A STUDY IN SEA-AIR INTERMODAL PORT SELECTION: STRATEGIC DECISION MAKING FOR UNITED STATES SOUTHERN COMMAND

GRADUATE RESEARCH PAPER

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Abstract

World events and subsequent dramatic changes in the expeditionary force structure and strategy of the U.S. military have forever altered the traditional approach to operational employment and readiness under previous paradigms. Greater degrees of flexibility and speed are required to carry out operations, which are aided by the utility of intermodal transport options to quickly and efficiently move large force package rotations in support of geographic combatant commanders' (CCDR) requirements. The United States Transportation Command (U.S. TRANSCOM) is responsible for making decisions on the most efficient mix of sea and airport operations to support U.S. Government and Department of Defense (DoD) movement requirements worldwide, and the selection of the best port pairs is critical in executing that mission. U.S. TRANSCOM has used a decision model which evaluates ten sea and airport factors to prioritize port pairs, but recent humanitarian assistance/disaster relief operations in Haiti brought new attention to United States Southern Command's (U.S. SOUTHCOM) need for constantly evolving logistical planning. This research uses a "value focused" methodology to identify factors and data sources to broaden the scope of the existing model to help U.S. TRANSCOM remain flexible in supporting worldwide CCDRs including U.S. SOUTHCOM.

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To my wife and daughter

Acknowledgments

I would like to say thank you to my advisors LtCol Sandlin and Dr. Jeff Weir for their guidance and inputs during this process. I would also like to thank Capt Earl Bednar, LtCol Shane Hall and LtCol Shane Knighton at TRANSCOM for their help in gathering all available information on South American seaports and airports used to build the alternative set. Finally, thank you to Colonel Cristos Vasilas and Major Pablo Dieppa for help obtaining data, as well as inputs to the weights and measures used for this study.

Todd C. Markwart

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A STUDY IN SEA-AIR INTERMODAL PORT SELECTION: STRATEGIC DECISION MAKING FOR UNITED STATES SOUTHERN COMMAND

I. Introduction

Background

World events and subsequent dramatic changes in the expeditionary force structure and strategy of the U.S. military have forever altered the traditional approach to operational employment and readiness under previous paradigms. Greater degrees of flexibility and speed are required to carry out operations, which are aided by the utility of intermodal transport options to quickly and efficiently move large force package rotations in support of geographic combatant commanders' (CCDR) requirements. The United States Transportation Command (U.S. TRANSCOM) is responsible for making decisions on the most efficient mix of sea and airport operations to support U.S. Government and Department of Defense (DoD) movement requirements worldwide, and the selection of the best port pairs is critical in executing that mission. U.S. TRANSCOM has used a decision model which evaluates ten sea and airport factors to prioritize port pairs in European Command (EUCOM), Pacific Command (PACOM) and Central Command (CENTCOM) (appendix A). Recent humanitarian assistance/disaster relief operations in Haiti brought new attention to United States Southern Command's (U.S. SOUTHCOM) need for constantly evolving logistical planning. Identifying factors and data sources to broaden the scope of the existing model can help U.S. TRANSCOM remain flexible in supporting worldwide CCDRs including U..S. . SOUTHCOM.

This study expands the current port selection model using value focused thinking to identify those attributes that are most desirable to a decision maker. These attributes are used to choose the most desirable sea and airport alternatives in U.S. SOUTHCOM for intermodal operations during possible contingencies. Additionally, this research proposes new factors including cost, political concerns, as well as host-nation and operational considerations based on review of intermodal literature

Problem Statement

The purpose of this study is to examine the Sea-Air Intermodal Port selection process using a value focused approach. This model is intended to be a template for use by U.S. TRANSCOM to improve intermodal decision making tools currently in use.

> **Sub Problem 1**: Specify Evaluation Measures in the overall intermodal port mix decision, as well as objectives and scales for measuring their attainment.
>
> **Sub Problem 2**: Develop alternatives that might achieve these objectives.
>
> **Sub Problem 3**: Determine how well each alternative achieves each objective. Consider tradeoffs among objectives.
>
> **Sub Problem 4**: Select the alternative that best achieves the objectives, and perform sensitivity analysis.
>
> **Hypothesis**: Using strategic value focused thinking methods to guide the evaluation and implementation of the most relevant decision attributes will provide improvements to current intermodal port mix decision analysis.

Research Objectives and Methods

"A key to good decision making is to provide a structured method for incorporating the information, opinions, and preferences of the various relevant people into the decision making process" (15:1). As it applies to strategic decisions that are above the routine day to day level, this structured approach is necessary in sorting out complicated and confusing management level decisions with competing objectives. Because of the needed structure in important strategic decisions like intermodal port choice, Craig W. Kirkwood provides this structure in his textbook entitled "Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets" (15). This method of decision analysis makes extensive use of Microsoft Excel spreadsheets to organize quantitative objective measures and perform value analysis on multiple alternatives. While Excel is not the only method of implementing this method of decision analysis, it is useful for most Department of Defense (DoD) users given its widespread availability and familiarity of use. Overall, this process will follow the five steps to better strategic decision making as outlined by Kirkwood:

1. Specify objectives and scales for measuring their achievement
2. Develop alternatives that potentially achieve objectives
3. Determine how well each alternative achieves each objective
4. Consider tradeoffs among objectives
5. Select the alternative that, on balance, best achieves objectives

Ralph L. Keeney is another author whose work is foundational in this technique, and he further details ten steps that help guide the process to better decision making (10:55). These steps, shown in figure 1.1, provide a clear method to frame and analyze the intermodal port pairing decision process.

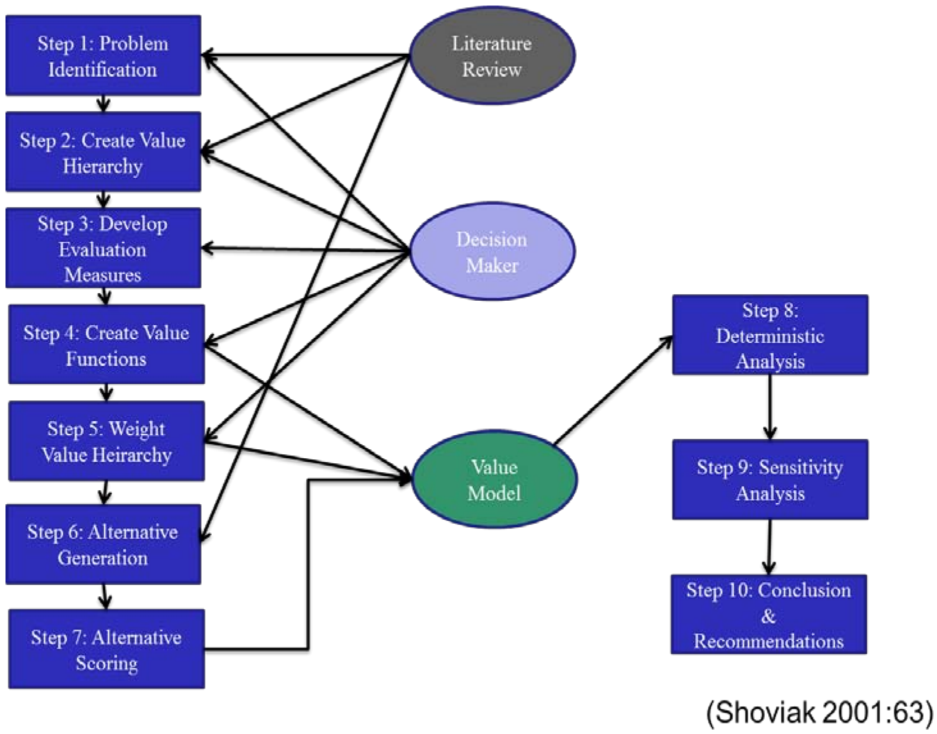


Figure 1.1. 10 Step Value Focused Thinking Process (Shoviak, 2001:63)

Beginning with the first sub problem, the evaluation measures in the overall intermodal port mix decision are specified, as well as the objectives and scales for measuring their attainment. Before solving this sub-problem, it is necessary to identify the overall decision in question, as well as create the value hierarchy of the most important factors involved in evaluating the alternatives. This effort is guided by the descriptions of Ralph L. Keeney's value focused thinking. He explains that conventional decision making approaches use Alternative Focused Thinking (AFT), which focus only on evaluating apparent alternatives and not whether they will achieve desired outcomes. The focus should instead be on values, where alternatives are relevant only as a means to achieve them. This method of Value Focused Thinking (VFT) entails clearly defining fundamental values in terms of objectives which serve to focus and guide the decision making process (11, 12). The cost of relying on an AFT can be choosing from a list of bad alternatives, whereas VFT can actually lead to the creation of new alternatives once the underlying values of a decision are clearly defined.

Several sources provide input to the factors included in the value hierarchy and evaluation measures used in the creation of a revised intermodal model. One of these sources includes an analysis of shipping port capacity drivers in North American ports as proposed by Michael Maloni and Eric Jackson (19). Their analysis provides insight into the ten most important container port capacity drivers (of North American ports) which are used to choose relevant measures in this model. Other major inputs include measures currently in use by the U.S. TRANSCOM model (32) and content analysis by Cullinane and Toy which identifies influential attributes in freight route/mode choice decisions (5). In addition to developing the hierarchy of the most important attributes of a decision and the specific evaluation measures that allow comparison, value functions of those measures must be created based on decision maker input. In addition to the value functions for the evaluation measures, decision maker input is also required to determine the relative weights among the competing attributes within the overall hierarchy. Once the hierarchy is created with weights assigned, and the evaluation measures are determined along with their value functions, the next sub problem can be achieved.

The second sub problem sets out to develop alternatives that potentially achieve our chosen objectives. Data specific to airports and seaport within U.S. SOUTHCOM are used to develop an alternative set with a focus on Central and South America. Once these alternatives are specified, sub problem three seeks to determine how well each alternative achieves each objective while considering the tradeoffs among them.

According to the model set forth by Kirkwood's "Strategic Decision Making", this is accomplished by determining a "value function". A value function combines the multiple evaluation measures into a single measure of the overall value of each alternative (15). This is accomplished by using Microsoft excel to calculate a weighted sum of functions over each evaluation measure. The final step is described by sub problem four, which entails selecting the alternative that best achieves the objectives and performing sensitivity analysis.

