OPTIMIZATION OF PORT OF VIRGINIA OPERATIONS THROUGH OBJECT-BASED SIMULATION MODELING

UNDERSTANDING THE EFFECTS OF PORT OF LOS ANGELES'S OPERATIONAL EMISSIONS

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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

The race to becoming carbon neutral is slowly but surely a critical goal for the world. According to Kevin Adler, a business journalist in the fields of energy at S & P Global, electric vehicles could be 45% of all new car sales by 2035; subsequently, electric vehicles could be *100%* of the new vehicle market by 2050 (Adler 2021). The momentum for the switch to electrification is steadily increasing not just for consumers but also for large-scale industries. In terms of this analysis, electrification refers to the use of hydrogen fuel cells and the transition away from diesel as a power source. With goals to "include a 65% reduction in greenhouse gas emissions and operating with 100% renewable energy by 2032", efforts to meet the carbon neutral goal through hybrid and electric vehicles are well underway at the Port of Virginia (Port of Virginia, 2021).

In order to help the Port of Virginia reach its emission goals, I will improve its current system of electric and hybrid port machinery through object-oriented simulation modeling with Simio. However, as the Port of Virginia attempts to become efficient and reduce its carbon emissions, several external factors, ranging from economic to social, influence the electrification of the port. One notable factor would be the incalculable arrival rate of ships at the port; from politics to supply chain issues, the arrival rate of ships is dependent on a slew of social and technical factors. While the rate can be estimated, changes at the port must withstand any arrival rate to ensure that operations run smoothly. Additionally, any changes to the current system have financial constraints that are set by the Virginia Port Authority committee (Dan Hendrickson, personal communication, 2022).

In the following, I will elaborate on how my technical project serves to analyze and optimize the current operations at the Port of Virginia through simulation modeling accompanied by a social analysis of how the Port of Los Angeles affects the surrounding environment and is

affected by it as well. For the technical aspect, I will create several use cases within Simio, an object-based simulation program, in order to understand and identify the optimal balance between hydrogen and electric-based port machinery. I will then apply actor-network theory to my latter, loosely coupled analysis to understand how the Port of Angeles affects the surrounding environment as well as analyze the human and non-human actors of the network that are related to the failure in hazardous emissions at the Port of Angeles. By analyzing both aspects of this project, technical and social, we will be able to understand the true ramifications of the electrification of the Port of Virginia as well as the actors involved in the failure of the Port of Los Angeles.

OPTIMIZING PORT OF VIRGINIA OPERATIONS THROUGH OBJECT-BASED SIMULATION MODELING

The maritime industry, which includes ports such as the Port of Virginia, is on its way to becoming 10% of the world's *total* greenhouse gas emissions (Isbell and Édes, 2021). This number needs to be drastically reduced by using renewable energy options such as switching from diesel to electric, also known as electrification, in order to prevent irreversible damage to our climate. Additionally, the global container trade is forecasted to grow 80% by 2050 (Probst, 2022). It is vital that ports improve their efficiency and decarbonization efforts to meet these demands in a decarbonated and optimized manner. The Port of Virginia has already initiated the process of reducing its emissions footprint but is still looking for methodologies to improve its outlook.

This technical project aims to aid the Port of Virginia in achieving its goal of going carbon neutral by 2040. To do so, my project focuses on the use of simulation modeling via Simio, an object-based simulation program. The use of simulation modeling for ports has grown increasingly popular over the past 54 years as it "promotes sustainable ship-port interfaces"

(Dragovic, 2016). My objectives are to create use cases, via simulation modeling, that utilize current data in order to allow for the understanding of the impact of using an optimal balance of electric and hydrogen machinery at the Port of Virginia. Currently, there are hydrogen, electric, and diesel-powered machinery at the port. Furthermore, examples of port machinery are ship-to-shore cranes, shuttle trucks, rail-mounted gantry cranes, and rubber-tired gantry cranes.

For our technical analysis, I plan to examine a variety of elements that are involved in the electrification of the Port of Virginia. An example of a use case is the optimal number of chargers for electric rail-mounted gantry cranes and the analysis of several varying cases of how the rail-mounted gantry cranes are impacted by the throughput of twenty-foot equivalent unit (TEU or container) in the port.

For further elaboration, a use case within Simio will analyze the impact on the throughput of TEUs in the system after allowing three rail-mounted gantry cranes to charge offline. Comparing the results of this scenario via variables such as TimeInSystem will provide insight into the system's performance after parameter changes. In this particular case, TimeInSystem would be a metric that quantifies how long it takes for a certain amount of TEUs to complete unloading and reach their destination within the port. This use case specifically provides the optimal number of charging hours with consideration for the TEUs throughput, thus saving on costs, reducing emissions, and allowing the port to reach its 2040 goals without reducing efficiency. An example of a use case using Simio can be seen below.

