarters construction. First, the size of new headquarters was enlarged without proper notice. A 1,500 m^2 expansion area, in addition to the NOFA of the 3,240 m^2 approved for future expansion, was built without informing the Government Property Agency and Financial Services and the Treasury Bureau (FSTB) of the change in user requirements. The incident highlights inadequacies in the control over change of user requirements and the decision-making arrangements (Audit Commission, 2014).

Second, three of the facilities in the new headquarters were not built according to the approved schedule of accommodation, and not conforming to the Accommodation Regulations (Audit Commission, 2014). They include the discrepancies in the provision of toilet/shower facilities in the Director-General of Civil Aviation's office and the rest rooms for accident investigators. The space originally planned for a viewing gallery of the education path was also converted into a multi-function room for meeting and recreational purposes (Audit Commission, 2014). As the department is spending govenrment's funding, which may be part of tax from taxpayers, the use of the funding and final function should be strictly monitored to prevent self-interest actions.

In purchasing the security and electronic systems under the design-and-build contract, the CAD had not complied with the Circular's requirements in seeking the FSTB's prior approval. The CAD also purchased more liquid crystal display (LCD) video display units than that mentioned in its application, leading to an additional expenditure of $156,000 (Audit Commission, 2014). It showed that there is lack of control and there is a tendency to maximise the budget.

Johnson (1991) commented that the bureau's lower-level employees often generate motivation of bureaucrats to enlarge the bureaucracy and it is subtle. In the CAD New Headquarters case, no opposing voice from the general-level staff was reported. By analysing the staff expenditure data from the annual report from 1999 - 2021, no significant maximisation of staff expenditure can be observed (Table 2) (Civil Aviation Department, 2022c). Nevertheless, there is a steady and continuous increasing trend of the total operating expenditure since 2010 and it is interesting to note that the breakdown and percentage of staff expenditure figure was no longer provided since 2015. The sustained increase in total expenditure may represent the overall expansion of the department. Further analysis should be done to verify in this aspect.

Table 2: Annual Expenditure of the Civil Aviation Department

Year	Total Operating Expenditure (In HK $Million)	Expenditure on Staff (In HK $Million)	% Expenditure on Staff of Total Expenditure
AY1999 / 2000	986	600	61
AY2000 / 2001	985	600	61
AY2001 / 2002	962	583	61
AY2002 / 2003	972	573	59
AY2003 / 2004	875	496	56
AY2004 / 2005	890	481	54
AY2005 / 2006	927	460	49
AY2006 / 2007	874	457	53
AY2007 / 2008	881	507	58
AY2008 / 2009	977	547	56
AY2009 / 2010	965	539	56
AY2010 / 2011	1,010	556	55

AY2011 / 2012	1,082	620	57
AY2012 / 2013	1,119	655	59
AY2013 / 2014	1,173	652	56
AY2014 / 2015	1,203	685	57
AY2015 / 2016	1,232	N/A	N/A
AY2016 / 2017	1,353	N/A	N/A
AY2017 / 2018	1,368	N/A	N/A
AY2018 / 2019	1,526	N/A	N/A
AY2019 / 2020	1,570	N/A	N/A
AY2020 / 2021	1,600	N/A	N/A

Source: CAD Annual Report 2001/2002 – 2020/2021, Civil Aviation Department, 2022c

The ancient adage that 'no one spends someone's else's money as carefully as he spends his own." is reflected in bureaucratic decision making (Johnson, 1991). To tackle bureaucracy problems and improve the situation, Johnson (1991) suggested that government accountants works are critical, but bureaucrats should not be tyrannized by the traditional, "generally accepted" principles of accounting. General guidelines would have to be established to avoid spending money on parties and personal benefits, with widest latitude allowed. Audit Commission (2014) recommended measures should be taken to ensure that the tender specifications for new building projects adhere strictly to the government's approval and timely approval is sought from the FSTB for procuring equipment in accordance with the requirements laid down in Financial Circular and details of the equipment to be purchased. These recommendations apparently targeted against the bureaucratic maximisation behaviour of the CAD.

Next, some bureaucrats who are not committed to the mission of the department are suggested by Johnson (1991) to join in different departments on a rotating basis. Also, privatisation is another way out to reduce the monopoly power. Private firms could bid to manage the air traffic control system. To evaluate the performance of budget-maximising monopoly bureaus, use of private supply of some public services would give a scale and dimension (Johnson, 1991). This issue can be put in the future discussion agenda of development of the CAD and air traffic control mechanism in Hong Kong.

In addition, efficiency and more importantly, honesty should be both emphasized in the administration of government programmes by the general public and legislators (Johnson, 1991). With the implementation or part of the above measures, the bureaucratic inefficiencies, in this case the CAD, would lessen, subject to regular review in future.

4. Rent-seeking case – licence application of Jetstar

Back to 40 years ago, rent-seeking activities already occurred in aviation industry. One typical example is that truck line airlines devoted considerable resources to maintain government control and limited entry in the airline industry (Johnson, 1991). A case in Hong Kong will be examined through the lens of rent-seeking phenomenon of public choice theory.

Jetstar Hong Kong Airways Limited (JHK) was set up in 2012 by Qantas Airways and China Eastern Airlines (So, 2013). On 10 June 2013, an application for licence under the Air Transport (Licensing of Air Services) Regulations (Cap. 448A) (the Regulations) was submitted by JHK to the Air Transport Licensing Authority (ATLA). JHK's application was objected to by Cathay Pacific Airways Limited, Hong Kong Dragon Airlines Limited, Hong Kong Airlines Limited and Hong Kong Express Airways Limited (the Objectors). The Objectors contended that JHK is ineligible for the licence since it did not have its principal place of business (PPB) in Hong Kong (Air Transport Licensing Authority, 2015). CPA pointed out that JHK having a Hong Kong-based shareholder did 'not determine management control or principal place of business under the Basic Law' (So, 2013).

Article 134(2) of the Basic Law stipulated that, the required licence to operate scheduled air services is to be granted to an airline incorporated and having the PPB in Hong Kong. However, the Basic Law does not set out any definition of the term 'PPB'. JHK or the Objectors did not draw to ATLA's attention to any discussion pertaining to this matter during the drafting of the Basic Law, either (Air Transport Licensing Authority, 2015). Under the Regulations giving the authority to grant, revoke or suspend licences to carry passengers, cargo or mail by air for hire or reward on scheduled journeys, thereby, ATLA would make the final decision on the licence application (Air Transport Licensing Authority, 2015).

JHK was extremely disappointed by the decision of refusing the application for licence (Jetstar Airways Pty Limited, 2015). Air Transport Licensing Authority (2015) decided that cases unequivocally indicate, that is not sufficient to establish and meet any PPB criteria even there is no dispute that the day-to-day management would be conducted in Hong Kong and managed by the JHK CEO in Hong Kong. CPA, Hong Kong Dragon Airlines Limited, Hong Kong Airlines Limited and Hong Kong Express Airways Limited could be regarded as the interest groups in the aviation market and their objections to JHK may likely be explained by rent-seeking action.

Rent-seeking may bring burden to the society or affected a particular sector (Huang, 2020). The production of airline service may be reduced, which will lead to a rise in price, i.e. the air ticket prices. Consumers could not choose additional or alternative local airline for air travel and airline services but only refer to the existing local airlines at that time - CPA, Hong Kong Dragon Airlines Limited, Hong Kong Airlines Limited and Hong Kong Express Airways Limited and consumers may be paying a higher air ticket price. The local airlines remained to keep their share in the market, specifically CPA and Hong Kong Dragon Airlines Limited accounted for the largest portion. Rent could be kept by adjusting the air ticket prices.

Naturally, the protection caused by rent-seeking behaviour restricts competitions within the industry and hinder the technology advancement and service enhancement (Huang, 2020). Low fare strategy and a new network creation was the business intention of JHK, aiming at addressing the miss out of Hongkongers (Jetstar Airways Pty Limited, 2015). The travel trade industries should enjoy the opportunities of flying in high value (Jetstar Airways Pty Limited, 2015). JHK planned to offer some overlapping short-haul routes with the same destinations with CPA, Hong Kong Dragon Airlines Limited, Hong Kong Airlines Limited and Hong Kong Express Airways Limited such as Taipei Taoyuan, Singapore, Tokyo Narita, Bangkok (Routesonline, 2013). If the licence application was successful, they could provide alternative choices for traditional waypoints and introduce more new destinations for Hong Kong travelers. Ultimately, the major four airlines continued to dominate the market. It might limit the new types air-plane meals, on-plane entertainments as well as flying experience and services brought by the new airline.

The other loss to the consumers as well as the industry by rent-seeking action is that resources are used for lobbying and setting barriers for market entry but not put in production (Huang, 2020). In the Jetstar case, some resources were used to employ barristers and experts to prepare the documents and provide legal advice to object Jetstar's application for licence to operate scheduled air services. On top of monetary resources, manpower was consumed, and communication efforts were paid to process the case and to hold a number of meetings not only with the legal teams and internal staff, but also with the ATLA and the media regarding this issue. Those are regarded as non-productive activities of the airline business (Huang, 2020). If those resources were re-directed to airline development, it would bring certain direct benefits to the passengers and consumers.