These four sub problems represent the steps toward achieving the ultimate goal of this research, and the 10 step VFT process represents the methodology by which this intermodal study is undertaken. The result will show that using strategic value focused thinking methods to guide the evaluation and implementation of the most relevant decision attributes will provide improvements to current intermodal port mix decision analysis.

Research Focus

This research focuses on the U.S. SOUTHCOM area of responsibility (AOR) and looks at relatively long-lead operations most likely requiring sea-air intermodal transport. It does not recreate or develop a new model for analyzing port pairs, but builds on the existing model, while making recommendations for other possible factors or relative weightings to sharpen the effects of the current model.

Assumptions and Limitations

This research is scope limited by the data available for the U.S. SOUTHCOM AOR. The specific airports and seaports analyzed by the model represent those with detailed surveys and estimates of capacity which can be input into the model. The ultimate goal for this effort is to demonstrate the effects of the improved model, and this is accomplished by using real world and notional data to compare the original and revised intermodal decision models. While the specific ports chosen for the real world analysis do not represent the full range of choices within the SOUTHCOM AOR, alternatives among the available data set may represent choices not previously considered and may therefore benefit from a value focused approach. Expanding this revised model with additional data port analysis tools will enable the comparison of all available alternatives within an AOR, and ultimately the ability to choose the most attractive intermodal choice for specific purposes. The resulting choice may or may not have been considered in the past, offering potential benefits over current ports in use. This research examines only the decision model for intermodal port options and does not undertake detailed distribution network design analysis.

II. Literature Review

What is Intermodal Transportation?

A well-functioning freight transport system is essential to the overall prosperity of any nation, and is a critical enabler of economic expansion, recreation and national defense. Dramatic advances in freight transportation as well as logistics and supply chain management have been the catalyst for the growth of the U.S. and world economies. A large part of the success of these endeavors can be attributed to the concept of intermodal transportation (3:7).. While the "concept of logistically linking a freight movement with two or more transport modes is centuries old", intermodal transportation can be defined as: "The concept of transporting passengers and/or freight on two or more different modes during a single journey, in such a way that all parts of the transportation process, including the exchange of information are efficiently connected and coordinated." (22:1) While this definition sheds some light on what "intermodal" means, it is important to note that this term is also used to describe the improved efficiencies and advances in the freight industry as well as the vast improvements to logistics and supply chain management. In order to better serve ever-expanding global trade at lower cost, address environmental concerns caused by transportation, and take advantage of the inherent benefits of each modal choice; the concept of intermodal transportation continues to gain more and more relevance over time (3:358). The continued growth and improvement of intermodal transportation is tremendously important to global trade and economic development worldwide, and its growth will be driven by a number of opportunities and challenges in the future. There are four specific factors proposed by the Committee on Intermodal Freight Transport which serve to further frame this discussion (6:1):

1. "Measuring, understanding, and responding to the role of intermodalism in the changing customer requirements and hypercompetition of supply chains in a global marketplace."

2. "The need to reliably and flexibly respond to changing customer requirements with seamless and integrated coordination of freight and equipment flows through various modes."

3. "Knowledge of current and future intermodal operational options and alternatives, as well as the potential for improved information and communications technology and the challenges associated with their application."

4. "Constraints on and coordination of infrastructure capacity, including policy and regulatory issues, as well as better management of existing infrastructure and broader considerations on future investment in new infrastructure."

Factor 1

Role of Intermodalism in the "hypercompetitive" market - The Committee on Intermodal Freight Transportation recommends redefining the definition of what intermodal means and how its effects can be measured. In light of the traditional container traffic definition, they suggest further refining intermodal transportation as "encompassing all single-bill shipments using multiple modes." This definition should expand to include not only twenty foot equivalent units (TEUs) but also bulk and non-bulk transloaded freight. In this case, the intermodal issue must be cast in a broader light to measure its impact upon the world from the local to the global level. By considering the expanded definition of what intermodal is, its far reaching effects can be measured in the way it enables global supply chain management and subsequent hypercompetition. This broader focus could allow better planning of education, training, and investments in infrastructure and focused relationship management between intermediaries to maximize supply chain efficiency.

Factor 2

Reliably and flexibly respond to changing customer requirements with seamless and integrated coordination of freight and equipment flows through various modes. Customers around the world are expecting smaller, faster and highly customized shipments in support of their supply chain strategies. The attributes customers demand are identical to those found in content analysis studies; in addition to cost, customers will continue to demand faster shipments, less variance, flexibility based on the characteristics of goods, and service facilitated by interrelationships between intermediaries (5:49). These links are being transformed through advances in communications technology including e-commerce.

Factor 3

Knowledge of current and future intermodal operational options and alternatives, and potential for improved information and communications technology and the challenges associated with their application. In addition to focusing on the fundamentals to optimize efficiency in current operations; managers who enable intermodal operations must continue to enhance their own education and training while integrating new technology and innovations. Information and communication technology advances present significant opportunities and challenges for all players in the intermodal realm. More and better information can lead to complete analysis of available tradeoffs and options, enabling critical managerial decision making and network optimization.

Factor 4

Constraints on and coordination of infrastructure capacity, including policy and regulatory issues, as well as better management of existing infrastructure and broader considerations on future investment in new infrastructure. Congestion at the intermodal line haul connectors and terminals has been characterized as the most pressing problem, which is only projected to get worse as worldwide demand grows (3:363). Limited capacity, lack of funds for maintenance and expansion, security concerns, increasing demand, and increased carrier capacity are all contributing to the problem. In addition to congestion; equipment shortages, positioning inefficiencies as well as labor issues form other major limitations to intermodal transport. Better management of existing infrastructure, investment in new infrastructure, and coordinated government policy are all required to mitigate these concerns and prepare for the future.

Why is it important?

Global trade is an enormous activity with a total of $15.8 trillion of worldwide merchandise exported in 2008; while the U.S. alone exported $1.3 trillion and imported $2.1 trillion in goods in the same year (3:323). Transportation comprises 22.8 percent of the world commercial service exports with an estimated 80 to 90 percent of all global trade moving via water transportation (3:324). Furthermore, it is estimated that 90 percent of the world's non bulk cargo is moved in shipping containers referred to as twenty foot equivalent units (TEUs). This trend has increased the number of worldwide containers by 30 percent between 2001 and 2005, and worldwide container volume is expected to reach 80 million TEUs by the year 2015 (3:362).

Intermodal is more than just taking a shipping container from a factory via railroad or truck and ultimately offloading it at the port of debarkation. Understanding intermodal transportation involves the knowledge of how to conduct business in the most efficient and cost effective manner within a framework of government policies and regulations, with efficient and error free transfer management to ultimately meet the constantly changing needs of the end customer. It also involves the structure of interaction within and between intermediaries who all contribute to the scheduling, tracking, documentation, and ultimate delivery to the customer. Furthermore, intermodal transportation is constantly evolving due to new technological advances within each mode and in the communication technology between them. Finally, examining intermodal transport is a key consideration in the development of coherent national and international transportation policy and regulation, as well as the only way to prioritize investment in critical enabling infrastructure.

It has been said that there are three main benefits from intermodalism which include: facilitation of global trade, better accessibility by linking individual modes, and overall improvements in cost without sacrificing customer service or accessibility (3:360). In the current and future global market, the design and implementation of transportation networks will be driven by the concept of "hyper-competition", where instead of individual firms competing for market share, supply chains compete against one another in a global market. The efficiency and effectiveness of intermodal supply chains directly influence the total landed costs and service levels for products and services; in turn directly impacting global competitive strategies worldwide. By focusing on the inherent benefits of the different modes, significant cost savings can be realized even with increased handling and transfer costs. In terms of importance, content analysis research has shown cost to be the number one consideration for customers when making the freight route/mode decision. Further top five considerations in order of significance include speed, reliability, characteristics of the goods transported, and finally the level of service desired by the customer (5:49). These attributes show that what is vitally important to customers is the competitive advantage that can be enhanced by reducing direct shipment costs and organizational costs through reduced variance; based on the speed and service levels needed for the specific supply chain strategy.

What is being done or has been done?

Factor 1

Role of Intermodalism in the "hypercompetitive" market - This first factor frames the overall discussion by expanding the definition of intermodal to all modes of transport in addition to containerized and trans loaded bulk or non-bulk freight. The additional following factors focus on the efforts by industry and government to continually improve the intermodal supply chains of the future.

Factor 2

Reliably and flexibly respond to changing customer requirements with seamless and integrated coordination of freight and equipment flows through various modes. In order to focus on the needs of the customer and provide the most efficient freight flow possible, the multiple conflicts between the intermediaries need to be addressed. Conflict in relations between intermediaries prevents close coordination and communication needed to optimize efficiency within the industry; many of these physical and organizational bottlenecks have developed out of the mode centric evolution of transportation over time (25). Close coordination is also critical between private industry and the governments who provide major infrastructure funding and create policy and legislation with far reaching effects. In order to provide dramatic cost reductions to both the carriers and shippers, better service to the customer, and less environmental pollution; the inherent advantages of the individual modes must be combined in efficient new ways. In some cases, carriers and shippers both are unwilling to change their operations based on long standing conflicts which may include incompatible goals, different perceptions of reality, differing roles, and lack of effective communication (25). Given intense economic pressures, rising fuel costs, enhanced technology, and an increased focus on green business practices, today's market leaders are beginning to fully realize that collaboration is imperative to their continued success.

Factor 3

Knowledge of current and future intermodal operational options and alternatives, and potential for improved information and communications technology and the challenges associated with their application. The technological advances in the last three decades have transformed the execution and planning of intermodal transport as well as the individual modes themselves. A recent trend within all industries involves the use of sensors, computers, and digital communication to collect, process and spread information. The development of the Intelligent Transportation System (ITS) in the U.S. is founded on the use of these new technologies (9). Some of these technological advances are outlined in the following paragraphs, beginning with Information Technology (IT).

