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Deep Water Port Investments

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Abstract: Ports are a vital part of the flow of commerce in the United States. US ports are falling behind international competitors when it comes to port upgrades. Therefore, there is an emphasis on upgrading US ports to make them more efficient. The United States Corps of Engineers (USACE) currently relies on a decision process that uses strictly subjective analysis when there are vast amounts of unused data that could be used in the decision process. Due to the subjectivity of their current decision process, USACE needs a more objective model that uses available data to better assess and prioritize port projects. This project used a systematic approach to create a value hierarchy that facilitated the development of the USACE Port Project Priority Model (UP3M). The U3PM allows users to input various port project data which is then used in value functions. These value functions assess the input and calculates the total value for a port project. This assists the decision maker by providing them with an objective way to compare different projects, helping to ensure optimal fund allocation.

Keywords: United State Corps of Engineers (USACE), Systems Thinking, Deep Water Ports, Decision Analysis, Value Modeling, Value Functions

1. Introduction

Ports are an extremely important part of the US economy as they are responsible for connecting billions of dollars worth of foreign commerce to domestic demand. They not only serve as avenues of entry for commerce, but also employ a significant number of people. A single port has a large impact on the US economy as it is the most cost-effective way to import bulk goods, ultimately linking foreign goods to domestic needs. USACE currently relies on the opinions of district and division commanders to allocate funds for port projects. This decision process leads to a potentially inefficient allocation of funds. A multi-objective decision prioritization model that utilizes historical data would bring more objectivity to the decision process and result in more efficient allocation of funds. By using this model, USACE can better assess which project provides the most overall value. The proposed model assesses risk, return on investment and necessity of project to guide a more objective and reasonable allocation of funds.

2. Background

The increasing size of shipping vessels is the driving force behind the need for port upgrades. After widening the Panama Canal, a new class of ships, post-Panamax ships, are able to pass through the canal and access Eastern ports. A decade ago, on average a ship's maximum capacity was 1,140 feet long and had a capacity of 7,700 Twenty-Foot Equivalent Units (TEUs). A TEU is how much cargo a 20-foot container can carry (Vulovic, 1999). Current shipping vessels are closer to 1,400 feet and can carry as much as 18,000 TEUs (Fend, Liam, Zhongzen, 2019).

It is beneficial for US ports to invest in post-Panamax accommodation due to the decrease in cost that larger ships provide. They offer a lower unit transport cost, as larger ships can carry more goods per trip (Guler, 2000). Additionally, 70% of goods destined for the East Coast currently use a land route to cross the US due to East Coast ports being unable to accept large shipping vessels (Morrison, 2012). If East Coast ports can accommodate post-Panamax vessels, then goods destined for the East Coast can use an all sea route, resulting in an estimated $2 million to $8 million saved per post-Panamax vessel (Morrison, 2012). Cost savings could then be transferred to the consumer, resulting in lower cost per good and a net economic benefit. In 2012, USACE conducted a study to assess US port preparedness for post-Panamax vessels. They found that of the 55 major US ports only 12 could accommodate post-Panamax vessels, showing the need for port investments (USACE, 2012).

Once a port can accept post-Panamax vessels, it must process their cargo. As a ship's length increases, its width increases, meaning that ports need to invest in larger cranes. Current Panamax cranes are suited to handle ships that are 12 to 13 containers wide, whereas post-Panamax cranes are suited to handle ships that are 18 containers wide (Conway, 2011). Ports can additionally upgrade their landside cargo vehicle fleet. In this area, sensors and automation can significantly improve port efficiency. Sensors are first used at gate operations, when semi-trucks arrive to pick up containers for shipment. These sensors tell the drivers where to pick up a container and where to deliver it, reducing queue time and congestion and increasing movement efficiency (Johansen, 2012). Port efficiency can also be improved through automation of ground vehicles. These vehicles move the containers between the ship and the yard where they are stored. By automating this process, ports reduce uncertainty and human errors leading to better allocation of yard space and precise container movements (Martin-Soveron et al., 2014).

Research on Asian port disruptions found a total of 15 port disruptions, of which 7 disruptions were due to natural disasters and 8 were due to manmade disasters or accidents. The natural disasters were earthquakes, tsunamis, typhoons, and bad weather and the manmade disasters were oil spills, ship collisions, and worker strikes. Typhoons had the most severe impact and worker strikes had the highest likelihood of recurring. To address these two risks, there should be a focus on loss mitigation to lessen the impact of natural disasters and mitigate the risk of labor strikes through labor law reformation and human resource management (Lam and Su, 2015).