Some of the economists argued that rent-seeking waste could be eliminated imply by restricting the size of government and its interferences in the economy. At the same time, the significant role of the government in the economy should not be neglected in setting rules and institutions that will minimise rent-seeking activities (Johnson, 1991). With the rapid changes in the consumers' demand and needs, whether to maintain this licensing mechanism and rent-seeking behaviour in the aviation industry in Hong Kong may require further discussion in future.

5. Conclusions

The sub-field of public choice theory including bureaucracy, budget maximization, rent-seeking and interest groups have been reviewed in this paper. The construction of the CAD new headquarters reflected the bureaucratic behaviour to a certain level. The new CAD headquarters project offered an opportunity for the

CAD to maximise the budget and size of the department. The rent-seeking action was observed in the strong opposition to JHK licence application by the dominating major airlines in Hong Kong, which might bring production loss to the consumers, industry and society. The realistic operations and policy of air transport market echoed with part of the public choice theory.

6. Limitations and directions for future research

This paper gives as an overview of how public choice theory is applied to governance and management of air transport and aviation industry in Hong Kong. Several major events were selected as case studies in this study, which may not be comprehensive to reflect the whole aviation sector under public choice theory. In addition to case studies and literature review, a quantitative research approach may be adopted to examine the industry, provided that quantitative data are sufficient.

For future research, first, another case study can be carried out on recent licence granted to a new airline operator to examine the interactions of interest groups within the industry and development as well as the public sector. (Civil Aviation Department, 2021b). The air transport policy and bureaucratic style of the public sector should be reviewed or even changed due to the closer integration of Hong Kong and other cities in the Greater Bay Area, which will definitely create a new era, especially during the recovery period after COVID-19 pandemic restrictions. Second, the flexibility of governance and service delivery by the public sector organisation, namely the CAD and the AAHK can be further investigated from the bureaucracy aspect. A better monitoring system may be introduced and tested for the operation and budget maximization of the CAD and the AAHK. Also, there are increasing expectations from users, travelers, tourists and citizens towards the users experience in the aviation and airport. Making references from other sectors as if town planning and railway development, public engagement and participation will be a key element in the future direction of the industry, which may require more study on its importance to public sector.

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Visualize the Hinterland Competition of the Gulf of Guinea Port Group

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Abstract

Purpose –The purpose of this study is to identify the spatial structure of the hinterland competition within the Gulf of Guinea port group.

Design/methodology/approach – With the support of the raster model in GIS, we developed a spatial interaction model and delimited the captive and contestable hinterland by *penetration power.*

Findings –For the port group, the remote inland region of the landlocked countries have complicated hinterland competition. For the ports, the shape of the hinterland presents a *funnel effect*, and the scope of the contestable hinterland expands from the coast to the remote inland.

Practical implications – Our findings imply two aspects: (1) the significance of port collaborative planning to the port group and regional development. (2) Individual ports in the port group should pay more attention to the expansion of the remote hinterland. These conclusions can both theoretically and practically support the decision-making of port group investors and operators.

Originality/value – This study provides a method reference for the visualization of port groups' hinterland competition in underdeveloped regions. This method expands the application scope of Huff model from the perspective of *penetration power* and further confirms the *funnel effect* of competitive hinterland.

Keywords port hinterland; GIS; port competition; Africa; spatial interaction model

1. Introduction

The port hinterland is a land area over which a port sells its services and interacts with its users, playing an important role in shaping the supply chain of shippers and logistics service providers (Notteboom et al., 2020). Although the factors that determine the hinterland scope are extremely complex, inland accessibility and port attractiveness have been considered to be the two most significant. With the development of the port's regionalization, the concept of the hinterland has changed from static to dynamic one. One of the most remarkable characteristics is the reduction of the captive hinterland and the expansion of the contestable hinterland, which is generally considered as the impact of the increasing inter-port competition (Haralambides, 2002, Ferrari and Musso, 2011).

This trend is particularly evident for port groups acting as the gateway of regional trade. Owing to the high density of ports, the contestable hinterland of port groups is typically considerable. Convincing evidence is from China's five-port groups, some of which (Yangtze River Delta port group, Southeast Coastal Port Group and Pearl River Delta Port Group) have even been proved to be dominated by contestable hinterland (Wan et al., 2020). Another evidence is from the European port groups, in which the contestable hinterland exist not only within a port group (the northwestern European ports) but also between port groups (the North European and North Adriatic ports) (Kronbak and Cullinane, 2011, Rupnik et al., 2018). All the evidences show the importance of studying the overlapping hinterland of port groups, as it is the key area of supply competition among ports. Relevant researches mainly include identifying and visualizing the ports' captive and contestable hinterland, which will both help the port and the port group devise more effective hinterland development strategies.

The hinterland competition also exists within African port groups, which play an increasingly important role in the global shipping chain. A typical case is in the Gulf of Guinea port group, which includes about 26 ports of varying sizes (see Figure 1 for their location). As it is the only gateway of seaborne trade for landlocked countries in West Africa, there has been a long-term problem of hinterland overlap in the port group. Notably, the three major ports in West Africa (Abidjan Port, Tema Port, and Lomé Port) compete fiercely for the hinterland in Burkina Faso. More details can be seen in Appendix A of Huang et al. (2021).

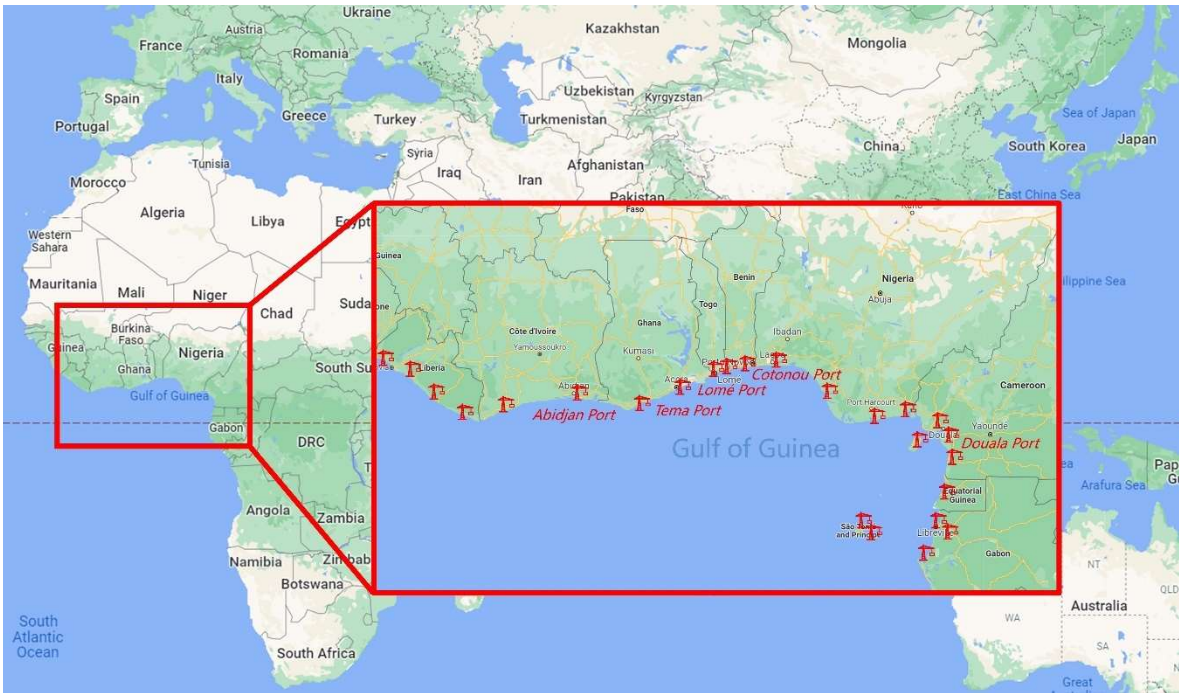

Figure 1: The location of the Gulf of Guinea port group

The fierce and complex hinterland competition shows that the competitive hinterland within the Gulf of Guinea Port Group is dominant, which implies the need for a more detailed division of the spatial hierarchy of the hinterland competition. In related research, Huff model became one of the most popular tools because of its theoretical and practical value. However, it only models the choice of discrete ports for shippers. It is usually difficult to analyze the hinterland competition by adopting such model directly. Furthermore, the case we focus on is quite different from those in Asia and Europe. It is located in sub-Saharan Africa, which is one of the least developed regions in the world. This unique feature makes our research face two challenges. First, the lack of OD data and performance indicators makes it difficult to identify the hinterland through the measured traffic flow. Second, the local inland transportation infrastructure is underdeveloped, which makes it difficult to analyze the hinterland accessibility through a network model.