IT: Information technology allows for improved planning, scheduling, tracking, auditing and documentation to be performed real time. New communication and IT innovations along with the improved communication flows between all links in the chain are enabling better managerial decision making and process efficiencies not possible in the past (6:5). Specific advances have been brought about by the internet and e-commerce. Business to business e-commerce (B2B EC) and electronic data interchange (EDI) enabled by internet connectivity are leading the way in industry innovation. Business can profit from faster, more accurate and less costly transactions with carriers who fit their supply chain strategy at the lowest cost. Furthermore, EDI systems can minimize paperwork and speed up information flows via web enabled transaction processing. Information flows between intermediaries have also been significantly enhanced; allowing for greater flexibility and easier coordination between the modes. Another major IT enabled capability has come in the form of better in transit visibility (ITV) of both cargo and intermodal fleets. Real time tracking of cargo and vehicles is helping to improve service levels through efficient fleet management, identification of unwanted variance, improved security, and optimal inventory management based on time definite delivery of goods. Finally, the coupling of real time control and logistics decision making software with the advances in IT, EDI and ITV allow distribution service providers like Fed-Ex, DHL and UPS to optimize their intermodal networks. With this in mind, it can be argued that the expansion and exploitation of IT is the true enabler of the flexible, efficient intermodal supply chain.

Maritime: It is estimated that 98 percent of intercontinental containerized freight moves via ocean carriers, which accounts for 60 percent of the trade value (3:368). Despite this fact, the ocean carriers are a very diverse industry who can ship any commodity anywhere in the world with many pricing alternatives. Newly implemented vessel tracking systems of the ITS are contributing the better in transit visibility and proactive management of intermodal linkages. The continuing trend in maritime transport is towards larger ships with more container capacity, exemplified by current 15,000 TEU post Panamax ships like the newly created Emma Maersk. To take advantage of greater economies of scale, many ocean carriers are relying on larger vessels; putting significant pressure on the ports in terms of congestion and suitability. Significant investments by port authorities are needed in order to expand capacity, deepen channels to accommodate larger ships and address the environmental concerns of doing so.

Rail: The rail industry is making some of the largest investments in new infrastructure of all the modes; particularly leading the way in terms of integrated automation. Furthermore, the evolution of the lightweight articulated rail car is allowing the use of double stack TEUs with lower equipment acquisition costs, smoother ride quality to protect against breakage and greater enroute security. The Intelligent Railroad Systems are being developed by private industry and government to harness new technologies for train control, braking, smarter crossings, enroute error detection, and overall planning and scheduling systems. An integrated approach to system design is encouraged as a means of compounding the benefits that will result. The overall intent is to increase safety, reduce delays, reduce costs, raise capacity, raise service levels, lower emissions, and improve economic viability (9). In addition to the integration of better information processing, other initiatives include the Nationwide Differential Global Positioning System (NDGPS), Positive Train Control (PTC), electronically controlled pneumatic brakes (ECP), and Radio Frequency Identification tag (RFID) technology integration (9). Long term infrastructure renewal and reinvestment will also result in double tracking and triple tracking of high volume segments in the United States, along with greater increases in the speed of rail shipments over existing tracks. Incremental high speed rail (HSR) will have capabilities of 90-150 mph; new HSR infrastructure will be capable of 200 mph, while magnetic levitation has shown potential well above 200 mph.

Motor Carriers: The major innovations within this industry include better fuel efficiency of tractors, alternative fuels, the use of global positioning system (GPS) technology, larger trailers, and the use of IT to improve operations through better visibility of assets. The overwhelming intracontinental market share of trucking is slowing beginning to give way to the increased accessibility, service levels, and dramatically lower costs of rail.

Air: The role of the air carrier is continually expanding with particular emphasis on time definite delivery of high value goods. While some larger military aircraft like C-17s and C-5s can carry the 20 and 40 foot international organization for standardization (ISO) ocean containers, the majority of intermodal cargo must be transloaded at a higher cost than pure TEU shipments alone (22:389). The expansion of this mode is being aided by advances in air traffic control systems, data links, weather systems along with higher capacity and more fuel efficient aircraft. While some pure cargo air hubs are currently being constructed to ease congestion and aid accessibility, this civilian industry must cope with the challenges of aligning supply with demand and maintaining profitability. For both military and civilian operations, the fluctuating price of jet fuel, along with the high costs of security requirements will continue to be major sources of pressure. This pressure will continue to place more emphasis on gaining maximum efficiency and cost savings from the combined synergy of intermodal transportation planning.

Factor 4

Infrastructure capacity, policy and regulatory issues, better management of existing infrastructure and future investment in new infrastructure. It has been noted that freight transportation is a joint enterprise between the government and private industry. In general, the government is responsible for coordinated planning and major investment in infrastructure in terms of highways, ports and harbors, airports and airways, and inland waterways; while the private sector generally owns their own transportation equipment and some components of the transportation infrastructure.

Within the last three decades, significant changes to U.S. government policies have dramatically transformed the freight transportation industry from one defined by limited flexibility and strict regulation into one defined by technological change and driven by market forces. Examples of this deregulation include the Railroad Revitalization and Regulatory Reform Act of 1976, the Airline Deregulation Act of 1977, the Motor Carrier Act of 1980, the Rail Staggers Act of 1980, the Bus Regulatory Reform Act of 1982, and the ICC Termination Act of 1995 (3:62-63). The benefits of deregulation have been dramatic in terms of industry profitability and the competitive world-class transportation options available to customers worldwide. With growing worldwide demand, increasing sizes of vehicles, and larger volumes of TEUs around the world; the supporting ports and infrastructure are often not up to the challenges placed upon them. Port congestion, limited space for expansion and limited funding for critical intermodal linkages are serious pressing concerns for not only the ocean shippers but also for rail carriers. Significant infrastructure investment, equipment purchases, and operator hiring are necessary to meet these challenges and prepare for future expansion.

When it comes to integrated federal planning and funding for infrastructure, a 2007 GAO report concludes that there are three main barriers to effective funding of intermodal transport needs at the federal level (8:5).

1. Limited Federal Funding targeted towards intermodal projects. Funding is generally tied to a specific mode, which limits the ability of state and local agencies to address intermodal concerns with federal money. Although some federal money is available for intermodal purposes, all of these funds are congressionally designated for specific projects.

2. Limited Collaboration among stakeholders. State and local transportation agencies as well as the U.S. DOT are organized by mode, and the DOT even acknowledges that their organizational structure and funding programs can impede intermodal coordination. Additionally, it is noted that private sector interests in airport, rail and freight routinely do not take part in regional planning processes.

3. Limited resources to evaluate intermodal projects. Local planning agencies often lack the ability to measure and quantify the benefits of intermodal projects for regional purposes. Furthermore, it is often even more challenging to quantify benefits of intermodal projects at the national vs. regional levels.

Comprehensive U.S. legislation like the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 was an attempt by Congress to establish a policy for a national intermodal transportation system. In addition to increased funding levels and specific infrastructure planning guidelines, this act created the DOT's Office of Intermodalism, the Intermodal Transportation Advisory Council and the National Commission on Intermodal Transportation (8:14). While the ISTEA recognized the need for a larger focus on the national transport system as a whole, the reality is that the funding was still provided separately by mode. Furthermore, state and local governments have been given no requirements and limited funding to shift to a more intermodal approach. This GAO reports also notes that subsequent legislation of the Transportation Equity Act for the 21st Century (TEA-21), and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) both retain the same basic policy goals and programs as previous versions. In general, the GAO recommendations for effective policy include increasing the collaboration between operating administrators and increasing the level of guidance and funding for intermodal initiatives. They further recommend that the U.S. Secretary of Transportation designate one office or operating administration to lead the coordination of intermodal activities at the federal level. While the DOT's Office of Intermodalism is statutorily required to fulfill this role, their focus is more towards research. Overall, the way ahead is for

Congress and the U.S. DOT to reassess all transportation modes and the federal role within them, assess funding levels and options, and determine a consistent method of performance measurement to gauge the true impacts of intermodal initiatives. This course of action is much more likely to produce the efficient National Intermodal Transportation System of the future. This discussion is intended to highlight the point that effective government legislation and funding are critical to the development of intermodal infrastructure, and have tremendous impact in the overall capability and efficiency of intermodal port pairings in every country around the world.

The benefits of intermodal rail in particular are beginning to be fully realized by the officials in the U.S. Department of Transportation (DOT) who seek to "move more freight via rail and water carriage as a means to improve safety, preserve highway infrastructure and enhance air quality", further noting that "railroads will play an even larger role in the future than they have in the past" and that intermodal offers "significant public benefits." (2) Recently, the U.S. DOT has weighed in against the U.S. Surface Transportation Board (STB) expansion of power to regulate certain cargo classes including boxcar and intermodal traffic, adding that intermodal rail "has clearly demonstrated the inherent efficiency of rail for the long-haul portion of a move of a container or trailer to or from an intermodal yard or port" (2). Further emphasizing their position, the U.S. DOT has recently added large grants for stack train corridors by Norfolk Southern Railway and CSX Transportation. In addition, they have also awarded nearly two thirds of the $1.5 billion provided by the American Reinvestment and Recovery Act (ARRA) of 2009 for projects involving freight rail, passenger rail and mass transit (17). These investments were selected based on their "contribution to economic competitiveness of the nation, improving safety and the condition of the existing transportation system, increasing quality of life, reducing greenhouse gas emissions, and demonstrating strong collaboration among a broad range of participants, including the private sector" (17). While these investments are important steps, they show the same strategy of federal targeted funding towards individual modes as previous legislation. As a result they may not fully address inefficient intermodal connections at the state and local levels, even though they could yield advances in mobility (8:4).

Applied Intermodal Benefits

Intermodal options can very often lead to intense competition between the different types of carriers, but in most cases can yield benefits not immediately apparent. As a specific example in the U.S., the Port of Toledo has become the primary point of exchange between water carriers and railroads for the movement of coal. The railroads overcome the water carrier's access limitations by picking up in coal producing states and bringing it to Toledo; where the water carriers then take the coal up to ports along the northern part of the Great Lakes. (3:263). The railroads and Great Lakes water carriers realize increased business because of reduced costs to the shipper of this intermodal split, while the customer realizes cost benefits over all the rail transport option. In terms of cost and environmental benefits, it is again very apparent that ports are the critical enabler of efficient intermodal transportation.