3. Methodology

Due to the complexity of port operations and the fund allocation process, using a value-focused thinking approach was necessary. This type of approach focuses on idea generation to create an alternative that maximizes value to the stakeholder. The first phase of the Systems Decision Process, problem definition, was used for the project and it entails conducting research and stakeholder analysis. Research consisted of completing a literature review and conducting interviews with personnel at USACE. In order to synthesize the information from background research and stakeholder interviews a Finding, Conclusion, Recommendation (FCR) matrix was formed. This is a process where all findings from background research and stakeholder interviews are all placed into a matrix, allowing for easy synthesis of the findings into conclusions. These conclusions are then synthesized into recommendations, forming the FCR matrix. To better understand the role of USACE in port operations, a systemigram was created. A systemigram is a depiction of all stakeholders within a system that shows their relationships using arrows and verbs to show their interaction. With a better understanding of port operations via the systemigram and the FCR, the fundamental objective (FO) was then created. The FO is a statement that identifies the reason why the problem is being undertaken. This statement shows the goal that must be achieved by the system for it to be deemed successful. Once the FO is identified; a functional hierarchy that achieves the FO is created. The FO is then further decomposed into functions, objectives, and value measures to create a qualitative value model which provided the scaffolding of what the model must achieve. Functions are derived from the FO to assist in the achievement of the FO, and each function is then decomposed into an objective. The objective describes the preference of a function as to if the function is either maximizing, minimizing, or optimizing something. Finally, the objectives are decomposed into value measures which are used to show if an alternative achieves an objective. These value measures ensure that value to the client is captured by the objectives and functions, ultimately leading to an alternative that has the most value. The value measures are captured in the model by allowing users to input data on their port project. This data then is submitted and used as inputs to the value functions which assess the value for each input as well as for the entire project. The output is displayed in a data table showing the comparison between different projects as well as in a radar chart to allow the decision maker to assess individual value measure value for each project.

4. Analysis

Through the literature review and interviews, the FCR matrix was created. This FCR took 100 findings, consolidated them into 37 conclusions and consolidated the conclusions into 6 recommendations:

1. To accommodate post-Panamax vessels, ports need to have a minimum depth of 50 feet, upgrade to post-Panamax cranes, and increase quay size and number of quay cranes.
2. Ports should look at intermodal improvements by expanding into the hinterlands and coordinating with truck and rail.

3. Ports must coordinate across multiple stakeholders to increase throughput through multiple modes of transportation.
4. The model should be quantitative and use historical data to bin ports based on return on investment to predict future returns out to 5 years.
5. Ports can improve efficiency of operations through automation of equipment and utilization of technology that optimizes berth and quay crane scheduling. This helps to avoid the land constraint and improve where the port is most inefficient.
6. Due to increasing port demand in the East Coast, ocean connected ports like NY & NJ need significant upgrades and port maintenance; therefore, USACE must have effective authority and appropriations from Congress.

A systemigram was created to illustrate the many interconnected stakeholders to better understand the complexity of the system (Figure 1). The gray circle shows the physical parts of the port, such as berths, cranes, and automated shuttles. Around the outside of the port are the various stakeholders who ensure smooth operation of the port. For example, three stakeholders interact directly with the port, Terminal Operators operate the port, the Port Authority owns the port, and USACE maintains the port. The different tasks of these three stakeholders increases the overall complexity of the system. The systemigram showed that USACE has two roles in port operation, first to maintain the port and second to oversee port authorities. This narrowed the scope of the model to focus strictly on projects within the port, rather than improving the scheduling of ships entering a port or deciding which port a ship should go to.

