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CS 8803 – Critical Infrastructure Security and Resilience
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Security & Resilience of Shipping Container Infrastructure in Maritime Trade

1. Introduction & Background

The global container shipping infrastructure is the backbone of the world's supply chain network and directly affects every other critical infrastructure. It is a complex and expansive network that connects manufacturers, suppliers, and consumers from all corners of the globe. The shipping network is critical to the movement of goods from one point to another, and it has played a crucial role in the growth of international trade over the past century. Disruptions in the movement of freight containers can have debilitating impacts on a nation's security and well-being.

History:

The rise of globalization in the twentieth century saw the emergence of international trade as a prevalent economic activity. With the growing demand for goods, there was a need for a more efficient way to transport them across borders. The introduction of shipping containers revolutionized the way goods were transported, making trade more seamless and cost-effective. In 2022, the International Monetary Fund Security & Resilience of Shipping Container Infrastructure in Maritime Trade that 80% of the world's traded goods were moved by sea, with shipping containers accounting for the majority of that transportation.

Invented in the 1950s by the American businessman, Malcolm McLean, the shipping container transformed the way goods were packaged and shipped. Before the standardization of shipping containers, each manufacturer had different dimensions and handling facilities, making it difficult to load and unload containers. However, in 1961, all this changed with the standardization of shipping containers. Most containers are 20 ft or 40 ft long and 8 feet wide. Since then, the infrastructure that supports the handling of shipping containers has also been standardized, leading to a dramatic reduction in shipping costs and a significant expansion of maritime trade in many countries.

The standardization of shipping containers has brought about numerous benefits to the global economy. It has made the transportation of goods more efficient, cost-effective, and

reliable. Shipping containers are designed to be stackable, which means that they can be easily loaded onto ships quickly, thereby reducing the time and cost of transportation. Because of this, manufacturers have been able to scale up production, consumers have experienced lower prices for goods, and globalization has been accelerated.

Journey of a Shipping Container:

The shipping container infrastructure includes a wide array of port terminal facilities that play a crucial role in the movement of goods around the world. The infrastructure includes berths, cargo-handling equipment, and storage facilities.

Berths are allocated locations in a port where ships are moored for loading and unloading cargo. They are designed to accommodate different types and sizes of vessels and are equipped with a range of facilities, including cranes, forklifts, and other cargo-handling equipment. They are operated by trained professionals who work around the clock to ensure that cargo is moved efficiently and safely.

Ports also have storage facilities, such as warehouses and storage yards, where containers are stored. The storage facilities are also used to consolidate and deconsolidate cargo, which involves combining or separating shipments from different suppliers or destinations. The empty containers are stored in the Empty Container Depot.

The process of moving cargo from one point to another begins at the Empty Container Depot, where an empty container is fixed onto a truck chassis and taken to the supplier. The container is then loaded with goods, sealed, and taken back to the port's storage area. From there, the containers are loaded onto ships using cranes, and the ship carries the container to the destination port.

The journey from one port to another can take several weeks, depending on the distance and the speed of the ship. For example, it can take between two weeks and a month for a ship to sail from the port of Shanghai to the port of Los Angeles. Once the ship arrives at the destination port, the containers are unloaded and can be transported inland via railroads or trucks.

Resilience:

Rodin defines resilience as “the capacity of any entity to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience” [???]. Disruptions in a port can have far-reaching consequences for the global economy. Even a short-term disruption can cause delays and increased costs for businesses and consumers. Historically, the shipping container network has demonstrated a high degree of resilience in its ability to effectively manage disruptions.

Prior to the onset of the Covid-19 pandemic, disruptions in port operations were largely confined to local areas. In such instances, vessels were commonly held offshore or diverted to alternative ports. However, with the emergence of the pandemic, global disruptions to maritime freight transportation were encountered. The world’s 25 largest container ports handled approximately 50% of shipping container traffic and the pandemic was the first time all these chokepoints were simultaneously disrupted, testing the infrastructure to an extent never seen before.

Research suggests that a significant number of the world's largest companies, as much as 94% of the Fortune 1000, maintained a primary supplier located in the Wuhan region, contributing to a high level of dependence on Just-in-Time manufacturing. This manufacturing model, which operates within a pull supply chain structure, involves companies minimizing inventory holdings and producing goods only as orders are placed. Recently, corporations have considered transitioning towards a neoliberal approach that enables them to swiftly shift production to alternate countries in the event of emergency situations. However, this method may cause job losses and increased job uncertainty in regions affected by supply chain disruptions.