High fuel prices, the global recession, and an increased emphasis on "green" business practice have led to other instances where many shippers are turning to intermodal options never considered before. In this case, the railroads and the trucking industry in the U.S. are partnering to take advantage of their modal strong points. Companies like Bon-Ton Stores Inc. are rethinking their supply chains and are using intermodal for the first time ever. In this case, they have shifted a significant portion of freight to rail, showing how regional expansion of intermodal capabilities have opened up viable solutions not previously considered (27:1). In this specific example, experts agree that intermodal ship to rail is three times more fuel efficient than trucking and can savings of 10-15 percent due to deduced line haul costs (27:2). Freight shipped on one intermodal train could take upwards of 200 to 280 trucks to haul the same load. This provides one example of how integrated intermodal strategies can reduce congestion, ease the burden on other critical infrastructure, provide similar levels of customer service, provide significant cost savings, and pollute less. Shippers have traditionally resisted the use of intermodal because they saw it as slow and unreliable, but opinions are changing due to real constraints and economic pressures in addition to evolving capacity and intermodal options.

The European Intermodal Distribution concept which was adopted by U.S. EUCOM in 2004 provides an example of tangible benefits of improved end-to-end supply chain distribution to the military (23). All cargo arriving by air to Ramstein AB, Germany is now rapidly moved by truck and consolidated at a Joint Theater Distribution Center (JTDC) for all destinations reached by ground transportation. In the past, loads were not consolidated, inefficiencies were many, and the costs of intermodal transportation and distribution-hub operations were unchecked (23). The benefits of effective intermodal organization and management have led to improved in-transit visibility, more reliable flow of goods and improved joint service cooperation.

Approximately $8 million have been saved in the first year alone, delivery times have decreased from 5-7 days to less than 24 hours and port hold time has been dramatically reduced from 5 days to ½ day. (23)

Over time, there has been significant expansion of the concept of intermodal transportation and its benefits. The major gains of customer service improvements through seamless coordination and technology, easing of congestion on traditional overcrowded shipping lanes, and significant environmental benefits provide a few examples of how an integrated intermodal transportation system can provide real service and economic benefits. These concepts can be applied to military users just as easily as they currently apply to the business world. Along with the benefits, there are many challenges ahead for intermodality; which can be met by focusing on the customer, enabling efficient linkages and reduced barriers between intermediaries, harnessing new innovations and evolving critical infrastructure through effective policy.

III. Methodology

This chapter discusses the methodology used in this research to provide an analysis of the most attractive intermodal port pairs. Then, the sources of data, scenario used and the model output are discussed.

Revised Intermodal Decision Model

To evaluate the intermodal decision making process, this research proposes changes in structure and measurements to the existing model in use by U.S. TRANSCOM. Specific information for each airfield and seaport location is gathered from airfield surveys provided by U.S. SOUTHCOM as well as detailed seaport reports provided by the Military Surface Deployment and Distribution Command Transportation Engineering Agency (SDDC TEA) to minimize subjectivity within the model.

Value Focused Thinking

Since effective decision making should be done strategically, and in a way that is adapted to the ends we wish to achieve; it follows that a structured approach should be used in a formal decision making process (15:3). As such, the 10 step process shown in Figure 1.1 is used to construct this model.

Step 1: Identify the Problem

U.S. TRANSCOM has expressed interest in a model for assessing the suitability of paired seaports and airfields to support intermodal operations to drive down costs while still being effective. They specified a variety of factors to consider, including political feasibility, port quality, port-to-airfield transportation, and airfield quality. Specific questions include, what are the right factors to evaluate, what are the proper ways to measure those factors, and what are the proper ways to combine those factors to help leadership determine where to focus efforts. While a current model does exist as shown in Appendix A, there are always opportunities to capture additional criteria to improve the ultimate outcome.

Step 2: Create the Value Hierarchy

Several sources provide input to the development of the value hierarchy. One of the most important is the existing model itself; in addition to the description of the problem description above which identifies factors like political feasibility and port-to-airfield transportation that are not accounted for in this model. Additional sources include an analysis of shipping port capacity drivers in North American ports as proposed by Michael Maloni and Eric Jackson (19). Their survey based analysis provides insight into the ten most important container port capacity concerns of North American ports. These factors as shown in Table 3.1 are accounted for in the revised value model through road and rail connections, terminal staging capacity, overall port and handling infrastructure capacity, and the additional costs associated with handling and processing of cargo.

Rank	Category
1	Local Roads
2	Terminal Space
3	Local Rail
4	Longshore Efficiency
5	Truck Local
6	Berth Space
7	Available Land
8	Longshore Cost
9	Longshore Capacity
10	Rail on Dock

Table 3.1. North American Port Capacity Concerns

Content analysis by Cullinane and Toy identifies influential attributes in freight route/mode choice decisions (5). These attributes are shown in Table 3.2, and further underscore the importance of cost, security, and the relative capabilities of the mode choice. While the concepts of reliability and speed are not directly addressed in the revised model, these are assumed to be at acceptable levels for the given scenario. Furthermore, if speed were the highest priority concern, then pure air transit would be the logical choice. Instead, this model holds that significant cost savings are possible when combining the benefits offered by different modes of transport.

Rank	Category
1	Transit time reliability
2	Speed
3	Cost/Price/Rate
4	Loss/Damage
5	Capability

Table 3.2. Influential attributes in freight route/mode choice decisions

The hierarchy of the revised model, as shown in Figure 3.1, has five key concerns on the first tier which include political considerations, seaport and airport suitability, seaport and airport throughput, as well as additional cost factors. The throughput measures of the seaports and airports are further broken down into five sub-objectives. These first and second tier objectives are then broken down into 27 separate quantitative measures shown on the far right side of Figure 3.1.

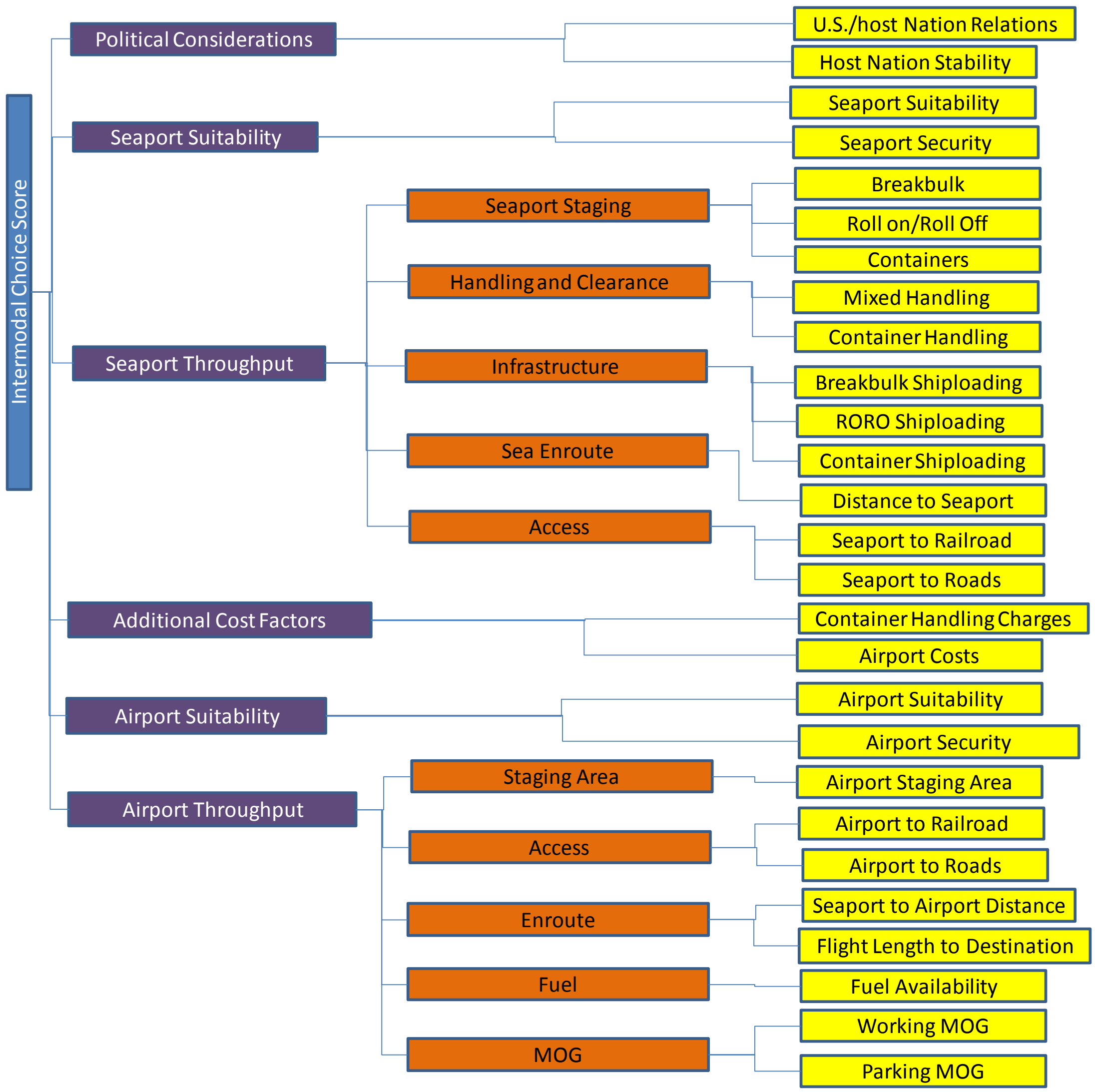


Figure 3.1. Revised Sea-Air Intermodal VFT Decision Hierarchy

There are a number of concepts that guide the development of value hierarchies, which include; "completeness, nonredundancy, independence, operability and small size" (15:16). Completeness is a function of whether each layer or tier, "adequately cover all concerns necessary to evaluate the overall objective of the decision." A value hierarchy must also be nonredundant, where no two evaluation considerations in the same layer or tier should overlap. These two properties can be summed up by saying that the evaluation considerations in each layer must be “collectively exhaustive and mutually exclusive.” Next, the value attached to variations in the level of the evaluation measures must not depend on any other measures. This independence allows combining the evaluation measures to determine an overall preferability of alternatives (15:18). Operability addresses how easy the hierarchy is to use, and how understandable it is by the end user. Lastly, a small value hierarchy is easier to communicate and requires less effort to collect data for the evaluation measures. Overall, “the quest for completeness and fine detail must be balanced against the need to finish an analysis within a realistic time frame and budget” (15:19).