In this context, a two-step method was proposed in this paper. Firstly, the Huff model supported by the GIS raster model was developed. Secondly, the conception of *penetration power* was adopted to analysis the hinterland competition. Based on this method, we clarified the hinterland competition of the Gulf of Guinea port group and delimited the contestable hinterland and captive hinterland of the individual ports. These studies will not only clarify the present situation of the hinterland competition in the Gulf of Guinea port group but also expand the application of the Huff model.

The remainder of this paper is structured as follows: Section 2 reviews the literature about the hinterland modelling and overlapping hinterland. Section 3 describes the construction of the spatial interaction model. Section 4 describes the empirical study involving the Gulf of Guinea port group, which is performed to demonstrate the model implementation and visualization. Section 5 discusses the results of empirical analysis. Section 6 summarizes the results of the study and highlights several future research directions.

2. Literature review

The spatial interaction model (SIM) represented by the gravity model and the Huff model has always been a classic theory for studying the port-hinterland relationship (Reilly, 1931, Huff, 1963). With the development of the geographic information system (GIS), there is increasing literature introducing the inland transportation network in the spatial interaction model (Moura et al., 2017, Santos and Soares, 2019, Wan et al., 2020). These approaches make the inequality of inland connection fully considered in the spatial interaction model, and demonstrate the high availability of GIS technology in the study of port-hinterland relationships. However, these cases are located in Europe or East Asia with a perfect transportation network. Therefore, the network analysis method based on the vector model has usually been used to analyze transport accessibility, but it is not practical for low-income regions with insufficient transportation infrastructure development (Banick et al., 2021). Considering the advantages of the raster model in this context, Huang et al. (2021) integrated the raster and vector model to analyze the impact of intermodal corridors on the evolution of the hinterland of the Gulf of Guinea Port Group. For a more comprehensive review of the spatial interaction model and GIS grid vector model, see Sections 2.1 and 2.3 in Huang et al. (2021).

With the development of port regionalization, the overlapping hinterland has attracted increasing concern. Morgan (1951) considered dividing hinterland into two categories: primary and secondary. The former refers to the area where the port is well established, while the latter refers to that with rivalry among ports. Notteboom and Rodrigue (2005) revealed the discontinuous development of contemporary port hinterland. They pointed out that some emerging spatial forms (e.g., the *island formation*) may increase the uncertainty of hinterland ownership. Similar to the approach proposed by Morgan (1951), Langen (2007) divided the hinterland into captive (dominated by one port) and contestable ones (competing by multiple ports). Based on the distinction made by Langen (2007), Kronbak and Cullinane (2011) further clarified the spatial structure of overlapping hinterland. Based on the concept of *penetration power*, the port hinterland was divided into the contestable hinterland with a funnel shape and the captive hinterland with a circle shape. However, due to the lack of SIM, port attributes were not fully considered in their research. Similar research can be seen in Rupnik et al. (2018) , which analyzed the impact of the dry port on the captive and contestable hinterland of Adriatic ports. By assigning different thresholds to membership degree, Wan et al. (2020) divided the hinterland of China's international hub ports into captive, contestable and potential ones. The projection pursuit model, huff model and GIS technology were integrated into this study to map the hinterland distribution of Chinese container ports. Their results confirmed these hinterlands overlap in considerable area.

In general, there is increasing literature studying the hinterland spatial competition in Europe and East Asia, but the cases in Africa have not gotten much attention. The lack of basic data and the complexity of the competition urge that more practical approaches are needed to visualize the captive and contestable hinterland of the Gulf of Guinea Port Group.

3. Methodology

3.1 Identification of Key Ports

For the convenience of research, we assume that the hinterland competition of the ports only occurs at the same hierarchy, and mainly focus on the hinterland competition between the key ports. To this end, we constructed a three-level comprehensive index system for these ports (Table 1) and divided these ports into three hierarchies based on principal component analysis-cluster analysis (PCA-CA), which has been proved to be practical in similar applications (Lu et al., 2018). The first hierarchy ports are considered as key ports, which are further chosen for hinterland competition analysis.

Table 1: Three-level comprehensive evaluation index system for port

Index			Index Number
Level 1	**Level 2**	**Level 3**	
Port Conditions	Geographic Conditions	Liner Shipping Related Index	X1

	Infrastructure Conditions	Number of Berths	X2
		Water Depth of Berth (m)	X3
	Management Level	Throughput ($\times 10^4$ t)	X4
		Information Level (1-9)	X5
Hinterland Conditions	Economic Conditions	National GDP ($\times 10^9$ USD)	X6
		Resource Richness (1-9)	X7
		Logistics Performance Level (1-9)	X8
Political Conditions	National Policy Conditions	Trade Tolerance (1-9)	X9
		Political Stability (1-9)	X10
		Government Support (1-9)	X11

3.2 Spatial analysis of hinterland competitiveness

3.2.1 SIM based on Huff model

SIM is used as the analysis basis of hinterland spatial competitiveness in this study. The basic method used in this study is adapted from the Huff model, which emphasizes the significant position of shippers in the port-hinterland relationship. This model was first applied in the market division of shopping centers and was later extended to the research of the port-hinterland (Huff, 1963, Zhuang and Yu, 2014).

As stated by Huang et al. (2021), there are two basic assumptions in this model: (1) The capture range of the hinterland is based on the shippers' subjective willingness. As the shippers are rational people, their decisions of port choice depend on the utility of the freight transportation; (2) The shippers always choose the cost path (i.e., the path with the least cumulative cost) as the transportation route between a specific origin and destination. Based on these assumptions, the model can be formulated as:

$$P_{ij} = \frac{A_j D_{ij}^{-\beta}}{\sum_{j \in J} A_j D_{ij}^{-\beta}} \tag{1}$$

Where:
i, j ($i \in I, j \in J$) = location point of hinterland and port;
P_{ij} = probability that the shippers at location i choose port j for freight transportation. That is, the competitiveness of port j at location i;
A_j = attractiveness of port j;
D_{ij} = transport accessibility between location i and port j;
β = parameter measuring the shippers' sensibility to D_{ij}.
It should be noted that the variable P_{ij} reflects not only the probability of the shippers in location i choosing port j but also the competitiveness of the port in this location. Therefore, this study considers P_{ij} as the basis for the analysis of hinterland spatial competition. To improve the accuracy of spatial analysis, the raster model is adopted to calculate the transport accessibility (D_{ij}), which will be described in detail in Section 3.2.2.

3.2.2 Implementation

According to formula (1), the calculation of hinterland competitiveness includes the solution of three parts: Port attractiveness, hinterland accessibility and spatial interaction model. The solution process corresponds to the following three steps.

Step 1: Calculation of port attractiveness

Port attractiveness is usually determined by a comprehensive evaluation method or a simplified scheme expressed by throughput (Wan et al., 2020, Moura et al., 2017). Considering that the three-level comprehensive evaluation system (see Table 1) comprehensively reflects the port development level, port attractiveness is calculated through the principal component analysis (PCA). See Li and Tang (2014), Lu et al. (2018) for more details.

Step 2: Calculation of Port-Hinterland Accessibility

The generalized distance based on shipping time is used to measure the accessibility between port and hinterland. This process is mainly based on the geospatial data of hierarchical road networks, and the GIS raster model is applied to calculate the cumulative shipping time between any inland area and port. Specifically, it can be divided into three sub-steps.

(1) Data import and processing

The geospatial data required for this process includes hierarchical road networks (Polyline), key ports (Point) and administrative divisions (Polygon). All geospatial data will be imported into ArcGIS and clipped to the specified scope and projected.

(2) Rasterization and assignment

With the support of the conversion tool in ArcGIS, the study area will be divided into mass square cells. With the support of the reclassification tool, these cells are assigned according to the corresponding transport conditions and the specific rules can be described as follows:

$$t_{\text{cell}} = \frac{d_{\text{cell}}}{v_{\text{cell}}} \tag{2}$$

Where:

t_{cell} = the trucks' shipping time crossing the unit cell;

d_{cell} = the cell size;

v_{cell} = the speed of trucks in different cells, which is assigned according to the categories of roads defined in step 1.

After all the cells are assigned, a cost raster database is formed, which is the direct data source of the spatial accessibility analysis.

(3) Calculation of Port-Hinterland Accessibility

The hinterland accessibility (i.e., the cumulative shipping time) between any inland location and port is calculated based on the cost raster database. This process is supported by the Cost Distance tool in ArcGIS.

Step 3: Solution of spatial interaction model

The port attractiveness and hinterland accessibility calculated in Step 2 are brought into the formula (1) to obtain the hinterland competitiveness of any port at any location. This process can be realized through ArcGIS Raster Calculator and Python script programming.

