# Prospectus

**Shore Power Technology at the Port of Virginia**
(Technical Topic)

**Actor-Network Theory and Power Grid Resilience to Environmental Shocks**
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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## Introduction

Seaports strengthen the national economy and generate employment by shipping U.S. exports and delivering vital goods and services to consumers. In 2018 alone, marine cargo activities at U.S. seaports accounted for 26 percent of the U.S. economy, generating nearly $5.4 trillion in total economic activity (Martin Associates, 2018). As the world moves towards an era of increased globalization of trade, total cargo handled at container ports is expected to grow. This growth in cargo handled is evidenced at the Port of Virginia – the $9^{th}$ largest port in the U.S. by cargo volume – where total containers handled increased by 14.5% from 2015 to 2019 (The Port of Virginia, 2018). This expanding volume of containerized cargo, while driving economic growth and strengthening international relations, has also generated increasing concern about the environmental effects of port operations.

Ocean going vessels including cruise, container, and refrigeration can require significant power while docked at berth and waiting for the loading / unloading processes to finish. Currently, most vessels utilize diesel auxiliary engines to generate this power, and emissions from these vessels can be significant contributors to air pollution. According to the United States Environmental Protection Agency, exposure to air pollution associated with such emissions can contribute to significant health problems including premature mortality, increased hospital admissions for heart and lung disease, increased cancer risk, and increased respiratory symptoms (EPA, 2017). The technical solution to this issue is to implement shore power technology at the Port of Virginia which will allow these vessels to "plug in" to the local electricity grid and turn off their auxiliary diesel engines while docked at berth.

However, a technical solution alone is insufficient to resolve this problem fully because it does not address the environmental, political, and economic factors that influence global adoption of shore power among all stakeholders within the maritime commerce supply chain. For example, the San Pedro Bay ports of Los Angeles and Long Beach have both implemented the necessary shore-side infrastructure to support the utilization of shore power; however, they still face problems regarding its implementation. One such problem is the relative cost of diesel fuel compared to shore-side electricity, which may disincentivize shipping companies to retrofit their vessels to make use of the shore power technology if diesel prices are low. Another such problem is the threat of environmental shocks, such as heat waves or earthquakes, which can strain demand for grid energy and in turn lead to the suspension of shore power. By failing to consider these economic and environmental aspects involved, the proposed technical solution of shore power would effectively be nullified, and vessels would continue pumping pollutants into the air.

To effectively minimize the adverse environmental effects of vessels docked at berth, both technological and social factors must be considered. Below, I outline a technical process for implementing shore power technology at the Port of Virginia and evaluating its economic feasibility. I also use actor-network theory to study the maritime commerce supply chain as a network and analyze how both human and non-human actors must interact to support a future in which shore power can be successfully implemented and utilized.

## Technical Problem

Ports are an essential component of the United States economy, serving as gateways for moving freight across the country and around the world. Globalization of trade has led to yearly growth in port container throughput, and as a result transportation infrastructure has adapted; ships and vessels are increasing in size. The U.S. Army Corps of Engineers estimates that bigger Post-Panamax size ships that currently call at U.S. ports will dominate world trade and represent

62% of total container ship capacity by 2030 (U.S. Army Corps of Engineers, 2012). Ports across the U.S. and the world, including the Port of Virginia, are tasked with meeting this increased cargo demand while minimizing their environmental footprint.

Equipment, vehicles, and marine vessels that burn diesel fuel are the primary source of combustion-related emissions at ports. Pollutants released by diesel engines include particulate matter (PM), nitrogen oxides ($NO_X$), carbon dioxide ($CO_2$), sulfur oxides ($SO_X$) and air toxics (EPA, n.d.). Diesel-powered equipment also produces significant greenhouse gas emissions that contribute to climate change (EPA, 2017). Ports are currently undergoing initiatives to reduce their emissions of such pollutants. In the Port of Virginia, for example, 25 diesel cargo carriers were recently replaced by hybrid diesel-electric vehicles in an effort to cut carbon dioxide emissions (Kennedy, 2020). Other initiatives to reduce emissions are along similar lines of replacing existing technologies with newer, more fuel-efficient ones.

However, the largest emitter of pollutants in ports are ocean going vessels, or OGVs, contributing to 52% of PM and 33% of $NO_X$ emissions in ports per year (Diesel Technology Forum, n.d.). By solely focusing on replacing existing port equipment such as drayage trucks, switch locomotives, and gantry cranes with newer, more fuel-efficient technologies, air pollution from the OGVs will continue to be a major problem. Thus, in order to fully address the problem of air pollution in ports, reducing emissions from OGVs is a top priority. As mentioned earlier, vessels and ships that are docked at berth still require power to carry out basic functions, such as lighting, chilling, refrigeration, cooling, heating, pumps, fans, emergency equipment, elevators, and more (Tseng & Pilcher, 2015). The majority of these vessels and ships burn diesel fuel to provide this energy. As a solution to prevent vessel idling and subsequent air pollution, vessels can utilize shore power to plug into the local electricity grid and turn off their auxiliary diesel engines while docked at berth.