Step 3: Develop Evaluation Measures

The revised intermodal value model is made up of five major attributes which include political considerations, seaport and airport suitability, seaport and airport throughput, as well as additional cost factors, which are broken down into 27 separate quantitative measures. The specific measures for this study are detailed below.

Political Considerations are the critical links between nations that can ultimately have a large impact on the stability and longevity of intermodal basing arrangements. Achieving the most politically favorable option is measured by U.S./host Nation Relations and Host Nation Stability as shown in Table 3.3. U.S./host Nation Relations are scored based on 1. open diplomatic communications 2. shared political goals 3. effective trade agreements in place and 4. shared security initiatives. An excellent rating corresponds to all four criteria present among partner countries, good corresponds to all but trade agreements, fair corresponds to only open diplomatic dialogue, and poor contains none of these criteria. This measure is obtained through foreign relations analysis provided through Country Watch. The Political Stability Index is calculated using an established methodology by Country Watch and is based on a given country's record of peaceful transitions of power, ability of a government to stay in office and carry out its policies. Threats include coups, domestic violence and instability, terrorism, etc. This index measures the dynamic between the quality of a country's government and the threats that can compromise and undermine stability. Scores are assigned from 0-10, where a score of 0 marks the lowest level of political stability, and a score of 10 marks the highest level of political stability (4).

Measure	Units of Measure	Scale	Levels and Values	Source
U.S./host Nation Relations	Categorical	Excellent Good Fair Poor	V(Excellent)=1.0 V(Good)=.66 V(Fair)=.33 V(Poor)=0	www.Countrywatch.com
Host Nation Stability	Index	0-10	V(10)=1.0 V(8)=.8 V(0)=0	www.Countrywatch.com

Table 3.3. Political Considerations Measures

Seaport suitability is the second of the key concerns in this model and addresses suitability in terms of the types of vessels it can adequately accommodate as well as the amount of security it can provide for staged and in transit cargo. Overall seaport suitability is broken down into two measures of seaport suitability and seaport security as shown in Table 3.4. The measure for seaport suitability is based on whether the port can physically accommodate and effectively load given ship types. The category of all ship types includes Large, Medium-Speed Roll-on/Roll-off Ships (LMSR's), Fast Sealift Ships (FSS's) and large container vessels which typically have lengths in excess of 900 feet and drafts greater than 34 feet. The most category contains smaller Roll-on/Roll-off, container, crane, dry cargo/ammunition, and fast combat support ships which fall into a range from 600-900 feet in length with drafts from 30-38 feet. The limited range includes ships of the same type from approximately 300-600 feet in length with shallower drafts; while the restricted range includes those ships less than 300 feet in length and drafts of approximately 20 feet or less. The restricted range includes vessel types like fleet ocean tugs and down range support ships.

The measure of seaport security is based on six separate criteria that include: 1. adequate perimeter fencing 2. armed guards 3. access to inspect goods upon arrival and exit 4. Container Security Initiative (CSI) agreement in place 5. X-ray scanning devices in use and 6. Radiological scanning devices in use. A rating of secured corresponds to all six criteria met, mostly refers to all but radiological and X-ray scanning, somewhat refers to fencing and armed guards present only, and unsecured has less than acceptable basic security initiatives like fencing and guards.

Measure	Units of Measure	Scale	Levels and Values	Source
Seaport Suitability	Categorical	All Most Limited Restricted	V(All)=1.0 V(Most)=.60 V(Limited)=.25 V(Restricted)=0	TEA assessment
Seaport Security	Categorical	Secured Mostly Somewhat Unsecured	V(Secured)=1.0 V(Mostly)=.60 V(Somewhat)=.25 V(Unsecured)=0	TEA assessment

Table 3.4. Seaport Suitability Measures

Seaport throughput is the third key concern within this model and is intended to measure the ability of the chosen seaport to effectively process, handle, store and move cargo to the next mode. This measure is made up of breakbulk, roll-on/roll-off, and container staging capacity; container and mixed handling capacity; breakbulk, roll-on/roll-off, and container shiploading capacity; distance to seaport; as well as road and rail network connections as shown in Table 3.5.

The measures for breakbulk, roll-on/roll-off, and container handling, staging and shipping capacity are based on the throughput of each port; evaluated using the Port Operational Performance Simulation (POPS). This computer model used by the SDDC TEA is based on a weak-link analysis in which each subsystem is analyzed separately and then compared to find the least capable subsystem, which then defines the maximum throughput capability of the terminal or the port. The model yields throughput capability for the three subsystems (terminal handling, staging, and shipping) measured in short tons per day (STPD) (21). The POPS output is detailed in the seaport infrastructure report compiled by SDDC TEA for the ports of this model.

The distance to seaport measure is the sea distance in nautical miles based on the standard sea routes for commercial shipping traffic. This measure penalizes destinations over 3000 NM based on the theater in question and decision maker input. For the purposes of this model, all Central American ports on the Pacific Ocean side are supplied by the U.S. port of Los Angeles/Long Beach, and all Atlantic Ocean facing Central American and Caribbean ports are supplied by the U.S. port of Savannah, Georgia. In the case of east coast U.S. ports shipping to west coast Central American ports and vice versa, the additional costs of transiting the Panama Canal should be added to the shipping cost factor.

The last two measures of seaport road and rail connections assess the level of ground transport connectivity; based on seaport surveys, TEA assessments and reference to rail and road network maps for each country of analysis. The seaport to rail measure is based on the proximity of the seaport to the nearest railhead of suitable capability and service direction. If the line is either assessed as not suitable or does not provide service in the direction of the paired airport, then the measure is set to a zero value of 100 NM. The seaport to road measure classifies the type of road quality that predominates from the seaport to the halfway point between the airport pair and itself.

Measure	Units of Measure	Scale	Levels and Values	Source
Breakbulk Staging	STPD[1]	0-70000	V(70,000)=1.0 V(20,000)=.8 V(0)=0	TEA assessment
RO/RO[3] Staging	STPD[1]	0-70000	V(70,000)=1.0 V(20,000)=.8 V(0)=0	TEA assessment
Container Staging	STPD[1]	0-70000	V(70,000)=1.0 V(20,000)=.8 V(0)=0	TEA assessment
Mixed Handling	STPD[1]	0-35000	V(35,000)=1.0 V(10,000)=.8 V(0)=0	TEA assessment
Container Handling	STPD[1]	0-35000	V(35,000)=1.0 V(10,000)=.8 V(0)=0	TEA assessment
Breakbulk Shiploading	STPD[1]	0-35000	V(35,000)=1.0 V(10,000)=.8 V(0)=0	TEA assessment
RO/RO[3] Shiploading	STPD[1]	0-35000	V(35,000)=1.0 V(10,000)=.8 V(0)=0	TEA assessment
Container Shiploading	STPD[1]	0-35000	V(35,000)=1.0 V(10,000)=.8 V(0)=0	TEA assessment
Distance to Seaport	NM[2]	0-10000	V(0)=1.0 V(3,000)=.8 V(10,000)=0	www.Ports.com
Seaport to Rail network	NM[2]	0-100	V(0)=1.0 V(10)=.8 V(100)=0	TEA assessment
Seaport to Road network	Categorical	4 Lane Highway 2 Lane Highway Surface None	V(4 Lane Highway)=1.0 V(2 Lane Highway)=.80 V(Surface)=.25 V(None)=0	Airfield survey

Notes:
1. STPD = Short Tons Per Day
2. NM = Nautical Miles
3. RO/RO = Roll on/Roll off

Table 3.5. Seaport Throughput Measures

The fourth area of concern for this decision model is entitled Additional Cost Factors and is comprised of container handling and airport costs as shown in Table 3.6. The container handling charges in this model are World Bank estimates of the fees levied on a 20-foot container imported to the host country in U.S. dollars (31). All fees associated with completing the procedures to export or import the goods are included. These include costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport. The cost measure does not include tariffs or trade taxes and only official costs are recorded (31). For the purposes of this model, each TEU is assumed to average approximately 50,000 pounds gross weight; and the fees assessed on breakbulk and rolling stock cargo are assumed to hold roughly to this same ratio. As previously mentioned, any additional overall cost factors for shipping unique to the specific port alternative can be allocated on a per TEU basis. Airport costs are a measure of the additional costs for documents, administrative fees for customs clearance, landing fees, air navigation fees, aircraft servicing fees and other additional costs. The airport costs for this model are assigned on a per mission basis and are comprised of the sum of all average known fees excluding aircraft operating costs and fuel.

Measure	Units of Measure	Scale	Levels and Values	Source
Container Handling Charges	\$/TEU[1]	0-2500	V(0)=1.0 V(1,300)=.8 V(2,500)=0	www.worldbank.org
Airport Costs	\$	0-50000	V(0)=1.0 V(10,000)=.8 V(50,000)=0	Airfield Survey

Notes:
1. TEU = Twenty Foot Equivalent Unit

Table 3.6. Additional Cost Factor Measures

The fifth area of concern deals with airport suitability as shown in Table 3.7. This tier is further broken down into airport suitability and airport security measures. Airport suitability is measured through airfield surveys and suitability reports provided by Air Mobility Command's (AMC) Tanker Airlift Control Center (TACC). The category for all is comprised of C-5 and smaller aircraft, most is defined as C-17s and smaller, and limited is based on C-130s and smaller. The restricted category represents the lowest valued option that would provide less than C-130 capability. Suitability is based on runway length and weight bearing capacity, obstacles around the airfield, as well as the weight bearing suitability of the parking aprons.

While suitability is a key component of the attractiveness of a prospective airport, adequate security is another critical concern. This measure is based on airfield survey data and consists of four main criteria: 1. Adequate fencing and access controls 2. Armed security guards 3. Security patrols and nearby response capable police forces 4. Military Installation. The highest valued option of secured meets all four criteria; while mostly secured meets all but the military installation criteria. A rating of somewhat secured is defined by the existence of only adequate fencing and armed guards; where unsecured does not even meet the most basic security measures.