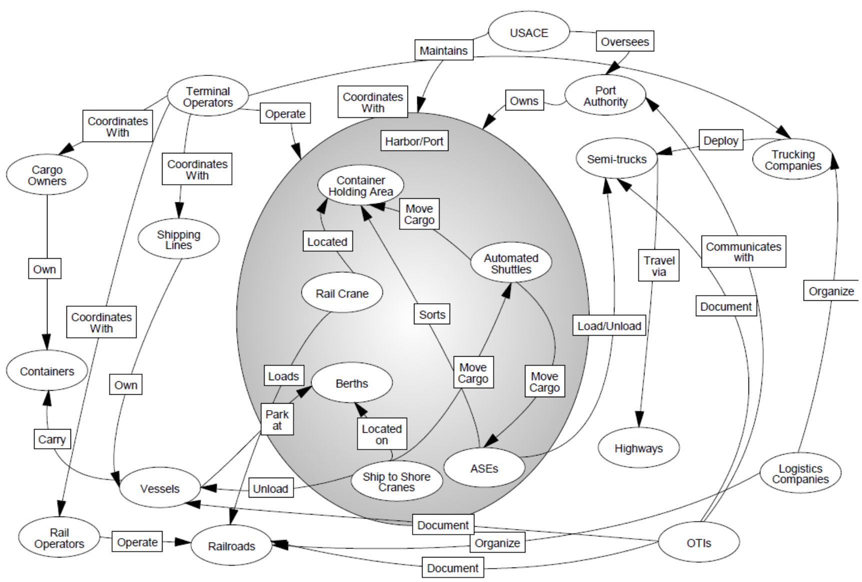

Figure 1. Port Operations Systemigram

After scoping the model to focus on new port projects, the recommendations from the FCR are incorporated into the FO: "Develop a model that incorporates a risk function and predicts return on federal investment. The model will prioritize proposed projects by predicted return and categorize them based on urgency."

The FO is then decomposed into the functions: assess risk, assess return on investment, and assess level of urgency. Assessing risk ensures that the project will help to mitigate current port risks, reduce the chance of system failure, and analyze the impact of the port project not occurring. The return on investment function analyzed the additional benefits that a specific project would bring to the port. This function allows the model to rank projects based on their expected return on investment. The final function, assess level of urgency, allows for subjective input from subject matter experts. Previous discussions showed that a completely objective model received pushback from subject matter experts. The incorporation of this function allows their inputs to be valued and still impact the port project selection process. These functions all relate to the FO by achieving a specific part of the FO. The risk function addresses the risk portion of the FO, the return on investment function helps predict project return on investment, and the urgency function allows the projects to be categorized based on their urgency.

This functional hierarchy is then further decomposed to generate the qualitative value model (Figure 2). The objectives that assess risk are minimize threat, minimize vulnerability, and minimize consequence. These objectives capture three different