3.3 Hierarchical division of hinterland competition

Although the hinterland competitiveness of the individual ports is analyzed in Section 3.2, the hinterland competition within the Gulf of Guinea port group has not been demonstrated. Inspired by Kronbak and Cullinane (2011), the *penetration power* is adopted to divide the hinterland competition hierarchy of the Gulf of Guinea port group:

$$z_{ij} = \frac{(P_i)_{\max} - P_{ij}}{(P_i)_{\max}} \tag{3}$$

Where:
$(P_i)_{\max}$ = the maximum value of the hinterland competitiveness of all ports at location *i*;
z_{ij} = the relative difference of the hinterland competitiveness between the port j and the maximum value in location *i*.
Constant *f* is defined as the *penetration power* of the hinterland competition. If $z_{ij} > f$, port *j* is considered less competitive in location *i*, and does not participate in the hinterland competition; If else, port *j* is considered more competitive in location *i*, and participate in the hinterland competition.

4. Empirical analyses

4.1 Identification Results of Key Ports

The Gulf of Guinea port group defined in this study includes 26 ports along the Gulf of Guinea. Their port numbers and basic information collecting for PCA-CA method are shown in Appendix A, table A1. Based on the PCA-CA method described in Section 3.1, four principal components are extracted from the initial variables (See appendix A, table A2 for scores of each component). As shown in Figure 2 and Table 2, these ports are divided into three hierarchies and eight ports are classified as the first-hierarchy ports. As the port state plays a leading role in the formulation of its port strategy, the hinterland competition within the same country's ports is not considered. In other words, at most one port in a country is considered to participate in the hinterland competition of the gateway ports. In this context, six gateway ports (Abidjan Port, Tema Port, Lomé Port, Cotonou Port, Lagos Port and Douala Port) are further selected from the first hierarchy ports. These ports will be regarded as the key ports for the analysis of the current situation of hinterland competition.

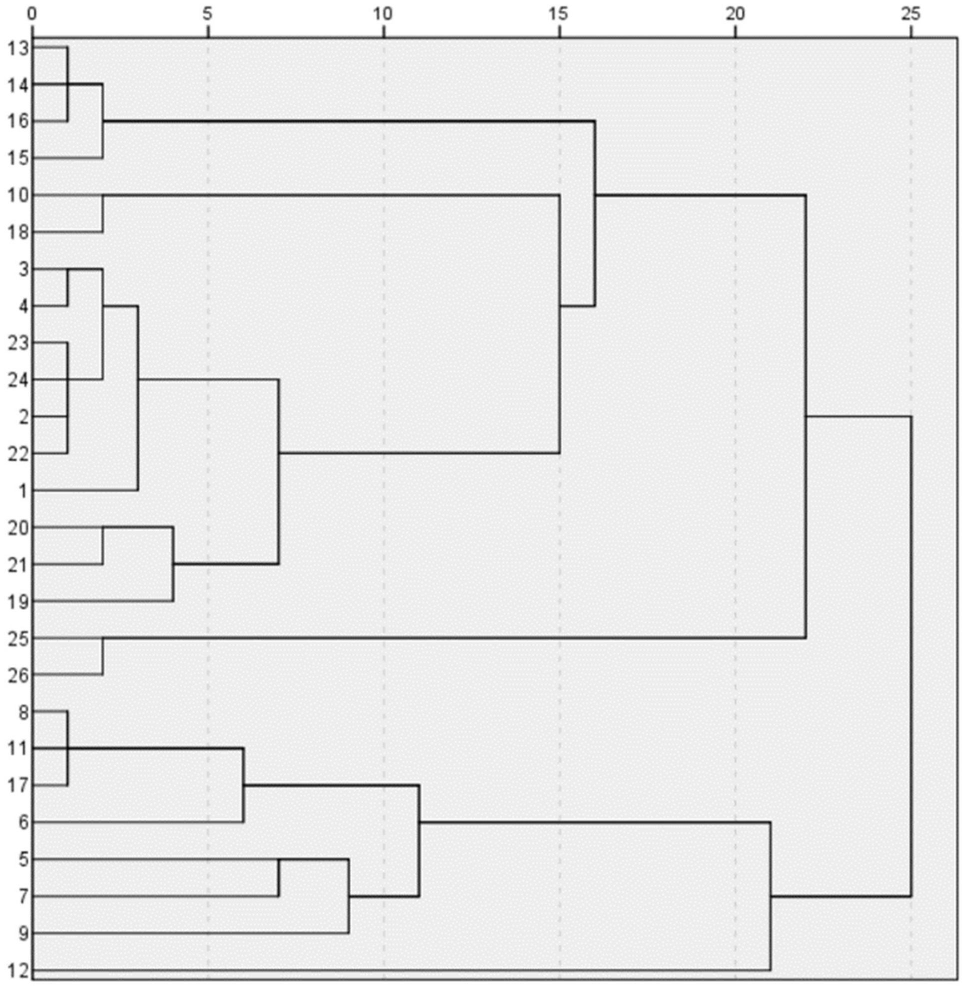

Figure 2 Results of the PCA-CA

Table 2: Results of port hierarchy division

Hierarchy	Port
1	Abidjan Port, Tema Port, Lagos Port, San Pedro Port, Takoradi Port, Lomé Port, Cotonou Port, Douala Port
2	Free Port of Monrovia, Buchanan Port, Harper Port, Port Greenville, Kpeme Port, Calabar Port, Harcourt Port, Onne Port, Port Warri, Limbe Port, Kribi Port, Bata Port, Malabo Port, Port Gentile, Port Libreville, Port Owando
3	San Antonio Harbour, Port of Sao Tome

4.2 Spatial Scope

The Potential hinterland of these ports includes countries along the Gulf of Guinea and the landlocked countries in West and Central Africa. Locations of the potential hinterland and key ports are shown in Figure 3.

Figure 3: The spatial scope of this study

4.3 Analysis Results of Port Group Hinterland Competition

The basic geospatial data is shown in Figure 4. Considering the underdevelopment of railways and inland waterways, modes other than road are not included. These data are accessed from the Natural Earth (Version 4.1.0 in 10m resolution, released in 2018), of which the roads are divided into three categories: Major Highway, Road and Unknown. Based on the field research, Major Highway and Road are classified as first-class roads and Unknown as the second-class road for research. we stipulate that ports whose hinterland competitiveness is greater than 80% of the maximum value will participate in the hinterland competition (i.e., $f = 0.2$). The value of β was derived from the work of Zhuang and Yu (2014). The values of other parameters are obtained from China Harbour Engineering Company Ltd. and Hohai University (2020) and field research.

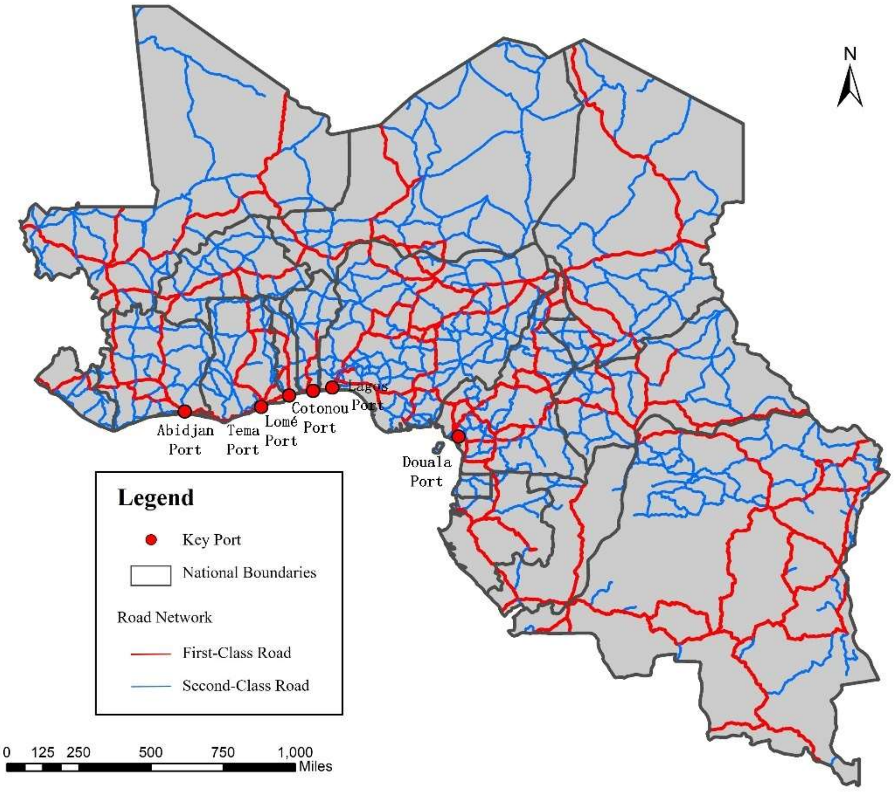

Figure 4: The processed geographic data

Based on the methods proposed in sections 3.2 and 3.3, we divide the hinterland hierarchy of the Gulf of Guinea port group with the support of the ArcGIS 10.2 and Python 2.7 script programming (as shown in Figure 5 and Table 3). The hinterland competition hierarchy of the port group is further transformed into that of each port (as shown in Figure 6). The locations where only one port competes is defined as the captive hinterland, while the locations where two or more ports compete is defined as the contestable hinterland.

