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Seaport Continuity Modelling Toward Pandemic Disaster Preparedness in the Future

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A seaport is an important economic and logistics node for any country. It provides opportunities for country development, deepening regional cooperation and promoting prosperity in the global supply chain. Seaports around the world are facing difficulty, congestion and delays, especially during the Covid-19 pandemic. Not only that, thousands of seafarers were also stranded at sea due to restrictions and prevention purposes, as well as seaports facing shortages of manpower, equipment and containers. The resulting supply chain bottlenecks hampered economic recovery. While the pandemic seems to be over, it may come again, new deadly germs may appear in the future. European researchers have isolated 13 new viruses from seven different ancient Siberian permafrost samples. Their study highlighted climate change melting the permafrost which revived a host of zombie and contagious viruses. Seaports should gradually shift to a "just in case" supply chain model and establish seaport continuity modelling to ensure sustainability and practicability of the operating system for future outbreaks. Survey activity and Analytic Hierarchy Process (AHP) analysis are used to determine the priority criteria of seaport continuity modelling and then a modelling is established based on the findings results. Initial results show that port efficiency (0.4352), port digitalization (0.3435) and port resilience (0.2213) are the main criteria for the establishing of the modelling. While port community system (0.1486) is the first sub-criterion, marine operation, terminal operation and hinterland operation (0.1451) are the second sub-criterion, artificial intelligence (0.1160) is the third sub-criterion, among others. The establishment of seaport continuity modelling can minimize the negative impacts for future pandemics and strengthen seaport capabilities in times of uncertainty.

1. Introduction

The SARS-CoV-2 virus caused the Coronavirus Disease 2019 (Covid-19) pandemic in the year of 2019 (Lunor et al., 2023). Most of the patients encountered mild to moderate respiratory sickness and could recover through their own autoimmune system. Some patients however, may become seriously ill and need special treatment, e.g. older adults and those with underlying medical conditions were more likely to suffer severe disease. Everyone at any age may be affected by the Coronavirus and become serious or die. The best way to prevent the spread of Coronavirus is to be aware of distance restrictions, wear a mask, wash hands with soap and use alcohol-based hand sanitizers to protect ourselves. Currently, vaccinations are available to prevent infection or reduce the risk of severe disease.

Travel restrictions have been lifted and most of the countries are actively exploring tourism markets to stimulate economic development. The pandemic seems to be over, but it also seems to be co-existing with humanity. Will there be another pandemic in the future? Before answering this question, let's look at the past pandemics that occurred throughout history.

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Around 1350, a plague disease swept across Europe. The plague reduced Europe's population by one-third and killed tens of millions of people. It was a serious illness caused by the bacteria Yersinia pestis. Because it causes tissue blackening and necrosis, the plague is also known as “Black Death”. Historians believe that many Europe countries began to move towards a modern economic model with dominance from Western Europe after the plague (BBC News, 2021).

Europe colonized America in the late 15th century. European colonists brought various deadly diseases to the Native Americans, whereas Native Americans had no resistance to these diseases, resulting in many deaths. The large number of deaths also had an impact on the climate at the time. A dramatic increase of forest conversion to pasture led to a decrease of carbon dioxide in the atmosphere and this caused a drop of temperatures around the world. Many volcanic eruptions caused an abundance of smoke and the decrease in solar activity pushed the earth into the "Little Ice Age". The consequences were severe, with the world experiencing food declines and famine. (BBC News, 2021).

China's Ming Dynasty lasted for three centuries. Its politics and culture influenced large areas of East Asia. The plague occurred in the late Ming Dynasty. In 1641, plague broke out in northern China killing many people. Nearly 60 % of the residents of Jingdu died of the plague. Unfortunately, drought and locusts occurred at the same time in North China, resulting in crop failure. The plagues in the late Ming Dynasty most likely included plague and malaria. One of the reasons for the destruction of the Ming Dynasty are famine and plague (BBC News, 2021).