Researchers investigating the case of the Port of Los Angeles noted that traffic experienced a steep decline during the early stages of the pandemic, largely due to the imposition of stringent lockdown measures in China. Additionally, consumer patterns underwent a shift as demand for household goods and electronics rose while the demand for services declined. The subsequent resumption of manufacturing activities in China during mid-2022 resulted in a substantial increase in cargo volume at the Port of Los Angeles. However, while traffic at the port had declined by approximately 1% compared to 2019, most of the traffic occurred in the latter part of the year. As a result, severe congestion and a

scarcity of empty containers and chassis developed, contributing to a worldwide shortage of shipping containers.

2. Non-Malicious Threats

Though the concept of a “non-malicious” threat might give the impression that it is not associated with significant damage, the categorization is meant to group incidents that lack any intent to cause harm. These threats do not occur with any objective, but they still have the potential to compromise the entire infrastructure. Disruptions frequently arise from unintended or unexpected events such as human error, crew complications, or natural disasters.

Climate & Natural Disasters:

Natural disasters are largely caused by forces beyond human control, but by developing effective response and mitigation plans, their effects can be lowered. Events such as storms, floods, and wildfires can disrupt loading operations and harm port infrastructure, an issue that is becoming more prevalent due to their increased frequency and severity. Port closures can force ships to take detours or remain idle, extending their travel time and increasing costs. Extreme weather conditions such as cyclones can obstruct shipping lanes, resulting in delays, vessel damage, lost cargo, and shipwrecks.

Several major hurricanes ravaged the Caribbean and southeast United States in 2017, including Harvey, Irma, and Maria, which caused major damage to ports and other shipping infrastructure. In September 2017, Hurricane Maria hit Puerto Rico’s Port of San Juan, one of the major centers for container shipping. It was severely damaged because of the storm, causing it to be closed for several days and forcing ships to be rerouted elsewhere, such as the ports of Miami and Jacksonville in Florida. The issues with the port were devastating for the entire island, as it serves as one of the primary points of entry and distribution for essential goods.

The scale and unpredictability of natural disasters make it hard to protect the shipping container infrastructure. However, with advance warnings for floods and cyclones, incoming ships can be safely rerouted, and logistics systems can manage traffic in a more streamlined

fashion. Improving weather prediction models and investing in ocean sensor technology can help businesses and governments prepare for emergencies. Moreover, the resilience of port infrastructure can be improved through redundancy. Research has revealed that wharves, cranes, and electrical equipment are among the most vulnerable components of ports when it comes to natural hazards. Having a stockpile of backups for such equipment can prove to be beneficial. A notable example is the 1989 earthquake that affected the Port of Oakland, which was able to maintain operations by redirecting traffic from damaged to undamaged terminals.

As Rodin states, resilience isn't just about recovering from shocks and stresses; an infrastructure also needs to adapt over time to deal with changes. Scientists have found that climate change is causing extreme weather conditions to become more frequent and severe as time passes, meaning that our prevention and response measures will have to evolve as well.

Crew & Staff Issues:

Though this paper refers to ships going from one place to another, and containers being loaded or unloaded, it is important to remember that there is a human element in all the components of this infrastructure. The people involved in this industry are faced with unique challenges and hazards that constantly make headlines. For example, many crew members have become stuck in legal limbo, contractually not allowed to leave ships that were abandoned or seized by authorities, turning their workplace into a prison. The nature of the work itself also takes a toll, requiring long voyages across dangerous waters with lackluster breaks or connections to the rest of the world.

While at sea, crew members might experience prolonged periods of loneliness, family separation, and exposure to harsh weather. Stress and fatigue can bring on mental health problems such as depression or anxiety. Additionally, crew members frequently come from diverse cultural and linguistic backgrounds, creating communication and interpersonal barriers on board. The Covid-19 pandemic has exacerbated these issues, with crew members being stranded at sea for extended periods due to travel restrictions and quarantine measures. The increased rates of anxiety, depression, and suicide among crew members have raised concerns about the psychological well-being of seafarers.

The harsh working conditions of the industry have made it hard to attract new workers and discontent among current staff can lead to contract disputes and strikes. Recent news reports indicate that the twin ports of Los Angeles and Long Beach were compelled to shut

down on April 6, 2023, due to labor shortages. While the local union has attributed this situation to their members' attendance at the monthly meeting and observance of Good Friday, there are concerns regarding the underlying motives, given that negotiations pertaining to increased wages and automation in the new contract are currently ongoing. It is believed that there have been repeated disruptions since the last contract expired in June.