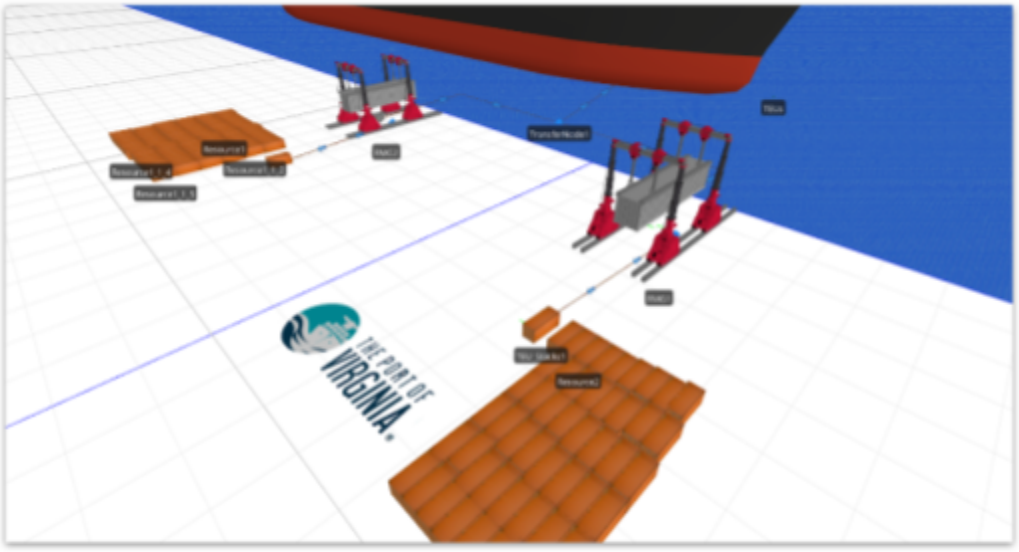

Figure 1. Use case for RMG cranes vs. TEU arrival rate

Examining these scenarios will give the Port of Virginia a comprehensive understanding of the benefit of using a different configuration of electric machinery compared to present parameters.

Our research for our simulations will be derived from research articles on other port systems, the effects of electrification at other ports, trade-off analysis of electrification, utilization data of similar cranes and machinery, et cetera. In addition, meetings with Port of Virginia employees and data received from the Port of Virginia will also be heavily referenced in our simulation to ensure that our models represent the Port of Virginia as accurately as possible. By creating these simulations, this analysis will allow us to understand the environmental impact of the Port of Virginia in a quantifiable manner and thus, allow us to achieve cost-effective electrification of port machinery that also meets the port's carbon-neutral goals. To present our findings, our tentative deliverables will include a final presentation to the Port of Virginia as well as a report and presentation as per the Systems and Information Engineering degree requirements.

UNDERSTANDING PORT OF ANGELES'S OPERATION EMISSIONS EFFECTS ON THE ENVIRONMENT THROUGH ACTOR-NETWORK THEORY

While the size of container ships and trucks will likely not increase due to the limitations of existing infrastructure such as the Suez Canal and the standard width of a highway lane, the need for resources will continually grow (Baraniuk 2022). From increasing population densities in almost every country to the rise in e-commerce, the demand on ports will only increase.

Containers or TEUs are the backbone of the supply chain industry, which is responsible for almost every product that surrounds us; consequently, ports are just as essential in ensuring the delivery of goods to consumers as almost all containers must go through a port first (Friesen, 2021). This relationship between containers and ports is just one of many in the network that influences the Port of Angeles's operations.

For elaboration, an example of a port's effect on surrounding communities can be seen in its current emissions. In a study at the Port of Los Angeles, "Long Beach communities in close proximity to the Port of Los Angeles experience higher rates of asthma, coronary heart disease and depression, compared to other communities" (OECD, 2014). Conducting a sociotechnical analysis of the electrification and optimization of the Port of Angeles through the lens of actor-network theory will not only reveal the actors, both human and non-human, involved in the network but also provide insight into how the port affects surrounding communities and the effects of its electrification on these actors. Moreover, I will be able to understand why this network of heterogeneous actors at the Port failed in that their emissions were so high that they caused harm to the surrounding communities. Specifically, I can investigate which specific actors, if any, threaten the network's stability and ability to perform without causing harm. I argue that a rise in demand due to e-commerce as well labor shortages due to COVID-19 led to

an increase in congestion at the Port of Los Angeles; subsequently, this congestion resulted in an exponential increase in hazardous emissions (Roh, 2022).

As a brief overview, actor-network theory is a sociotechnical approach in which both human and non-human elements (heterogeneous actors) are considered within a network (Cressman, 2009). Actor-network theory serves to quantify relationships between actors not by power, but rather by the strength of the association between them. Furthermore, ANT utilizes the idea that "there are no causes, only effects" when viewing networks of "people, organizations, technologies, nature, politics, and social order(s)" (Cressman, 2009). By understanding the various relationships and actors involved at the Port of Angeles, we can ensure that our efforts in the technical aspect of this project are not in vain.

I plan to examine the effect of corporate policies, politics, disruptive technologies, and community perspectives at Port of Los Angeles. Conversely, I plan to also examine how the Port of Los Angeles affects these elements. An analysis through actor-network theory would serve to shed light on other potential effects and relationships in the port's actor-network system, especially after the port increases its efficiency and capabilities after it improves its operational emissions in order to avoid similar mistakes again.

CONCLUSION

In an effort to increase optimization and decrease emissions, the Port of Virginia has requested the University of Virginia to help achieve its goals. Through the use of simulation modeling with Simio, our team will analyze and offer recommendations for the electrification of their port machinery. This utilization of modeling will allow us to understand the optimal balance between hybrid, diesel, and electric port machinery. Thus, not only will emissions be drastically reduced but also operational costs as well. While our models will have several assumptions and

estimations, our technical deliverables to the port will be valuable in helping their decision-making process. Additionally, evaluating the network that the Port of Los Angeles is connected to will ideally be positively impactful as well as the results of this study can be applied to the similar operations of the Port of Virginia. Understanding the Port of Virginia and the Port of Los Angeles through both a technical and a socio-technical approach will allow us to understand crucial elements that are related to the networks involved and the effect of electrification on operational emissions.

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