The outbreak of Haitian yellow fever in North America resulted in the loss of French colonial power and the rise of the United States of America. In the 18^{th} century, Napoleon decided to send troops to Haiti to suppress the rebellion and regain colonial power. Tens of thousands of French troops landed in Haiti and were invincible on the battlefield. At this time, yellow fever broke out among the French at Haiti and caused tens of thousands of French to die during the pandemic. In the end, only 3,000 French returned to France. Yellow fever originated from Africa and Europeans had no immunity to it. After Haiti was defeated by the plague, Napoleon not only gave up Haiti, but also gave up his colonial ambitions in the continent of North America (BBC News, 2021).

In the 19^{th} century, rinderpest disease broke out in Africa which accelerated the expansion of European colonialism in Africa. The rinderpest virus killed large numbers of cattle in Africa between 1888 and 1897. It resulted in famine and serious social problems among African society. Consequently, European countries took the opportunity to establish their colonial power in Africa. (BBC News, 2021).

The influenza pandemic began at the end of World War I and caused many people to die. It has been called the deadliest pandemic. Influenza killed 40 to 50 x 10^6 people worldwide from 1918 to 1920 and infected more than one-third of the global population at that time. The influenza virus was never truly eliminated, but the influenza strain H1N1 gradually faded and became a regular seasonal influenza that continues today. Since then, many new pandemic strains have had echoes of H1N1, such as avian or swine flu viruses, which have spliced together to create new pandemic strains. They broke out in 1957, 1968 and 2009. The influenza pandemic that was reported in Spain was called the "mother of all pandemics" due to every major influenza outbreak always having a trace of the virus. Genetic analysis showed that “avian flu” that came from bird species was a variant of "Spanish flu" known to humans before 1918, had become an entirely new strain of the virus (BBC News, 2022).

Melting glaciers caused by climate change results in more uncertainty. Glaciers have blocked ancient viruses under the ice. Global warming has caused these viruses to appear again (European Space Agency, 2021). Recent research and analysis has found that many viruses previously frozen for long periods of time have resurfaced due to the melting of glaciers and have infected surrounding wild animals. There are many unknown ancient viruses in glaciers, which may cause uncertainty and danger for the Arctic ecosystem and may even form the next wave of pandemic that will be difficult to control in the future. Lake Hazen in Canada is one of the largest freshwater lakes in the Arctic region. The latest research found that ancient viruses inside the glacier have infected wild animals, raising concerns about whether the next wave of pandemic will be caused by cross-infection between humans and animals. The report points out that global temperatures have increased, causing ice in the polar circle to begin to melt. As a result, the viruses and bacteria that were originally frozen in the lake water will reawaken. Another research points out that viruses reactivated from Siberian permafrost still can be infectious, even after 30,000 years. The research also warned that as temperatures rise and glaciers gradually melt, the chances of organisms being exposed to the virus are increasing and the possibility of the next wave of pandemic is also increasing (CTEAM, 2023).

History has highlighted that pandemics will not completely end and may break out in another form in the future. People cannot stay and wait for history to repeat again. People should learn to cope with viruses based on experience and at the same time build a certain degree of resistance to the virus, both in terms of health and economics. History has also pointed out that there is a very close connection between animals, humans and the environment, and if one of them changes, the rest will too. The pandemic caused economic losses and suffering; people should learn from experience how to respond quickly to reduce the impact of a pandemic if it happens again in the future.

The maritime industry occupies a very important position in the field of transportation and even in the development of the national economy. It is one of the important pillars of the economy. About 90% of the world's cargoes are transported by sea. Seaports are the backbone of economies of all sizes. Imports, exports and transhipment cargoes are transported through terminals. They have been faced with trouble during the Covid-19 pandemic. During the pandemic, seaports implemented strict control measures, such as increasing quarantine procedures for crew members, prohibiting ships from entering and berthing, and even closing some affected seaports. As a result, the seaports faced problems such as insufficient manpower, logistics paralysis and damaged goods. People should learn from these lessons and prepare contingency measures for future pandemics. Public's reaction to the pandemic remains focused on the present, and presently, the harbour has not taken steps to prepare for possible future outbreaks. Proposing seaport continuity modelling for future pandemics aims to address this gap.