The issue of labor shortages and strikes is not limited to the ports of the United States alone. Reports have emerged of congestion at several ports in European countries such as the United Kingdom, Netherlands, and Germany, primarily due to labor actions. To mitigate the risk of labor-related disruptions, it is essential to ensure that terminal workers receive fair compensation and are provided with reasonable working hours. Another approach that can be adopted is the establishment of a labor pool, whereby laborers can be allocated to ports based on demand during periods of increased incoming cargo. Such measures can go a long way in promoting stability and efficiency within the global shipping industry.

Human Error:

The shipping container industry is a dynamic, complex system with many stakeholders, including cargo owners, truckers, dock workers, vessel operators, and terminal operators. Processing containers involves several steps, from preparation and coordination to execution and verification. All parties involved, as well as the economy as a whole, could suffer from any errors made at any of these stages. The need for increased attention and caution in the shipping industry has been highlighted by many prior incidents. An Allianz Global Corporate & Specialty report estimated that 75% to 96% of marine casualties involve human error.

The Suez Canal, a man-made waterway that connects the Mediterranean Sea to the Red Sea, is an essential link in the supply chain for a wide range of goods, and it is estimated that 12% of global trade goes through it annually. The 400-meter-long Ever Given container ship got stuck in one of the narrowest parts of the Suez Canal, blocking the waterway. The blockage caused by the ship's grounding created congestion in both directions, trapping hundreds of ships in the canal until it reopened. The disruption delayed the delivery of goods and raw materials and had an impact on many different industries, including oil, manufacturing, agriculture, and retail. Additionally, the cost of freight shipping saw sudden growth of more than 300% in the days after the blockage. Investigations are ongoing to

determine what caused the incident. According to preliminary reports, the grounding may have been caused by strong winds and a sandstorm. However, some have suggested that human error could have contributed, especially considering that no other ships veered in the canal that day. This incident lasted 6 days and 7 hours and prevented an estimated \$9.6 billion worth of trade.

The Ever Given blockage serves as a stark reminder of the drawbacks associated with the increasing sizes of container ships. While these ships offer significant economies of scale, there are also notable risks involved. Fully loaded large container vessels are typically less seaworthy and more prone to capsize, particularly when containers are stacked to excessive heights, which renders them more susceptible to strong winds. Additionally, there are allegations that Ever Given was traveling at an excessive speed and that its crew lacked sufficient experience. The implementation of proper crew training protocols and more strict regulations can play an instrumental role in mitigating risk.

3. Malicious Threats

The shipping container industry is also vulnerable to malicious threats, which are carried out by actors that have the intent to harm or damage infrastructure, usually for monetary or political gain.

Cyberattacks:

As with most infrastructures in the modern world, the shipping container network has become increasingly digitized. Logistics and accounting systems rely on computer algorithms, important communications are transferred through the Internet, and even the vessels themselves are outfitted with digital systems to accomplish critical tasks, such as navigation. Unfortunately, this opens up the door to cybersecurity attacks, which have the ability to cause massive problems in the real world without requiring significant resources or geographical proximity to the target.

An impactful cyberattack that devastated the shipping industry occurred in the summer of 2017. The malware, commonly referred to as NotPetya, was spread through a compromised software update for a popular Ukrainian tax preparation program, M.E.Doc. NotPetya was designed to encrypt and destroy data on infected computers running Windows operating systems, making them unusable until a ransom payment was made through

cryptocurrency. However, the changes made by the malware were intentionally irreversible. Additionally, ransomware typically provides each victim with a unique wallet address, helping the attackers track which ransoms have been paid, yet in this case, only a single and fixed wallet. These two factors led experts to believe the objective was merely sabotage. According to official reports, the suspected attackers were a Russian military intelligence hacking group that aimed to disrupt Ukraine's industries and infrastructure. Since the software was used by "nearly anyone who files taxes or does business" in Ukraine, it affected a wide range of organizations, from financial institutions to airports, and even spread to other countries [1]. The total damage caused by the attack was estimated to be more than \$10 billion.

Unfortunately, one of the most affected businesses was Maersk, a Danish shipping company that was the world's largest container ship operator from 1996 to 2022 and has an annual revenue of over \$100 billion. The malware infection on Maersk's IT systems managed to cripple its communication network, lock employees out of their work computers, and shut down ports terminals operated by the company, even as far as New Jersey. It took months for the company to recover from the attack and it was estimated to have lost up to \$300 million in revenue. A concerning detail about this event was that the attack is generally considered to have been preventable since Microsoft had already published a security update months before the attack that addressed the vulnerability NotPetya had exploited.