Measure	Units of Measure	Scale	Levels and Values	Source
Airport Suitability	Categorical	All Most Limited Restricted	V(All)=1.0 V(Most)=.60 V(Limited)=.25 V(Restricted)=0	TACC/ASRR
Airport Security	Categorical	Secured Mostly Somewhat Unsecured	V(Secured)=1.0 V(Mostly)=.60 V(Somewhat)=.25 V(Unsecured)=0	Airfield survey

Table 3.7. Airport Suitability Measures

The last area of focus for the revised model assesses airport throughput as shown in Table 3.8. These measures include airfield staging capacity, airport access to road and rail networks, distance between the seaport and airport, flight length to destination, airfield fuel availability, and the maximum parking and working capacity of the airfield.

The first measure of airfield staging capacity is based on availability, where the available level corresponds to a staging capacity greater than 100 short tons or 200,000 pounds. Having adequate staging capability allows preparation of outbound cargo for air shipment, and 200,000 pounds is roughly equal to the cargo capacity of one short range (~<1500 NM) C-17 mission. The limited category has capacity for 100 or less short tons, while unknown means that staging is either unknown or not available for use.

The next two measures of seaport road and rail connections assess the level of ground transport connectivity; based on airfield surveys and reference to rail and road network maps for each country of analysis. The airport to rail measure is based on the proximity of the airport to the nearest railhead of suitable capability and service direction. If the line is either assessed as not suitable or does not provide service in the direction of the paired seaport, then the measure is set to a zero value of 100 NM. The airport to road measure classifies the type of road quality that predominates from the airport to the halfway point between the seaport pair and itself.

The seaport to airport distance measures the ground distance between the port pairs based on the most direct and efficient route using either road or rail networks based on availability.

Flight length to destination is based on nautical miles from the intermodal airport pair to the destination airport. The distance is measured in nautical miles, based on great circle routing, which is the shortest distance between any two points on the globe (29). An accepted C-17 planning distance of 3,500 nm for maximum nominal range with a load of 45 short tons or 90,000 pounds is the current estimate in use by AMC. (30:19). This model penalizes destinations greater than 3000 nm from the airport of embarkation, and 1,500 nm represents the decision maker's 80% value decision for this theater. A distance of 2,500 nm allows a C-17 to carry approximately 190,000 pounds to the destination and return within a crew duty time that allows a basic crew of only three based on the limitations of AFI 11-2C-17V3. This estimate is based on an average enroute speed of 7.8nm/minute with crew alert and intermediate ground times of 2 hours and 45 minutes.

Fuel availability measures the average daily on-hand storage capacities of fuel at each airport for airlift aircraft. Fuel is a critical factor in airfield throughput analysis, and can significantly limit operations if unavailable. Data for this measure is gathered from airfield surveys in addition to TRANSCOM Joint Petroleum Office (JPO) estimates of storage capacity. Rapid resupply capability within acceptable lead times could be factored in to measure an estimate of average daily availability during lead time.

Maximum on Ground Parking (MOG) is divided in two separate measures of Working MOG and Parking MOG. Working MOG represents the number of C-17s and C-5s that can receive fueling, loading and unloading or maintenance at the same time; whereas Parking MOG is only a measure of the number of aircraft that can be parked at the same time within the confines of the airfield. Parking MOG is generally stable and is based on the limits of the airfield, but Working MOG can improve dramatically with additional personnel and resources. This revised model considers current assessed

Working MOG levels available at each airfield without significant augmentation, and further uses only C-17s for calculations. One C-17 is assumed to equal two C-130s and two C-17s are assumed equal to one C-5.

Measure	Units of Measure	Scale	Levels and Values	Source
Airfield Staging Area	Categorical	Available Limited Unknown	V(Available)=1.0 V(Limited)=.5 V(Unknown)=0	Airfield survey
Airport to Rail network	NM[1]	0-100	V(0)=1.0 V(10)=.8 V(100)=0	Airfield survey
Airport to Road network	Categorical	4 Lane Highway 2 Lane Highway Surface None	V(4 Lane Highway)=1.0 V(2 Lane Highway)=.80 V(Surface)=.25 V(None)=0	Airfield survey
Seaport to Airport Distance	NM[1]	0-750	V(0)=1.0 V(40)=.8 V(750)=0	Google earth
Flight Length to Destination	NM[1]	0-3000	V(0)=1.0 V(1,500)=.8 V(3,000)=0	www.gcmap.com
Fuel Availability at airfield	U.S. Gal(millions)	0-5.2	V(5.2)=1.0 V(0.5)=.8 V(0)=0	Airfield Survey/ JPO estimate
Working MOG[2]	Airplanes	0-10	V(10)=1.0 V(2)=.8 V(0)=0	Airfield Survey
Parking MOG[2]	Airplanes	0-20	V(20)=1.0 V(6)=.8 V(0)=0	Airfield Survey

Notes:
1. NM = Nautical Miles
2. MOG = Maximum on Ground

Table 3.8. Airport Throughput Measures

Step 4: Create Value Functions

A value function is necessary when conducting a multiobjective value analysis, and this function combines the multiple evaluation measures into a single measure of the overall value of each evaluation alternative. This is accomplished by specifying single dimensional value functions (SDVF) for each evaluation measure, and applying weights to each one (15:53). The technique for this research uses an interview document to gain inputs from the decision maker or subject matter expert (SME) to build the SDVF. For continuous measures, the SME is asked to determine the level that represents 80% value for attainment of a specific measure. This process is then repeated across all additional continuous measures. For discrete measures, the SME is asked to rate the value of each level on a scale from zero to one for each separate measure. All SDVFs used in this revised model are included in Appendix D.

Step 5: Weight Value Hierarchy

All individual measures and objectives within the hierarchy are not of equal importance. It is also necessary to interview the decision maker to determine their preferences for relative levels of importance between measures and objectives. Appendix B shows the resulting local and global weights based on decision maker input.

Step 6: Alternative Generation

The alternatives for this intermodal pairing decision are based on airfield surveys and seaport simulation output available for the SOUTHCOM theater. All possible attractive alternatives are not included in this analysis due to the lack of available data sources. The chosen airfields and seaports are evaluated on their relative levels of attainment of the chosen measures and objectives. The alternatives chosen include the most attractive ports within the Central American and Caribbean countries with available data.

Step 7: Alternative Scoring

The alternatives scored for the real world analysis are comprised of 11 airports and 6 seaports within the SOUTHCOM AOR with survey data available. To illustrate differences between the original and revised model, an additional data set is scored based on notional port alternatives. This theoretical data set is scored to illustrate the potential benefits of the revised model to account for additional sources of value not included in the original model.

Steps 8, 9; Deterministic Analysis, and Sensitivity Analysis; are presented in Chapter IV. Step 10, Recommendations, are presented in Chapter V.

Scenario Set Up

To assess the suitability of intermodal port pairs, this scenario focuses on response to a simulated crisis in the SOUTHCOM theater by establishing intermodal options to support ongoing sustainment. In this case, the crisis response area is located in central South America in and around the landlocked country of Bolivia. The initial rapid response phase is assumed to be complete, allowing longer lead time operations to fill resupply needs. Cargo flows are assumed to begin from the ports of Long Beach on the U.S. west coast and the port of Savannah, Georgia on the U.S. east coast. This shipborne cargo then arrives at one of six seaports in Central America that include Guantanamo Bay, Cuba; San Lorenzo and Puerto Cortes, Honduras; Manzanillo, Balboa and Cristobal, Panama. From these ports, the cargo will flow to the best airport pairing and then on to the final destination. The eleven intermodal airports included in this scenario are Guantanamo Bay NS, Cuba; Ilopango Intl and Comalapa AB, El Salvador; Trujillo, La Chieba, Toncontin Intl, Soto Cano AB, and La Mesa, Honduras; and Tocumen Intl, Howard, Albrook, Panama. From these intermodal airport pairs, the cargo flows to the final destination of Viru Viru International Airport in Santa Cruz, Boliva. Figure 3.2 shows a map of the origins and destinations considered in this research. Appendix C also shows closer views of the intermodal alternatives considered for this scenario.

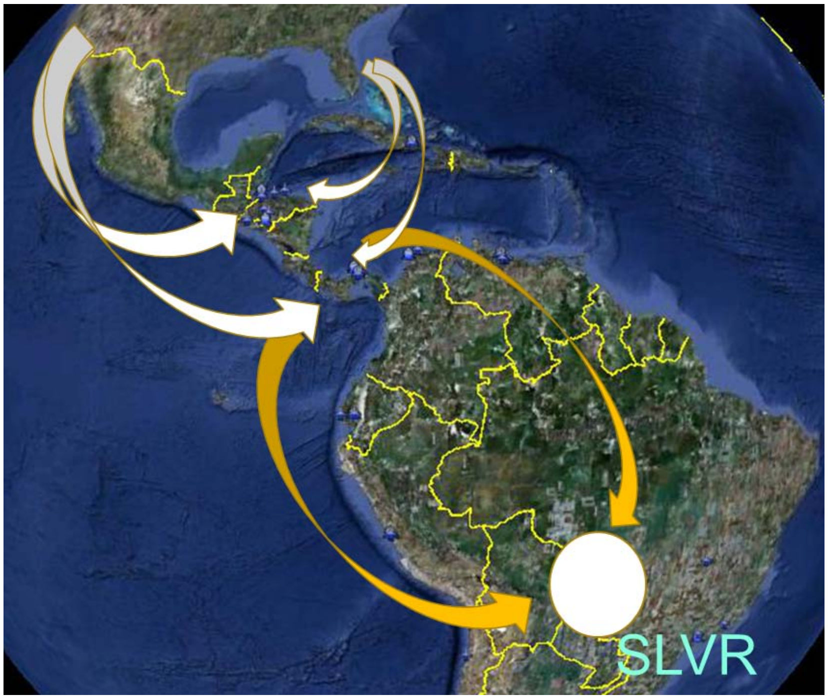


Figure 3.2. Origins and Destinations

Model Outputs

This model looks at the most feasible alternatives using the six seaports and eleven airports. Each intermodal port pair is evaluated on how well they meet each of the measures and then the alternatives are ranked from highest to lowest score for the overall model output. The resulting 24 alternatives are then compared to the existing TRANSCOM model outputs for the same alternative set. Sensitivity analysis on the revised model weights will assess how these alternative rankings change based on decision maker priorities. Finally notional alternatives are created and input into both models for comparison. The results of the revised model developed in Chapter III are shown next in Chapter IV. This output shows the best currently assessed alternative for intermodal operations in U.S. SOUTHCOM as well as the improved responsiveness of the revised model.