2. Methodology

Every pandemic has impacts on society, while COVID-19 brings thoughts to society and industry. Will we need to change our business and operating manners? How do we survive and maintain operations if a pandemic comes back again? What type of business model is most suitable to operate? To answer these questions, an extensive survey and research activities were carried out to determine criteria and priority dominant criteria. Following a thorough review study and validation via pilot testing, this study established three main criteria and nine sub-criteria. These are detailed in Table 1, along with descriptions for each criterion.

Table 1: Descriptions for each criterion

No	Criterion	Description
1	Port digitalization	Port digitalization involves the transformation of port operations into digital processes.
2	Port efficiency	Port efficiency refers to the operational effectiveness of a port, particularly in terms of maximizing output or achieving a specific output while utilizing limited resources.
3	Port resilience	Port resilience is characterized by the ability to sustain satisfactory service levels despite disruptions.
4	Digital twin	A digital twin serves as a comprehensive portrayal of the entire port within the digital realm, encompassing all physical components, processes, connections, and interactions among stakeholders and activities.
5	Artificial intelligence	Artificial intelligence refers to machines, particularly computer systems, simulating human intellectual functions.
6	Port community system	Port Community System, an open electronic platform, connects the distinct databases and systems of different businesses and organizations.
7	Marine operation	To aid in navigation when approaching and manoeuvring within the port, also known as the port's physical capacity to support ship operations, encompassing services such as pilotage, wharfage, and mooring.
8	Terminal operation	Port terminals can be categorized based on the types of cargoes they handle, which in turn determine the purpose and function of the port. terminals, and container terminals.
9	Hinterland operation	Hinterland operations involve connectivity, which is characterized by three key metrics: the linkage between inland facilities and seaports, the range of available transport options, and the capacity of those options.
10	Absorptive capacity	The capacity of a port or terminal to withstand a disruption using its current infrastructure and services, all while upholding the same level of service.
11	Adaptive capacity	Adaptive capacity refers to a port's ability to adjust its operations and management either before or during a disruption.
12	Restorative capacity	Restorative capacity refers to a port's ability to recover from a disruption and return to its standard level of service.

Eight experts were selected from related maritime and education industries through a pairwise comparison questionnaire. This research utilized the Analytic Hierarchy Process (AHP) to evaluate the data and identify the most significant criteria. The AHP method was applied for data analysis, where data was input into an Excel template specifically designed for AHP, enabling to identify the priority dominant criteria and assess consistency

ratios (CR). AHP provides a structured framework for crucial decision-making by quantifying criteria and diverse options, and by aligning these elements with the primary objective. This framework streamlines the process of making numerous decisions through evaluating and prioritizing criteria.

3. Seaport continuity modelling development

Table 2 shows the weights of main criterion and local weight of sub-criterion. The results outcome show that port efficiency is the first-priority criteria (0.4352), the second priority criteria is port digitalization (0.3435), and the third priority criteria is port resilience (0.2213). Next, port digitalization has three sub-criterions; these are digital twins, artificial intelligence (AI) and port community system. According to local weight measures, the first-priority sub-criterion is port community system (0,4326), the second priority sub-criterion is AI (0.3378) and the third priority criteria is digital twin (0.2296). Port efficiency has 3 sub-criterions, and their local weight score is the same (0.3333). Port resilience has 3 sub-criterions, whereas adaptive capacity and restorative capacity scored the same value (0.4545) while the last was absorptive capacity (0.0910). A consistency ratio (CR) of 0.1 or lower represents a reasonable degree of consistency (Saaty, 1980). The CR scores for both the main criterion and sub-criterion are below 0.1, indicating their acceptability.