The industry seems determined to continue increasing its reliance on digital systems, likely due to the lucrative optimization opportunities and the improved scalability of operations, so it is important to consider cybersecurity defense a priority. For the most part, the security of the shipping container infrastructure could be improved by implementing generic safety measures. These include requiring timely software security updates and patches, creating threat intelligence teams to monitor cyber activity and cooperate with authorities, segmenting critical systems to mitigate the spread of malware, and having backup analog systems for critical tasks.

Physical Attacks:

A more concrete threat to the industry is malicious actors physically attacking or capturing a shipping vessel. In the past, attacks on naval supply lines were common in times of war because they could impair an enemy's military operations. For example, during

World War II, German U-boats repeatedly attacked U.S. merchant ships in the Atlantic, fearing that they were transporting supplies to Great Britain. However, the evolution of modern warfare and the increasingly interdependent global economy have made such incidents rarer.

Recently, the primary manifestation of this threat has been maritime piracy. The objective of the pirates is usually monetary gain, either through theft, extortion, or ransom. An infamous hotspot for these situations is the coast of Somalia. In April 2009, four armed Somali pirates boarded the Maersk Alabama container ship, which was carrying food aid to Mombasa, Kenya. The pirates took the ship's captain, Richard Phillips, hostage and demanded a ransom in exchange for his release. The U.S. Navy responded to the situation by sending warships to the area, and negotiations continued for several days. On April 12, 2009, the U.S. Navy SEALs launched a successful rescue operation, killing three of the pirates and freeing Captain Phillips. The fourth pirate was taken into custody and later charged and convicted in the United States.

The incident received widespread media coverage and highlighted the ongoing problem of piracy in the waters off the coast of Somalia. It also led to increased calls for greater international cooperation in addressing the issue, including increased naval patrols and efforts to improve the economic conditions in Somalia that drive piracy. However, experts say that government efforts have been too focused on the coast of Somalia, allowing piracy to rise in other regions, such as Nigeria and Guinea. Companies have also tried to tackle this problem on their own, with many cargo ships now hiring security details, a practice that used to be uncommon due to the importance of minimizing the onboard crew. This has generally proved to be effective, as small pirate groups seem unwilling to engage higher-risk targets. For example, security forces of the Maersk Alabama, which was renamed Tygra after being acquired by a different company, successfully repelled four attempted hijackings since the Spring 2009 incident through returned fire or warning shots. However, ships usually only have a few guards onboard, meaning that they can be overwhelmed by large and organized attacks, such as those potentially being carried out by nation-states or terrorist organizations.

Embargoes & Blockades:

Embargoes and blockades can have significant effects on the shipping container industry, which relies heavily on international trade and the free flow of goods across borders. When a country imposes an embargo on another country, it typically prohibits or restricts trade between the two nations. This can result in a significant reduction in the volume of goods being shipped, particularly if the embargo affects key industries or products. Similarly, blockades can have a significant impact on shipping container traffic, particularly if they affect key trade routes or ports. A blockade can prevent ships from entering or leaving a port, disrupting the flow of goods and causing significant delays and losses for shipping companies.

The impact of embargoes and blockades on the shipping container industry can be significant, with many companies facing reduced revenues and increased costs as a result. Shipping companies may be forced to re-route their vessels, resulting in longer transit times and increased fuel costs. They may also be forced to cancel or delay shipments, resulting in lost business and reduced profits. The consequences of the lack of shipping routes can be severe for areas that are reliant on importing key commodities. For example, the recent Russian blockade of Ukrainian ports has hampered the transportation of grain out of Ukraine, which is one of the world's main producers of the resource, increasing food insecurity in certain parts of the world.

Overall, these measures can have far-reaching effects on the shipping container industry and the entire supply chain infrastructure, highlighting the importance of stable trade relations and the need for effective diplomatic solutions to disputes between nations. Moreover, the industry can become more resilient to the whims of global politics through international agreements that guarantee the movement of ships designated as carrying critical goods, such as food and medicine.

4. Conclusion

Countries around the world have become increasingly connected, specialized, and interdependent. As a consequence, there has never been a greater need to transport goods and materials, from grain to high-end technology, with shipping containers seemingly leading the charge on this issue. However, our reliance on this infrastructure has made it critical to guarantee its smooth and continuous operation. Disruptions can cause disastrous crises, such

as famine and medicine shortages. The Covid-19 pandemic has showcased how important the security and resilience of the shipping container infrastructure are to our lives and the global economy. Hopefully, some of the measures suggested in this paper will be implemented or improved in the future to help the backbone of the world's supply chain stay afloat.

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