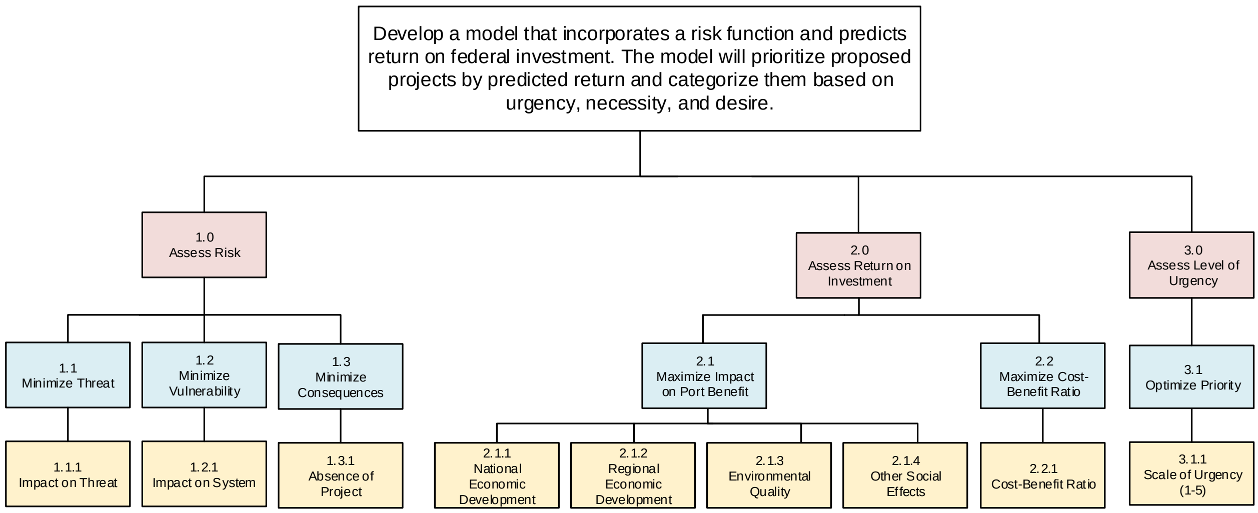

Figure 2. Port Investment Value Hierarchy

aspects of risk, with minimize threat capturing external risks, minimize vulnerability assessing internal risks, and minimize consequence assessing the risk of inaction. The objectives associated value measures are impact on threat, impact on system, and absence of project, respectively. The impact on threat is a proxy score that assesses a project's ability to reduce the effect of an external effect. The impact on system is a proxy that assesses a project's ability to reduce the effect of an internal effect. The absence of project assesses the additional risk from the project not occurring by assessing the current OCA rating which is a proxy scale that assesses the system's current ability to continue operation. These value measures effectively capture information on the different aspects of risk, achieving their related objectives and ultimately the risk function.

To assess the return on investment, the model must both maximizes impact on port's benefit and maximize the project's cost-benefit ratio. These objectives achieve the return on investment function because they are both measurements that show the positive aspects of the port project, allowing the model to properly assess return on investment. The maximize impact on port benefit objective is composed of the project's National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), Other Social Effects (OSE). These are all scores given to a project by USACE before it is approved. The NED assess the project's impact on the national economy. The RED assesses the project's impact on the local economy through its ability to create jobs. The project's OSE ensures the project does not negatively impact local cultural areas. The EQ assesses the project's impact on water and air. By collecting these value measures, it ensures the model assesses all aspects of project benefits. To further ensure a correct return on investment assessment, the project's cost-benefit ratio is also used. Unlike the various benefit value measures, the cost-benefit ratio is regarding monetary value. This ratio directly measure's the project's ability to produce a positive return on investment. Utilization of these value measures ensures that both monetary and non-monetary benefits are incorporated into the selection of port project funding.

Finally, the urgency scale is incorporated for three reasons. First, stakeholder engagement showed that generating a 1 through n list of port projects in the past met resistance. By binning projects based on urgency and then ranking based on value, it prevents a 1 through n list from occurring. Second, it allows for subject matter experts to provide input to the model. Secondly, it ensures that projects for highly lucrative ports do not overshadow necessary projects for smaller ports. For example, suppose there is a Port A that generates significantly higher revenue than Port B. Without the urgency value measure there is the chance that all Port A projects would be selected before any Port B project despite a project being vital to Port B's operation. The urgency value measure ensures that Port B will be able to place their vital projects into the top bin for selection. This function is captured by the objective of optimizing priority. This objective effectively captures urgency by allowing for subject matter experts to use their experience to impact the project prioritization process. The related value measure is the scale of urgency, which is a proxy scale of 1 through 5 with 1 being highest priority and 5 being the lowest. This achieves the objective by creating standard definitions for what each number means, allowing the subject matter experts to more effectively assess their project's urgency level.

5. Results

The results were used to develop the multi-objective decision model, the USACE Port Project Priority Model (UP3M). The UP3M was developed in R and is an interactive app, allowing users to input their project's name, district, division, impact on threat score, impact on system score, Operational Condition Analysis (OCA) rating, NED, RED, EQ, OSE, cost-benefit ratio, and urgency. Additionally, the UP3M contains a sidebar menu that gives access to pages with information on the UP3M, value measure definitions, and the methodology behind the UP3M. The value measure data is inputted via different sliders and drop-down menus for each specific value measure to ensure the inputs are within the allowable range. Once the data is inputted, the user submits the data by clicking a submit button. The UP3M then observes the button click and saves the data to the server where it is then used as variables in the value functions. Due to lack of stakeholder input, there is equal weighting among the value measures and each value function was assumed to be linear. The server has the value functions stored locally and these functions can be edited if the stakeholder's value functions change. The value functions return how much value the individual input has. From these inputs, a data table is created, showing the project's name, district, division, total value, and urgency level. The total value is calculated by summing the value of each individual input. Projects within this data table can then be sorted based on their division, district, urgency level, or total value. This allows the decision maker to easily organize and compare different projects. Additionally, a radar chart is made from the inputs showing the individual value for each value measure. This radar chart is significant because it allows the decision maker to compare the individual value for each value measure of different projects. This feature greatly assists the decision maker when two projects have the same total value score.