IV. Results and Analysis

Introduction

This intermodal decision model produces a rank ordered evaluation of 11 airports and 6 seaports in the U.S. SOUTHCOM theater. This section reviews the results of the revised intermodal model with this real world data; which are then compared to the existing model results with the same data set. In addition to output comparison, a discussion of problems with internal scale consistency in the existing model is presented. Finally, this section presents an analysis of revised model sensitivity based on changing weights assigned to different cargo types, followed by analysis of the maximum theoretical differences between the models with notional port data. Appendix E shows all graphic model results as well as overall output comparison.

Results

The revised model shows the top ranked choice Port of Manzanillo in Panama, with Tocumen International airport as the most valued intermodal pair. Overall, options within Panama represent the top ten ranked alternatives with the exception of Puerto Cortes/Soto Cano AB as the seventh ranked option. With the amount of weight placed on Political Considerations at 40%, this measure represents not only the majority of the value in the revised model, but also the most variation among alternatives with a mean of 33.4% and standard deviation of 4.8%. Other sources of variation among alternatives are accounted for in airport suitability (μ 6.8%, s.d.2.6%) and airport throughput (μ 7.3%, s.d.1.6%). The options in Panama gain large amounts of value based on heavy decision maker weighting for flight length to destination as well as handling, staging and shiploading for containerized cargo. The options in Panama represent excellent alternatives not only because they are require less flight time to the destination and have good political conditions, but because they have high seaport throughput capacity; with the Port of Manzanillo as the clear winner for containerized cargo and the Port of Cristobal as a close second. The revised model results are shown in Figure 4.1.

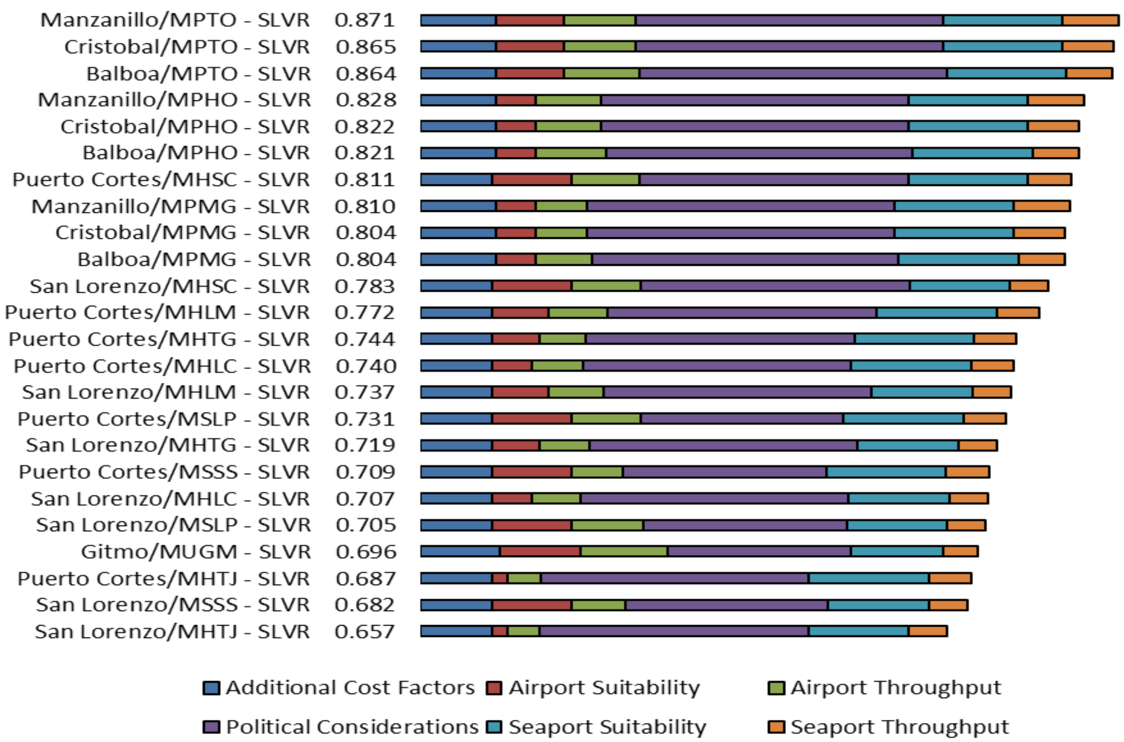


Figure 4.1. Revised Model Results

Original Intermodal Decision Model

The results of the original U.S. TRANSCOM model are shown in Figure 4.2. The results differ from the revised model, and those differences are discussed next. Overall, the current model has a greater mixture of alternatives from the three focus areas, with six of the top ten representing Panamanian options, three options in Honduras/El Salvador and the tenth ranked option representing the Cuban pair at Guantanamo Bay. The largest sources of variation among alternatives are accounted for in airport suitability (mean 11.3%, std dev 5.4%) and airfield security (mean 6.1%, std dev 3.4%).

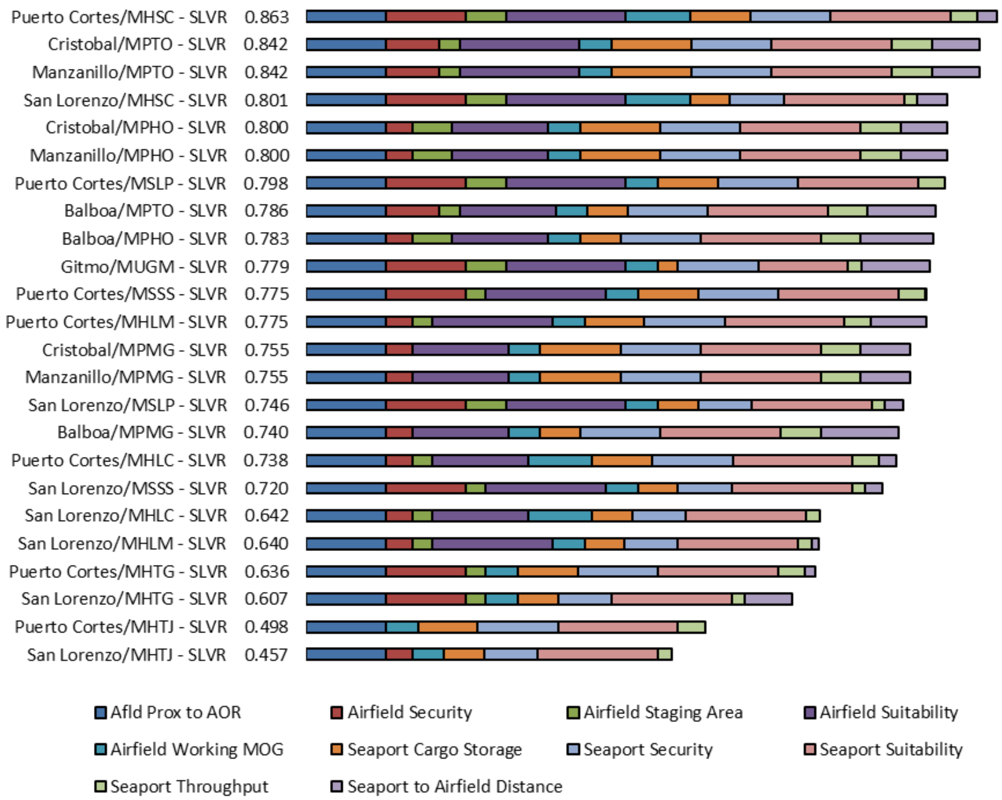


Figure 4.2. Original Model Results

Comparison

Side by side comparison of the output from the two models is shown in Table 4.1. The color coded comparison shows the original model results on the left side and the revised model on the right. The top half of ranked alternatives is assigned a unique color in the original model column, and those same colors are used for the corresponding alternative on the revised model side to highlight major differences between the two. The differences are attributable to two factors, one being the weight assigned by the decision maker to political considerations in the revised model. This concern takes three specific alternatives of Puerto Cortes/MSLP (Comalapa AB), Puerto Cortes/MSSS (Ilopango Intl) and Gitmo/MUGM (Guantanamo Bay NS) and ranks them significantly lower based on lower quality of U.S. Foreign relations with El Salvador (MSSS & MSLP airfields) and lower values for Host Nation Stability of Cuba and Honduras. This factor alone accounts for one of the primary reasons why Puerto Cortes/MHSC (Soto Cano AB) is lowered from the winning alternative in the original to the seventh ranked option in the revised model. The second major factor that accounts for differences is the way in which the revised model disaggregates different types of cargo categories to uncover strong and weak points of seaport throughput. Based on clear preferences for containerized cargo by the decision maker's weights in the revised model; the port of Manzanillo, Panama has a clear advantage over all other alternatives in terms of loading, storing and clearing containerized cargo. The port of Cristobal, Panama maintains a consistent second place in the container cargo measure, with Puerto Cortes, Honduras in third place.