Table 2: Weights of main criterion and local weight of sub-criterion

Main Criterion	Weights of Main Criterion （Ranking Order）	Sub-Criterion	Local Weight (Ranking Order)
Port Digitalization	0.3435 (2)	Digital Twin	0.2296 (5)
		Artificial Intelligence (AI)	0.3378 (3)
		Port Community System	0.4326 (1)
		CR: 0.0044	
Port Efficiency	0.4352 (1)	Marine Operation	0.3333 (2)
		Terminal Operation	0.3333 (2)
		Hinterland Operation	0.3333 (2)
		CR: 0.0000	
Port Resilience	0.2213 (3)	Absorptive Capacity	0.0910 (6)
		Adaptive Capacity	0.4545 (4)
		Restorative Capacity	0.4545 (4)
CR: 0.0019		CR: 0.0000	

Table 2 displays ranking order of sub-criterions based on global weight results. The results show that the first-priority sub-criterion is port community system (0.1486). The second sub-criterion score is marine operation, terminal operation and hinterland operation, they scored the same global weight of 0.1452. Artificial Intelligence (AI) scored number three, 0.1160. The fourth priority sub-criterion by score are adaptive capacity and restorative capacity, both with 0.1006. Digital twin scored fifth, 0.0789. Absorptive capacity scored 0.0200. The consistency ratio (CR) values are below 0.1, there are acceptable (Saaty, 1980).

Tae et al. (2015) emphasized that seaports are very important for economic development in a nation. They also highlighted that Malaysian seaports are among the busiest and most important for world trade. The pandemic disaster impacted shipping trips and seaport (Mańkowska et al., 2021). Seaports faced a rapid decline in cargo throughput resulting in lower activity in the supply chain (Notteboom et al., 2021). Intentionally, seaport continuity modelling is proposed to minimize the impacts of the uncertainty in the future. In line with results from Table 2, a seaport continuity modelling is developed and displayed in Figure 1.

Port digitalization is crucial for operation continuity during a pandemic due to many workers who work from home. Port digitalization allows them to get in touch no matter where they are, regardless of them being management staff or non-management staff. Seaport digitalization can facilitate port operations. It also assists in identifying and implementing best practices across ports (Paulauskas et al., 2021). The digitization of seaports is important to create effective digital systems and improve port operations during the pandemic. Especially during the epidemic, it is necessary to work from home, which will effectively establish connections and monitoring operations between various departments.

Port efficiency is vital in supply chain connection. A seaport is an interchanging point between the sea and land. Import cargoes are carried by ship and discharged at seaports and then moved to the next station by rail or road or sea. Cargo may be carried forward by air if necessary. Export cargoes follow the reverse procedure. Lee and

Song (2020) emphasized port efficiency as a key factor in maritime trade. Port efficiency encompasses the time it takes for ships to berth, load and unload cargo, customs clearance time and costs, compliance with regulations and inland transport connections. Notteboom et al. (2021) stressed that effective coordination and communication between hinterland transport providers and all stakeholders along the logistics chain can reduce transport costs and time, thereby increasing the overall efficiency of port operations. Port efficiency also encompasses shipping, terminal and hinterland. These factors are interrelated and are affected by seaport governance, infrastructure, technology (Buics and Prayogo, 2023) and regulations.