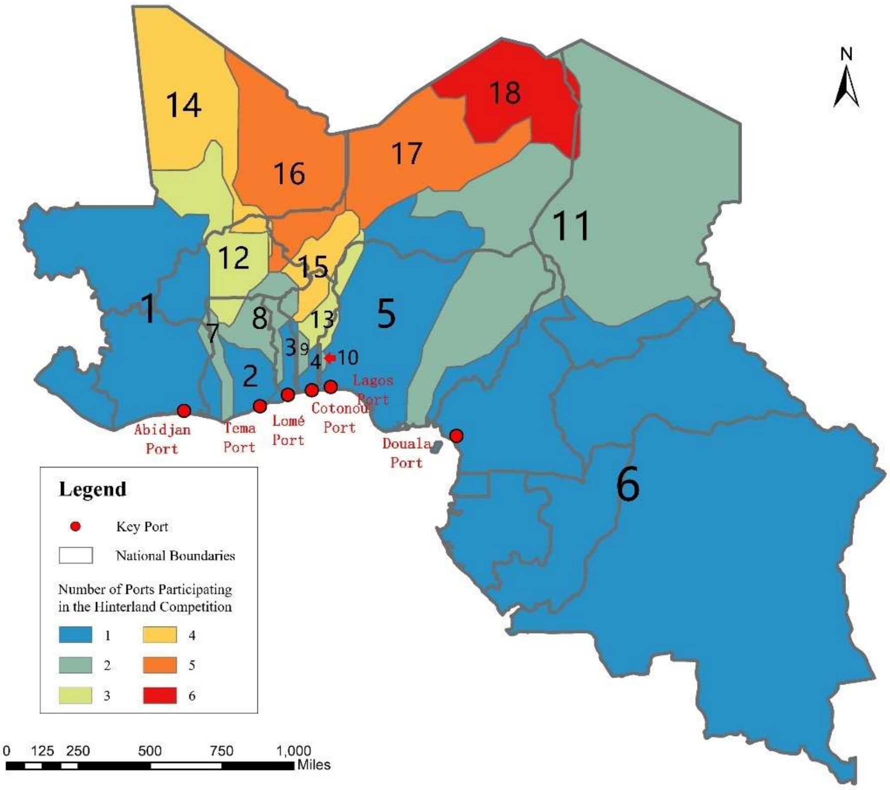

Figure 5: Hierarchy division of hinterland competition in the Gulf of Guinea port group

Table 3: Hierarchy division of hinterland competition in the Gulf of Guinea port group (list)

Type	**Region Number***	**Port**					
		Abidjan Port	**Tema Port**	**Lome Port**	**Cotonou Port**	**Lagos Port**	**Douala Port**
Captive Hinterland	1	√					
	2		√				
	3			√			
	4				√		
	5					√	
	6						√
Contestable Hinterland	7	√	√				
	8		√	√			
	9			√	√		
	10				√	√	
	11					√	√
	12	√	√	√			
	13			√	√	√	
	14	√	√	√		√	
	15		√	√	√	√	
	16	√	√	√	√	√	
	17		√	√	√	√	√
	18	√	√	√	√	√	√

* The number is consistent with Figure 4

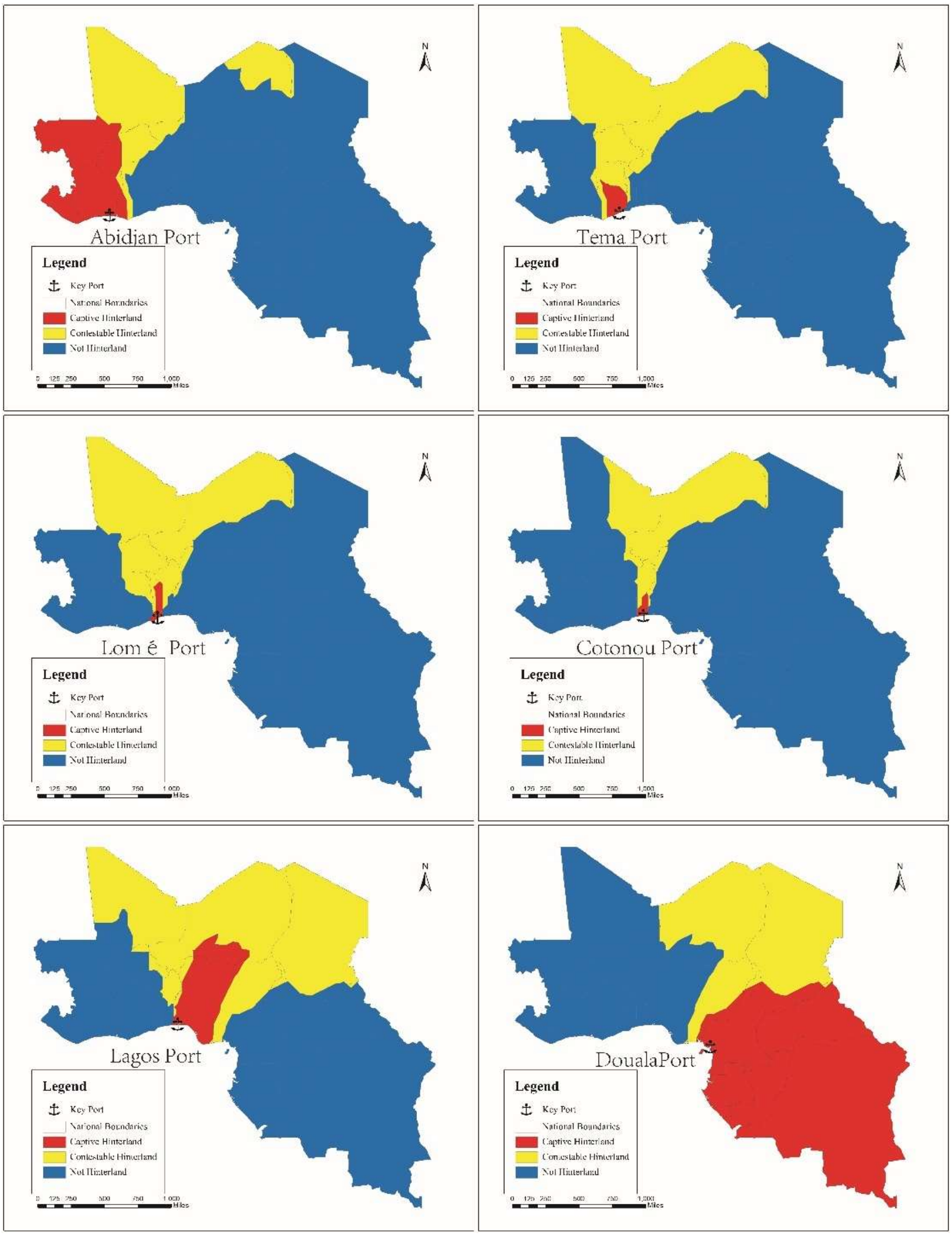

Figure 6: Contestable hinterland and captive hinterland of the individual port

5. Discussion and implications

Our simulation results demonstrate that the hinterland competition of the Gulf of Guinea Port Group is widespread. In general, the contestable hinterland is dominant and the intensity of competition in different regions is unbalanced. On the one hand, there is fierce hinterland competition in the landlocked countries in West Africa (Mali, Niger and Burkina Faso), which is consistent with the field research results of Japan International Cooperation Agency (2018). The complexity of the hinterland competition in this region increases from the coast to the remote inland and presents four hierarchies. The most complicated location is in eastern Mali and northern Niger (region 16-18 in Figure 4), in which the hinterland freights are competed by 5 or more ports. On the other hand, the hinterland competition in Central Africa is not obvious. Due to the lack of adjacent and competitive ports at the same level, Douala port has captured a fairly broad captive hinterland. This finding implies the significance of coordinated planning among ports. For the super managers of the port group, excessive dense and homogeneous port layout probably lead to confusion and vicious competition in the hinterland. The establishment of a hierarchical port system will not only contribute to the win-win situation of the ports in the group but also give full play to the driving force of the port group in the hinterland economy.

For port individuals within the port group, there are great differences in the spatial form between captive and contestable hinterland. The spatial form of the port's contestable hinterland presents a *funnel effect* (i.e., the spatial scope of it gradually expands to the remote inland, Figure 5), which is consistent with the conclusion of Kronbak and Cullinane (2011). However, the ports' captive hinterland is shrinking inland. Abidjan port and Douala port, which are located at the edge of the port group, obtain a considerable captive hinterland; The captive hinterland of Tema port, Lomé port and Cotonou port, which are located in the core of the port group, is very limited. This finding implies that the relative location conditions in the port group have an important impact on the port's development. In addition, the *funnel effect* demonstrates that the remote inland is of great significance to the development of the port hinterland. The development of intermodal corridors (e.g., railway and inland waterway) and inland transhipment hubs (e.g., dry ports and inland ports) will help ports seize the hinterland share in multi-port competitive regions, which has been researched in Huang et al. (2021).