The goal of this technical project is to design a shore power technology for the Port of Virginia's Norfolk International Terminal. This shore power technology will connect to energy from the local grid and allow shipping companies to purchase the energy they need to power their OGV operations while docked at berth. I will perform a forecast analysis of future emissions reductions, including PM, $NO_X$, $CO_2$, $SO_X$, to determine the predicted efficacy of the project. Furthermore, I will perform a cost-benefit analysis of implementing such a technology at the Norfolk International Terminal to determine the project's overall economic feasibility. I plan to perform the analysis regarding possible implementation of a shore power technology at the Port of Virginia's Norfolk International Terminal next semester.

**STS Problem**

In 2006, the ports of Long Beach and Los Angeles created the Clean Air Action Plan (CAAP) to reduce port-related air pollution and make strides towards a zero-emission future. Since then, the ports constructed the landside infrastructure to make shore power possible at all of their terminals; the Port of Long Beach alone completed more than $185 million of such infrastructure upgrades (The Port of Long Beach, n.d.). Overall, the project has been successful, but critics today are dubious about shore power's widespread adoption.

Many people today argue that adoption of shore power is vulnerable due to certain economic constraints. According to EPA's 2017 report, Shore Power Technology Assessment at U.S. Ports, shipping lines are less likely to use shore power rather than diesel fuel due to "high up-front vessel commissioning costs associated with shore power, the cost of purchasing the electricity while in port, and lower cost options available such as Advanced Maritime Emission

Control (AMEC) systems that scrub exhaust gases and do not require power retrofits" (EPA, 2017). In addition, a report by the European Sea Ports Organization (ESPO) noted taxation on electricity as a barrier for shipping lines to retrofit their vessels. Currently, ships that plug into shore power at ports in the EU must pay taxes on electricity, whereas electricity produced from typical diesel engines is tax-exempt (Sukharenko, 2019).

Both the high costs of retrofitting the vessel and the tax on electricity at EU ports serve as rogue actors in the network of global shore power adoption in the sense that they have the potential to disrupt and break the network. To ensure adoption of shore power, the state of California has enacted legislation to help stabilize the network and mitigate the effects of these rogue actors. The Shore Power Regulation is a California law administered by the California Air Resources Board (CARB) that imposes regulations on vessels docking at California ports. From 2014-2016, 50% of any shipping line's vessel visits to each California port must shut down their auxiliary engines and plug into shore power (The Port of Long Beach, 2014). This number was increased to 70% between 2017-2019 and 80% past 2020. This actor – the California legislation – ensures that shipping lines will retrofit their vessels to make use of the California ports' shore power, else they face financial penalties for not complying with the regulations.

However, these economic constraints are not the only vulnerabilities that can prevent the adoption of shore power. In addition to money, there are environmental factors that need to be considered. For example, an environmental shock such as a heat wave or earthquake can put immense pressure on the demand for grid energy or even shut down parts of the power grid, ultimately resulting in the suspension of shore power. Such environmental factors directly affect the power grid and thus the efficacy of shore power. If we continue to believe that only the aforementioned economic constraints have the potential to prevent shore power adoption, we will never understand the role environmental factors play alongside these economic constraints in preventing global shore power adoption.

I argue that the current network in California is still vulnerable, not just due to these aforementioned economic constraints, but also due to environmental shocks that can strain the demand for power from the grid. Grid power serves as the biggest infrastructure challenge for implementing shore power at ports due to its volatility, both in price and in quantity. To analyze the success of shore power adoption in the face of such environmental shocks and economic constraints, I will use the science, technology, and society (STS) concept of actor-network theory. A key takeaway from actor-network theory is the idea of a network builder who recruits heterogeneous actors to accomplish a goal. In the case of global shore power adoption, both environmental shocks as well as economic constraints serve as heterogeneous actors that must work together to support a future in which shore power can be sustainable. Another main idea in actor-network theory is that human and non-human actors have a semiotic relationship; their identities in the network are defined through their interaction or associations with other actors (Cressman, 2009). In the face of an environmental shock, the power grid is directly affected and therefore the shore power network is affected. Accommodating a future in which shore power can be adopted, then, requires a more resilient and stable power grid, one that can be independent from the effects of environmental shocks. To support my argument, I will analyze evidence from California's recent heat wave in August 2020 which resulted in the suspension of shore power at the ports of LA and Long Beach.

## Conclusion

The technical report will deliver a framework for shore power adoption in the Port of Virginia's Norfolk International Terminal to reduce future diesel emissions. The report will provide forecasted reductions in emissions as a result of shore power's implementation, as well as a cost-benefit analysis to gauge economic feasibility. The STS research paper will seek to provide further insight into the concept of actor-network theory by analyzing the success of the Port of Long Beach and Port of Los Angeles's shore power technology as a result of the associations and interactions between various actors in the maritime commerce supply chain, including power grid resilience to environmental shocks.

The results of the technical report will help to resolve the broad socio-technical issue of how to leverage both technological and human processes to reduce our environmental footprint in ports. The technical report will provide a solution to this problem by providing the technological means by which future emissions can be reduced, whereas the STS paper will provide further insight into the complex interactions and associations between actors to ensure the technology is utilized successfully.

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