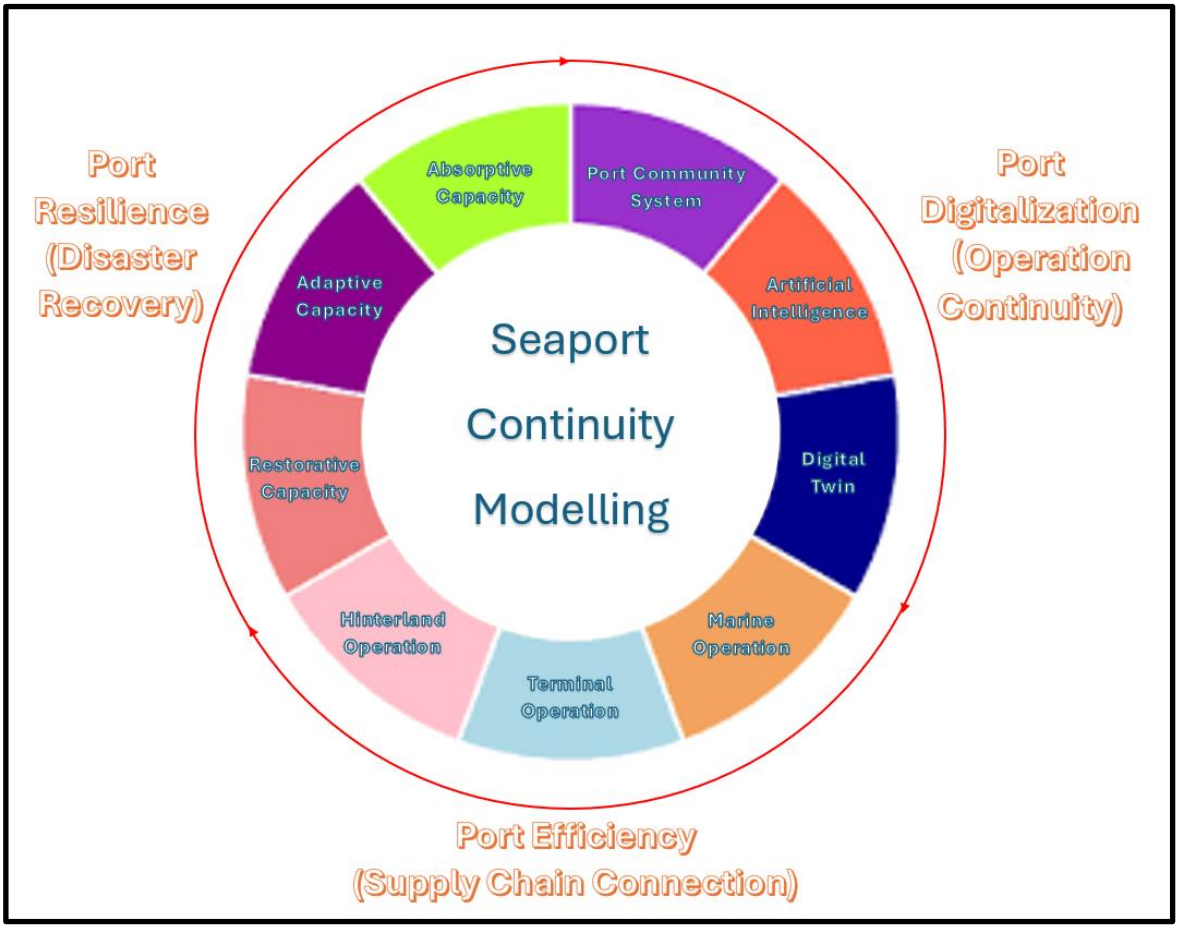

Figure 1: Seaport continuity modelling

Port resilience is important in disaster recovery. Seaports face distress during pandemics. Resilience enables them to resist difficulties and regain vitality within critical periods. Port authorities need to focus on pandemic control and follow government law and regulations, at the same time they also need to ensure the seaport operation and performance is maintained. Port resilience plays an important role in mitigating supply chain disruptions (Wendler-Bosco and Nicholson, 2017). Port resilience refers to the vulnerability of the system and the ability to return to adequate service levels within a reasonable time after a disruption (Kurapati et al., 2015). Nair et al. (2010) also highlighted port resilience can quickly restore the entire supply chain after a disruption. He stressed that port resilience can be improved by addressing vulnerabilities and improving the system's rapid recovery ability from disruptions. This study focuses on both pandemic prevention and control and port productivity, and actively cooperating with stakeholders along the logistics chain to ensure smooth and orderly seaport operations.

4. Conclusions

This study aims to generate seaport continuity modelling that would be effective of a pandemic disaster were to happen again in the future. History from the past has pointed out that pandemics will not end, and it they will happen again and again. Preparedness for the next pandemic is crucial in the sustainability and practicability of seaport operation and management. There are three main components in modelling: port digitalization, port

efficiency and port resilience. Each of the main components has three sub-components. Port digitalization focuses on port community system, artificial intelligence and digital twin. Port efficiency emphasizes marine operation, terminal operation and hinterland operation. Port resilience highlights restorative capacity, adaptive capacity and absorptive capacity. This study stressed on Malaysian Seaports only. It focuses on priority main components and sub-components for the development of seaport continuity modelling. When industry, society and government unite to actively endorse seaport continuity modeling and confront risks and challenges directly, it can uphold its role in fostering economic growth during future pandemics. This ensures that all members of society can access the advantages offered by this model.

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