6. Conclusion

The main purpose of this research is to clarify the present situation of the hinterland competition in the Gulf of Guinea port group. To this end, we developed a SIM based on the Huff model and *penetration power*. The main contribution of this model is that it helps us finely divide the hinterland division hierarchy of the Gulf of Guinea port group, and delimit the contestable hinterland and captive hinterland of each port. The result shows that:

(1) There is fierce hinterland competition in the Gulf of Guinea port group. Abidjan Port, Tema Port, Lomé Port and Cotonou Port compete particularly fiercely in the hinterland of the three landlocked countries of Mali, Burkina Faso and Niger;

(2) The hinterland competition has obvious hierarchical structure characteristics. In general, the complexity of the hinterland competition increases from the coast to the remote inland;

(3) Subject to fierce hinterland competition, the captive hinterland of the individual port is relatively small and the contestable hinterland is relatively large. The spatial form of the contestable hinterland presents a *funnel effect*. The remote inland regions represented by eastern Mali and northern Niger will become the focus of future competition among these ports.

(4) The super managers of port groups should pay more attention to the collaborative planning of ports. The high density of homogeneous ports will lead to the deterioration of hinterland competition.

(5) The relative location conditions are of great significance to the individual ports in the port group. The remote hinterland should receive more attention from the ports.

The contribution of this paper is three-fold. Firstly, considering the scarcity of similar studies in Africa, this study provides support for the local stakeholders' decision-making of the ports and the hinterland. Secondly, this paper proposed a practical method combining the SIM with *penetration power* in the research of hinterland. This method fully considers the inland accessibility and port attributes, and has been proved to be highly available in the visualization of hinterland competition. This expands the application of SIM and can be easily extended to other cases. Thirdly, the *funnel effect* confirmed in the European cases has been further verified in the African case. It accurately describes the spatial pattern of the competitive hinterland and implies the fierce competition of the port group towards the remote hinterland. For future research, incorporating sea-side factors into SIM and conducting various sensitivity analysis will help to study the impact of the intermodal chain on the hinterland's dynamic evolution.

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Appendix

Appendix A: Basic data and results of PCA-CA

Table A1: Basic data of PCA-CA

Port	Port Number	Value										
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
Free Port of Monrovia	1	8.27	4	7.1	295.86	2	30.71	8	2.2292	6.5	4	7
Buchanan Port	2	8.27	3	9.4	522.07	3	30.71	8	2.2292	6.5	4	5
Harper Port	3	8.27	1	5.5	0.36	2	30.71	8	2.2292	6.5	4	4
Port Greenville	4	8.27	2	8	1.87	2	30.71	8	2.2292	6.5	4	4
Abidjan Port	5	16.76	9	11.5	2573.83	6	587.92	5	3.0823	6.5	7	8
Port San Pedro	6	16.76	5	12	408.12	6	587.92	5	3.0823	6.5	6	6
Tema Port	7	18.5	18	11.4	1404.58	7	669.84	6	2.5653	5	6	7
Takoradi Port	8	18.5	9	10	804.08	5	669.84	6	2.5653	5	6	4
Lomé Port	9	35.86	14	15	1931.66	6	54.6	5	2.4475	6.5	5	6
Kpeme Port	10	35.86	2	11	300	3	54.6	5	2.4475	6.5	4	4
Cotonou Port	11	16.96	11	9.4	950.9	5	143.91	6	2.7499	5.5	4	5
Lagos Port	12	18.96	21	13.5	1909.97	7	4481.2	8	2.5321	4	4	7
Calabar Port	13	18.96	7	9	218.77	6	4481.2	8	2.5321	4	3	4
Port Harcourt	14	18.96	8	9.5	353.69	5	4481.2	8	2.5321	4	3	4
Onne Port	15	18.96	4	12	26.8	4	4481.2	8	2.5321	4	3	4
Port Wari	16	18.96	12	7	519.78	4	4481.2	8	2.5321	4	3	4
Douala Port	17	25.53	10	7.1	1130	5	387.6	7	2.5955	5.5	4	5
Limbe Port	18	25.53	1	20.1	0.97	4	387.6	7	2.5955	5.5	4	4
Kribi Port	19	25.53	1	6.4	1.2	4	387.6	7	2.5955	5.5	4	4
Bata Port	20	10.65	11	11	650	3	110.27	5	2.3176	4	3	4
Malabo Port	21	10.65	2	7.1	200	3	110.27	5	2.3176	4	3	4
Port Gentil	22	11.41	1	9.4	1200	4	166.58	8	2.1619	5.5	4	4
Port Libreville	23	11.41	1	9.4	365	3	166.58	8	2.1619	5.5	4	4
Port Owando	24	11.41	1	7.1	573	3	166.58	8	2.1619	5.5	4	4
San Antonio Harbour	25	5.24	1	9.4	8.17	2	4.29	2	2.6532	4	4	3
Port of Sao Tome	26	5.24	1	1.8	8.17	2	4.29	2	2.6532	4	4	3

Table A2: Results (Score) of PCA-CA

Port Number	Score				Port Number	Score			
	F1	F2	F3	F4		F1	F2	F3	F4
1	-1.011	-1.303	1.787	-1.377	14	-0.169	2.788	-0.126	0.172
2	-1.072	-0.994	1.6	-0.583	15	-0.701	2.56	-0.017	0.878
3	-2.403	-1.118	1.263	-0.623	16	-0.28	2.787	-0.212	-0.48
4	-2.135	-1.033	1.361	-0.292	17	1.049	0.05	0.171	-0.061
5	4.576	-2.436	-0.751	-1.008	18	0.251	-0.049	0.503	3.066
6	2.266	-1.824	-1.151	0.666	19	-0.852	-0.278	-0.064	0.982
7	3.555	-0.212	-0.193	-1.132	20	-0.926	0.667	-0.763	-0.405
8	1.054	-0.507	-0.667	0.057	21	-2.103	0.244	-0.925	-0.371
9	3.555	-0.828	0.733	1.232	22	-0.865	-0.328	1.279	-0.463
10	-0.259	-1.038	0.295	2.445	23	-1.645	-0.379	1.203	-0.116

11	1.088	-0.259	-0.563	-0.19	24	-1.704	-0.435	1.132	-0.554
12	3.688	2.821	0.465	-1.307	25	-2.13	-0.82	-2.935	0.204
13	-0.083	2.869	-0.178	0.209	26	-2.742	-0.947	-3.249	-0.952

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A Comprehensive Review on the Mergers and Acquisitions between Leading Container Shipping Lines

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Abstract

Purpose – Mergers and acquisitions are one of the development trends of the shipping industry today. This trend along with strategic alliances makes the market increasingly concentrated, thereby negatively affecting competition. Countries have made certain amendments to their laws to tightly control antitrust issues. This paper aims to review the impact of these M&A deals on the market structure and antitrust laws specifically in the shipping industry.

Design/methodology/approach – This paper analyses a case study and reviews some major antitrust regulations, including the regulations in the United State, the European Union and China.

Findings –The new wave of consolidation in the container shipping industry in the late 2010s was to cope with the depressed market conditions and poor financial returns. This has caused the market structure to change from competitive to moderately concentrated. Moreover, the merger and acquisitions between shipping lines also raises concerns about collusion and manipulation to fix prices after the early 2020s freight market boom.

Originality/value – Explore the possible extant monopoly violations practices in the shipping industry.

Keywords Anti-competition, Merger and Acquisition, Container Shipping

1. Introduction

Mergers and acquisitions could be considered the most cohesive form of cooperation as these lead to full or almost full integration of corporate activities (Merk, Kirstein & Salamitov, 2018). In acquisitions, one company buys all existing ownership rights of its rivals. Meanwhile, a merger is a fusion of two or more companies to form one trading entity.

In general, firms seek mergers and acquisitions to capture economies of scale in production, increase management efficiencies and exploit synergies between rival operations and markets (Fusillo, 2009). M&A may not only have long-term strategic and economic effects, but they may also impact directly and immediately on the value of the company as they induce a particular reaction in the stock market with the consequent increase or decrease in share price (Panayides & Gong, 2002).

Merger and acquisition are the factors causing the high level of concentration in the shipping industry Monteiro & Atkinson, 2010). To ensure market competitiveness, antitrust agencies are in-depth investigating these deals. Therefore, getting approval from countries is not easy for these deals. This study aims to provide an overview of the merger and acquisition between shipping lines, especially the difficulties in obtaining approval from governments through the analysis of a case study: South Africa rejected the merger deal between K Line, MOL and NYK.