USACE did not provide any data to assist with model validation, so the validation used notional data. To validate the UP3M, the data for Project A was inputted via the input menu found below in Figure 3. From these inputs, the UP3M returned a total value score of 63. The generation of the total value score provides a number that the decision maker can then use when deciding fund allocation between two projects. The incorporation of the radar chart also provides information vital to the decision process. For example, suppose Project A and Project B have the same total value score of 63. Project A's radar chart output (Figure 4) clearly shows that most of the value in Project A lies in its ability to reduce risk, rather than bring additional benefit to the port. This radar chart allows the decision maker to further delineate between projects outside of just their total value. The UP3M adds clarity to the project funding allocation process and can help ensure efficient fund allocation through the usage of data and subject matter expert input.

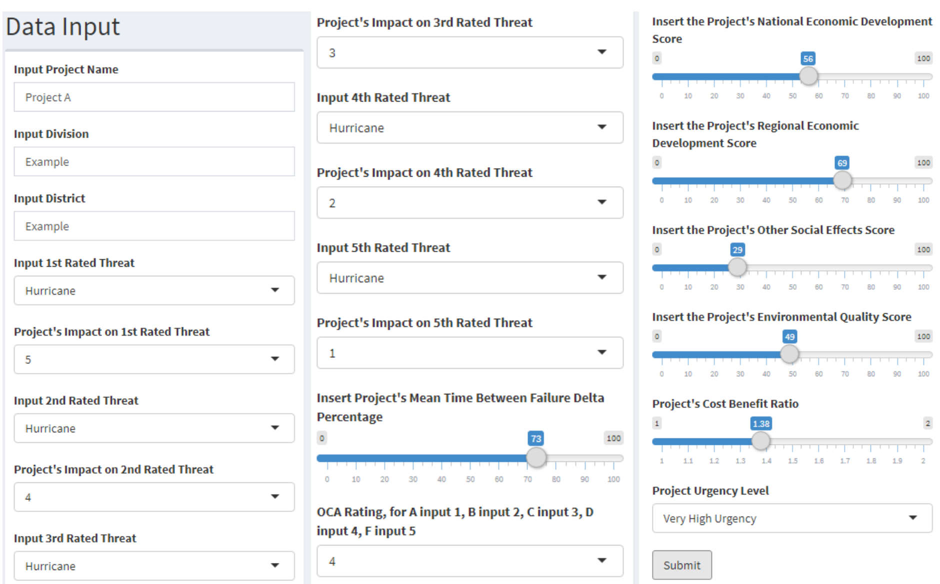

Figure 3. Project A- UP3M Data Input Page

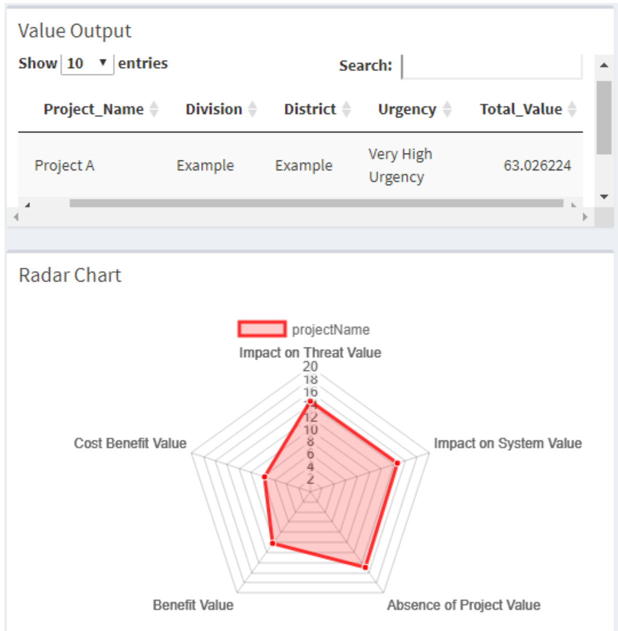

Figure 4. Project A- UP3M Radar Chart Output

6. Conclusion

The UP3M provides USACE with the ability to have a more objective decision process when deciding port project funding. This ultimately will lead to a more optimal allocation of limited funds, ensuring that the best projects receive funding. It replaces the subjective decision process currently used by USACE, but still allows for subjective input from subject matter experts via the urgency function. This helps ensure that all members of the decision process feel that they can make an impact on the fund allocation process, increasing the likelihood of the UP3M being adopted. The adoption of the UP3M by USACE is the first step in changing their culture of using subjective decision processes. By changing to the UP3M, USACE will be better able to optimally allocate funding to port projects, leading to more benefits to the nation as a whole.

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