2. M&A and market concentration

2.1 M&A activities between shipping lines

Maritime M&A appeared in waves with a peak in 1999. Three mergers took place: between Nedlloyd and P&O containers in 1997, between Wallenius and Wilhelmsen in 1999, and between CP Ships and TMM(Transportacion Maritima Mexicana) in 2000 (Goulielmos, 2017). And then this industry experienced years of no merger and acquisition activity after intensified consolidation in the early 2000s until 2016. The year 2013 marked the most difficult period in shipping history – the shipping market hit the bottom when the freight rate reached 725 USD/TEU, down 65% compared to 2012. Revenue of shipping lines decreased compared to the previous year (Ha& Seo, 2017). The bankruptcy of Hajin seems to underscore the dire situation going on in the shipping industry. Then shipping lines have responded with mergers and acquisitions to reduce the cost by the economies of scale effect. Therefore, the new wave of consolidation was a means for the container shipping industry to cope with the depressed market conditions and poor financial returns (UNCTAD, 2018).

Maersk, CMA CGM, and COSCO Shipping Lines have had many mergers and acquisitions over the years. Meanwhile, the others including MSC, Evergreen, YangMing, and HHM, have very few M&A activities or do not even have one. Details of the M&A for the top 10 shipping lines are as shown below.

The Top 10 shipping lines and their M&A activities

No.	Shipping line	Mergers and Acquisitions
1	Maersk	Maersk acquired EACBen Container Line Ltd in 1993; Safmarine and Sealand in 1999; the liner division of the Danish Torm Lines in 2002; P&O Nedlloyd in 2005; Hamburg Süd in 2016.
2	MSC	N/A
3	CMA CGM Group	CMA CGM Group acquired ANL(Australian National Lines) in 1998; Mac Andrews in 2002; Delmas in 2006; CNC, CoMaNav, and US Lines in 2007. In 2016, acquired NOL (parent company of APL). In 2017, acquired Mercosul from Maersk Line; acquired SoFraNa through its subsidiary - ANL. In 2018, acquired Containerships.
4	COSCO Group	COSCON Group merger with China Shipping Group to form COSCO SHIPPING Group in 2016. COSCO Shipping Holdings (a subsidiary of COSCO Group) acquired OOCL in 2017.
5	Hapag-Lloyd	Hapag-Lloyd merged with UASC fleet in 2017 and acquired NileDutch in 2021.
6	ONE	Merger between three Japanese shipping lines, including MOL, NYK and K Line.
7	Evergreen Line	Evergreen Marine acquired Lloyd Triestino in 1998, which was renamed as Italia Marittima S.P.A. in 2006.
8	HMM Co Ltd	N/A
9	Yang Ming Marine Transport Corp.	N/A
10	Wan Hai Lines	N/A

Source: compiled by the author from various sources

- COSCO Shipping Holdings acquired OOCL in 2017

COSCO Shipping Holdings is a subsidiary of COSCO Shipping Group established from the merger of two Chinese state-owned companies, China Ocean Shipping (Group) Company –COSCON and China Shipping (Group) Company – China Shipping in 2015. Meanwhile, OOCL is a subsidiary of Orient Overseas (International) Limited - OOIL established in 1970.

On July 9, 2017, COSCO Shipping Holdings has offered to buy OOIL for $6.3 billion. And on June 30, 2018, this deal was officially effective after it has been approved by authorities. After acquiring OOIL, it means that COSCO also owned the world's eighth-largest shipping line in the world at that time - OOCL. This has helped COSCO have a significant addition to its capacity and overtake CMA CGM to become the world's third-largest carrier.

- Maersk Line acquired Hamburg Süd in 2017

Hamburg Süd was established in 1871, is a shipping line of the Oeker Group, with 130 ships and a capacity of about 600,000 TEUs, mainly running the North-South shipping route.

On April 28, 2017, Maersk Line announced it would acquire Hamburg Süd from Oetker Group for EUR 3.7 billion on a cash and debt-free basis. And on November 30, 2017, Maersk Line announced this deal was closed because this acquisition has obtained approval from the authorities.

Hamburg Süd was established in 1871, is a shipping line of the Oeker Group, with 130 ships and a capacity of about 600,000 TEUs, mainly running the Northern - Southern Hemisphere route. At that time, Hamburg Süd was the 7th largest shipping line in the world.

The deal has helped Maersk increase capacity by 18.6% (increasing the number of ships to 741 vessels, the average age is about 8.7 years old), helping this world-leading shipping company expand its market share on shipping routes from Latin America to the rest of the world.

2.2 Formula used to calculate market concentration

There are two popular approach to indicate the degree of market concentration, CR ratio and HHI index. One of the most common approaches to measuring market concentration is to use the top 4 (CR4) or top 10 (CR10) concentration ratio. CR10 is a measure of the sum of the market shares of the 10 largest companies in the special market (or 4 in the case of CR4). CR4 and CR10 considers this market highly concentrated with CR4 = 80 and CR10 = 100 (Tanusondjaja, Dunn & Miari, C. 2020; Papatheodorou A, 2016). The detailed formula is as follows:

$$CRn = \sum_{i=1}^{n} \mathrm{s_i} \qquad (1)$$

In which,
CR(n): concentration ratio
S_i: the market shares of the i^{th} shipping company
n: the number of shipping company with higher market share

- Herfindahl-Hirschman Index (HHI)

According to the US Department of Justice, the term “HHI” stands for the Herfindahl-Hirschman Index, a commonly accepted measure of market concentration. HHI is calculated by squaring the market share of each competing firm in the market and then summing the resulting numbers. The maximum is 10000 points. The market is moderately concentrated when HHI is between 1,500 and 2,500 points. And the market is highly concentrated when HHI is more than 2,500 points. The detailed formula is as follows:

$$\mathrm{HHI} = \sum_{i=1}^{n} \mathrm{s_i^2} \qquad (2)$$

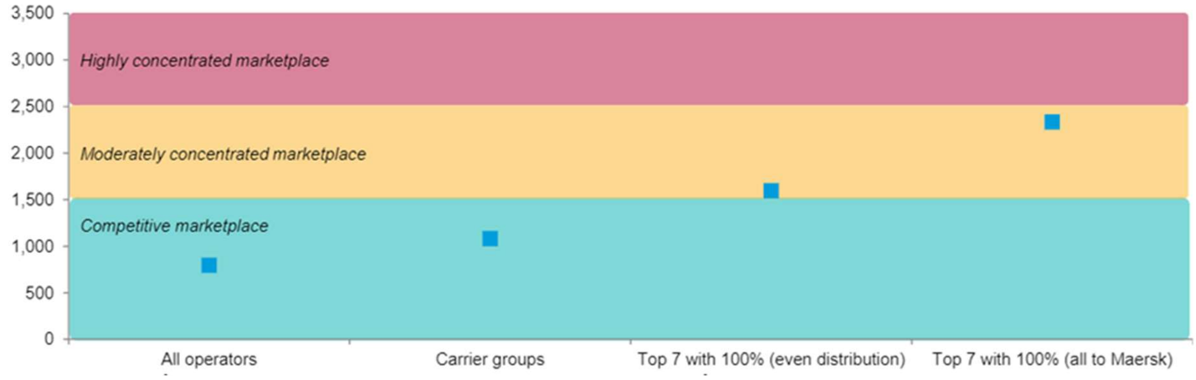
In which,
S_i: the market shares of the i^{th} shipping line (S_i %)
n: the number of shipping line in the market

2.3 Market structure after the M&A activities between shipping lines

Drewry has calculated HHI based on the capacity of shipping lines as of October 17, 2017, and concluded that the market remains competitive.

Accordingly, they calculated this index with 2 cases, case one is based on the market share of the top seven largest shipping lines in the world and divided the remaining shipping lines equally among these seven shipping lines. Case 2 is to take the market share of the remaining shipping lines and then distribute them all to the world's largest shipping line at that time, Maersk. And they found that in both cases, HHI is below 2500 points. Therefore, the market would become highly concentrated when there were mergers and acquisitions among these seven shipping lines. The detailed results as shown below:

Figure1. Herfindahl-Hirschman Index (HHI) of shipping market



Sources: Drewry, 2018

However, it should be noted that the HHI index in the container shipping market is increasing significantly. According to Merk, Kirstein & Salamitov (2018), the HHI index increased from 300 in 1998 to 1400 in 2018 and significantly increased during the period 2016 to 2018 as an inevitable consequence of a series of mergers and acquisitions occurred between the shipping lines. With a decreasing number of shipping lines, this HHI index might be increased exponentially in the future.

3. Regulation about M&A of major antitrust regulator

3.1 United States

The United States control antitrust based on three core laws: The Sherman Antitrust Act, the Federal Trade Commission Act, and the Clayton Antitrust Act. Each law has different governing content, specifically as follows:

Table 1. US Antitrust law

Antitrust law	the Sherman Antitrust Act	the Clayton Antitrust Act	the Federal Trade Commission Act
Year of Enactment	1890	1914	1914
Prohibited Activities	+ every contract, combination, or conspiracy in restraint of trade + monopolization, attempted monopolization, or conspiracy or combination to monopolize	+ addresses specific practices that the Sherman Act does not clearly prohibit, such as mergers and interlocking directorates	+ unfair methods of competition + unfair or deceptive acts or practices
The Enforcers	+ U.S. Department of Justice (DOJ) Antitrust Division + Federal Trade Commission (FTC)		

Sources: US Federal Trade Commission

M&A activities are covered by the Clayton Antitrust Act of 1914. In which section 7 applies to mergers "in any line of commerce" when their effect "may be substantially to lessen competition, or to tend to create a monopoly" unless the merger is statutorily exempt (Ruane, 2017).

The threshold under which a merger or acquisition is required to be notified to antitrust authorities is set forth in the Hart-Scott-Rodino Antitrust Improvements Act (HSR) of 1976. This threshold is divided into the Size-of-Transaction threshold and Size-of-Person threshold and will be changed from year to year. The detail as following:

Table 2. The US thresholds in recent years

Unit: million USD

Year	2019	2020	2021	2022
Minimum Size-of-Transaction	90	94	92	101
Size-of-Person (smaller person)	180	188	184	202
Size-of-Person (larger person)	18	18.8	18.4	20.2
Maximum Size-of-Transaction (transactions exceeding this value do not need to meet size-of-person tests)	359.9	376	368	403.9

Note: *"The size of person threshold is measured at the ultimate parent entity(UPE) level of each party and includes all entities controlled by each such ultimate parent entity."(*Holland and Knight, 2022*; FTC Notification Off ice, 2008)*

Source: compiled by the author from various sources

3.2 European Union

Unfair competition practices in the European Union are regulated based on the Treaty on the Functioning of the European Union – TFEU and the EC Merger Regulation. The agency responsible for enforcing the EU competition rules is the European Commission (EC). EC has the power and responsibility to investigate suspected anti-competitive conduct, issue prohibition decisions, impose fines, and conclude binding agreements with companies.

Article 1 of the EC Merger Regulation provides for the turn over thresholds under which a merger or acquisition is considered a concentration and then is governed by this law. A concentration must be notified in advance to the EC (article 4), then EC will initiate a review based on the factors set out in article 2. It should be noted that article 22 of this regulation allows one or more Member States to request the EC to review a concentration if it affects trade between them or threatens to significantly affect the competition of that Member State.

The most recent merger in the shipping industry that the EC assess is a merger between two mega South Korean shipbuilders - Daewoo Shipbuilding & Marine Engineering (DSME) and Hyundai Heavy Industries Holding (HHIH). On January 14, 2022, after undergoing an in-depth investigation, EC announced that they did not approve this merge. Because they believe that deal will reduce competition in the already highly concentrated LNG shipping building market and significantly increase prices for newly built LNG ships.

3.3 China

China has the highest level of antitrust law enforcement in Asia (Antitrust in Asia, 2018). China's Anti-monopoly law took effect on January 1, 2008, and consists of 57 articles. This law is promulgated to regulate monopolistic agreement, abuse of dominant market position, the concentration of undertaking, abuse of administrative power to eliminate or restrict competition, and investigation of suspected monopolistic conducts. After AML came into force, the State Council has identified three agencies to implement this law including the Ministry of Commerce (MOFCOM), the National Development and Reform Commission (NDRC), and the State Administration of Industry and Trade (SAIC). However, on March 17, 2018, the China National People's Congress approved the establishment of a new agency, the State Administration for Market Regulation (SAMR). This agency is responsible for antitrust enforcement, which is previously divided among the three agencies. SAIC will dissolve into SAMR meanwhile MOFCOM and NDRC will continue to exist but not perform other antitrust functions.

For mergers and acquisitions activities, it is regulated in chapter 4 of the AML. In which, article 20 states as follows:

"Article 20. A concentration refers to the following situations:

(i) the merger of undertakings;
(ii) the acquisition by undertakings, whether by purchase of securities or assets, of control of other undertakings;
(iii) the acquisition by contract or any other means, of control of other undertakings or of the ability to exercise decisive influence over other undertakings."

Accordingly, a concentration that reaches the turnover threshold must be notified in advance to the antitrust agency and required documents must be submitted for review and made the decision. During that time these concentrations will not be performed. The factors used for assessment are mentioned in article 27. And if the transactions eliminate or restrict competition, the antitrust agency will issue a decision not to approve under article 28.

Table 3. China turnover threshold

Turnover	Combined	Two parties
First threshold	Worldwide	Nationwide
	exceed RMB 10 billion approximately USD 1.6 billion	At least two stakeholders and each of them has generated revenue exceeds RMB 400 million approximately USD 65.3 million in China
Second threshold	Nationwide	
	exceed RMB 2 billion approximately USD 326.5 million	At least two stakeholders and each of them has generated revenue exceeds RMB 400 million approximately USD 65.3 million in China

Source: compiled by the author from Lee and Li Attorney(2008)

4. Case study

- Background

On October 31, 2016, the three largest shipping lines in Japan, NYK, K-line, and MOL, announced merging themselves into a new shipping line – ONE(Ocean Network Express). These three shipping lines will integrate their container shipping business and the container terminal operating segment, excluding Japan (Greg Knowler, 2016). Thus, their container terminal operations in Japan were merged, other port business activities such as bulk shipping, car transport, ferry operations, and logistics will be operated independently.

- Decisions made by the countries

In March 2017, Singapore officially approved this merger.

"After reviewing the parties' submissions and the feedback received, CCS concluded that the creation of the joint venture, if carried into effect, will not infringe the prohibition in the Act against anti-competitive mergers," Competition Commission of Singapore (CCS) said.

Meanwhile, on May 3, 2017, the US Maritime Commission rejected the merger because it was outside the commission's jurisdiction and referred the case to the US Department of Justice.

"The Shipping Act does not provide the Federal Maritime Commission with authority to review and approve mergers" (FMC, 2017).

- South Africa's decision and the reason for a rejection

On June 22, 2017, South Africa announced that it had rejected a merger between three Japanese shipping lines. This merger does not raise concerns about reduced competition in the South African market because the market share of these three shipping lines in South Africa is not so large. South Africa made the above decision due to concerns about the manipulation and collusion of the three shipping lines to the car transport market, although it was not merged in this deal (Greg Knowler, 2017).

However, there is a basis for this concern because three Japanese shipping lines have been accused and investigated for cartel participation, collusion, and manipulation of the car transport market in South Africa and many other countries. The detail as follow:

Table 4. Japanese shipping lines have been accused by many countries

Time	Event
01/2015	NYK admitted to customer allocation, bid-rigging, price-fixing in the United States and agreed to pay a fine of USD 59.4 million.
12/03/2015	A senior officer of the Japanese shipping company-NYK was sentenced to 15 months in prison for his participation in price-fixing.
30/06/2015	The South African Competition Commission reached a settlement agreement with NYK for price-fixing and collusion in the transport of cars. NYK admitted and agreed to pay a fine of 104 million rupiahs (USD 8.5 million).
27/12/2015	The National Development and Reform Commission (NDRC) fined seven shipping companies, including K-Line and MOL for price-fixing.
03/08/2017	NYK was fined USD 25 million by an Federal Court of Australia, equivalent to USD 19.8 million for price-fixing and participating in Cartel.
21/02/2018	3 Japanese shipping lines, NYK, K-Line, MOL and two other shipping lines were fined EUR 395 million by the European Commission for participating in a cartel related to car transport for nearly 6 years (10/ 2006 – 09/ 2012). In which, K-Line was fined the most with a fine of EUR 39.1 million.
02/08/2019	K-Line was convicted and fined AUD 34.5 million equivalents to USD 23.4 million by the Federal Court of Australia. K-Line pleaded guilty to participating in the Cartel to fix prices on transporting cars, trucks, and buses to Australia between 2009 and 2012.

Source: compiled by the author from various sources

- *The response of shipping lines:*

But it seems that South Africa's decision has not significantly affected the merger of three Japanese shipping lines. Because only MOL and K-Line provide container shipping services in South Africa. NYK left this market in 2015 (Greg Knowler, 2017). So in the worst case, if it is not possible to get approval from this country, these three shipping lines can choose to abandon this market and carry out the merger as planned. However, on January 19, 2018, ONE has approved by all countries it requires including South Africa. And then ONE began its services on April 1, 2018.

5. Conclusion

Mergers and acquisitions are one of the major trends in the shipping industry alongside strategic alliances. These two trends have made the market more and more concentrated with fewer shipping lines. The market is now towards the oligopoly market which is dominated by a small number of shipping lines.

To ensure the competitiveness of the market, the countries are gradually tightening control over the consolidation activities of shipping lines. Previously the rule change has led to the disappearance of the shipping conference, now it is very likely to happen again for the alliance.

Meanwhile, building new mega container ships is a long-term strategy. If the shipping line has to operate independently, there are only the world's two largest shipping lines can operate efficiently. Therefore, shipping lines need to have a reasonable development strategy to both ensure business efficiency and not to violate the law at the same time.

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