Original model		Revised Model	
Puerto Cortes/MHSC - SLVR	0.863	Manzanillo/MPTO - SLVR	0.871
Cristobal/MPTO - SLVR	0.842	Cristobal/MPTO - SLVR	0.865
Manzanillo/MPTO - SLVR	0.842	Balboa/MPTO - SLVR	0.864
San Lorenzo/MHSC - SLVR	0.801	Manzanillo/MPHO - SLVR	0.828
Cristobal/MPHO - SLVR	0.800	Cristobal/MPHO - SLVR	0.822
Manzanillo/MPHO - SLVR	0.800	Balboa/MPHO - SLVR	0.821
Puerto Cortes/MSLP - SLVR	0.798	Puerto Cortes/MHSC - SLVR	0.811
Balboa/MPTO - SLVR	0.786	Manzanillo/MPMG - SLVR	0.810
Balboa/MPHO - SLVR	0.783	Cristobal/MPMG - SLVR	0.804
Gitmo/MUGM - SLVR	0.779	Balboa/MPMG - SLVR	0.804
Puerto Cortes/MSSS - SLVR	0.775	San Lorenzo/MHSC - SLVR	0.783
Puerto Cortes/MHLM - SLVR	0.775	Puerto Cortes/MHLM - SLVR	0.772
Cristobal/MPMG - SLVR	0.755	Puerto Cortes/MHTG - SLVR	0.744
Manzanillo/MPMG - SLVR	0.755	Puerto Cortes/MHLC - SLVR	0.740
San Lorenzo/MSLP - SLVR	0.746	San Lorenzo/MHLM - SLVR	0.737
Balboa/MPMG - SLVR	0.740	Puerto Cortes/MSLP - SLVR	0.731
Puerto Cortes/MHLC - SLVR	0.738	San Lorenzo/MHTG - SLVR	0.719
San Lorenzo/MSSS - SLVR	0.720	Puerto Cortes/MSSS - SLVR	0.709
San Lorenzo/MHLC - SLVR	0.642	San Lorenzo/MHLC - SLVR	0.707
San Lorenzo/MHLM - SLVR	0.640	San Lorenzo/MSLP - SLVR	0.705
Puerto Cortes/MHTG - SLVR	0.636	Gitmo/MUGM - SLVR	0.696
San Lorenzo/MHTG - SLVR	0.607	Puerto Cortes/MHTJ - SLVR	0.687
Puerto Cortes/MHTJ - SLVR	0.498	San Lorenzo/MSSS - SLVR	0.682
San Lorenzo/MHTJ - SLVR	0.457	San Lorenzo/MHTJ - SLVR	0.657

Table 4.1. Original vs Revised Model Results

Assessment of Scale Internal Consistency

In addition to differences already highlighted, there are others which require further analysis. One such difference is the inconsistent scale across measures the current model suffers from. Table 4.2 shows an example of how holding all internal measures with a constant scale from 0 to 1 in terms of value on the x-axis will yield consistent weights that are in accordance with decision makers preferences. In this example, all other measures are held at the lowest value of 0 while scoring each measure individually at their highest value of 1. By summing the products of each row's weight and value, each row is exactly equal to that measure's weight with no deviations. Finally, dividing the sum of all products of weight and value shows no errors in the proportions.

	Seaport Suitability	Seaport Security	Seaport to Afld Dist	Seaport Throughput	Seaport Cargo Storage	Afld Suitability	Afld Working MOG	Afld Staging Area	Arfld Prox to AOR	Airfield Security	sum w*v	sum w*v/sum
Weights	0.15	0.1	0.1	0.05	0.1	0.15	0.1	0.05	0.1	0.1		
	0	0	0	0	0	0	0	0	0	1	0.1	0.1
	0	0	0	0	0	0	0	0	1	0	0.1	0.1
M	0	0	0	0	0	0	0	1	0	0	0.05	0.05
e	0	0	0	0	0	0	1	0	0	0	0.1	0.1
a	0	0	0	0	0	1	0	0	0	0	0.15	0.15
s	0	0	0	0	1	0	0	0	0	0	0.1	0.1
u	0	0	0	1	0	0	0	0	0	0	0.05	0.05
r	0	0	1	0	0	0	0	0	0	0	0.1	0.1
e	0	1	0	0	0	0	0	0	0	0	0.1	0.1
s	1	0	0	0	0	0	0	0	0	0	0.15	0.15

Table 4.2. Consistent Scale Across Measures-Example

In the current model however, all measures do not hold to this constant scale, and this issue yields deviations in the true weights assigned to measures. An example of this concept is shown in Table 4.3, which shows the values assigned to the measures of Seaport Throughput and Seaport Cargo Storage have values at their lowest levels of 33% and 25% respectively. By applying the same procedure to this set of weights and values, we can see the deviations that result in the difference between the sum of the products of weights and values and their proportional relation. The deviations are not excessively large, but they essentially change the decision maker's true values. Based on decision maker preference, the weight for seaport suitability is supposed to be three times as important as airfield staging; but with the inconsistent scaling issue, seaport suitability is only 2.1 times more important than airfield staging. In another example, the weight for airfield suitability is supposed to be three times that of seaport throughput, but the true proportion is 2.55 based on inconsistent scaling across measures. This concept, further illustrated in Figure 4.4 represents a shortcoming of the current model which is easily corrected by changing these two measures. This error accounts for a portion of higher rankings for Guantanamo Bay and San Lorenzo in the original model relative to the revised; where both ports have low seaport throughput ratings in the original model.

	Seaport Suitability	Seaport Security	Seaport to Afld Dist	Seaport Throughput	Seaport Cargo Storage	Afld Suitability	Afld Working MOG	Afld Staging Area	Arfld Prox to AOR	Airfield Security	sum w*v	sum w*v/sum	Original Weights	Weight Difference
Weights	0.15	0.1	0.1	0.05	0.1	0.15	0.1	0.05	0.1	0.1				
	0	0	0	0.33	0.25	0	0	0	0	1	0.1415	0.1030	0.1	0.003
	0	0	0	0.33	0.25	0	0	0	1	0	0.1415	0.1030	0.1	0.003
M	0	0	0	0.33	0.25	0	0	1	0	0	0.0915	0.0666	0.05	0.017
e	0	0	0	0.33	0.25	0	1	0	0	0	0.1415	0.1030	0.1	0.003
a	0	0	0	0.33	0.25	1	0	0	0	0	0.1915	0.1394	0.15	-0.011
s	0	0	0	0.33	1	0	0	0	0	0	0.1165	0.0848	0.1	-0.015
u	0	0	0	1	0.25	0	0	0	0	0	0.075	0.0546	0.05	0.005
r	0	0	1	0.33	0.25	0	0	0	0	0	0.1415	0.1030	0.1	0.003
e	0	1	0	0.33	0.25	0	0	0	0	0	0.1415	0.1030	0.1	0.003
s	1	0	0	0.33	0.25	0	0	0	0	0	0.1915	0.1394	0.15	-0.011
										Sum	1.3735	1	1	

Table 4.3. Current Model Scale Inconsistency Across Measures

	Intended Weigh	Actual Weight	Percent Difference
Airfield Security	10.00%	10.30%	3%
Airfield Proximity to AOR	10.00%	10.30%	3%
Airfield Staging Area	5.00%	6.66%	33%
Airfield Working MOG	10.00%	10.30%	3%
Airfield Suitability	15.00%	13.94%	-7%
Seaport Cargo Storage	10.00%	8.48%	-15%
Seaport Throughput	5.00%	5.46%	9%
Seaport to Airfield Distance	10.00%	10.30%	3%
Seaport Security	10.00%	10.30%	3%
Seaport Suitability	15.00%	13.94%	-7%
Sum	100.00%	100.00%	

Table 4.4. Current Model Weight Deviations

Analysis

Further analysis of the revised model is presented to show the sensitivity of this model to account for varying decision maker preferences of cargo type. The graphic model output is shown in Figure 4.3, which shows the revised model output on the left. The weights for all container throughput measures are next set to 100% for seaport shiploading, handling and staging as shown in the second column. The same procedure is then repeated for roll-On roll-Off cargo, followed by breakbulk; with their output in columns three and four. The output reveals that the model is sensitive to changes in the cargo type required by the operation, and can be specified by the decision maker based on assigned weights. In the case of container preference, the revised model with current weights is virtually identical to the revised model with 100% emphasis on containers.

Revised Model	Revised Model- Containers	Revised Model- Roll On Roll Off	Revised Model- Breakbulk
Manzanillo/MPTO - SLVR 0.871	Manzanillo/MPTO - SLVR 0.874	Balboa/MPTO - SLVR 0.874	Balboa/MPTO - SLVR 0.871
Cristobal/MPTO - SLVR 0.865	Cristobal/MPTO - SLVR 0.862	Cristobal/MPTO - SLVR 0.870	Cristobal/MPTO - SLVR 0.868
Balboa/MPTO - SLVR 0.864	Balboa/MPTO - SLVR 0.857	Manzanillo/MPTO - SLVR 0.868	Manzanillo/MPTO - SLVR 0.864
Manzanillo/MPHO - SLVR 0.828	Manzanillo/MPHO - SLVR 0.831	Balboa/MPHO - SLVR 0.832	Balboa/MPHO - SLVR 0.829
Cristobal/MPHO - SLVR 0.822	Cristobal/MPHO - SLVR 0.819	Cristobal/MPHO - SLVR 0.828	Cristobal/MPHO - SLVR 0.825
Balboa/MPHO - SLVR 0.821	Puerto Cortes/MHSC - SLVR 0.816	Manzanillo/MPHO - SLVR 0.825	Manzanillo/MPHO - SLVR 0.821
Puerto Cortes/MHSC - SLVR 0.811	Balboa/MPHO - SLVR 0.815	Balboa/MPMG - SLVR 0.814	Balboa/MPMG - SLVR 0.812
Manzanillo/MPMG - SLVR 0.810	Manzanillo/MPMG - SLVR 0.813	Cristobal/MPMG - SLVR 0.810	Puerto Cortes/MHSC - SLVR 0.810
Cristobal/MPMG - SLVR 0.804	Cristobal/MPMG - SLVR 0.801	Manzanillo/MPMG - SLVR 0.807	Cristobal/MPMG - SLVR 0.807
Balboa/MPMG - SLVR 0.804	Balboa/MPMG - SLVR 0.797	Puerto Cortes/MHSC - SLVR 0.805	Manzanillo/MPMG - SLVR 0.803
San Lorenzo/MHSC - SLVR 0.783	San Lorenzo/MHSC - SLVR 0.787	San Lorenzo/MHSC - SLVR 0.779	San Lorenzo/MHSC - SLVR 0.777
Puerto Cortes/MHLM - SLVR 0.772	Puerto Cortes/MHLM - SLVR 0.777	Puerto Cortes/MHLM - SLVR 0.765	Puerto Cortes/MHLM - SLVR 0.770
Puerto Cortes/MHTG - SLVR 0.744	Puerto Cortes/MHTG - SLVR 0.749	Puerto Cortes/MHTG - SLVR 0.737	Puerto Cortes/MHTG - SLVR 0.743
Puerto Cortes/MHLC - SLVR 0.740	Puerto Cortes/MHLC - SLVR 0.745	Puerto Cortes/MHLC - SLVR 0.734	Puerto Cortes/MHLC - SLVR 0.739
San Lorenzo/MHLM - SLVR 0.737	San Lorenzo/MHLM - SLVR 0.741	San Lorenzo/MHLM - SLVR 0.733	San Lorenzo/MHLM - SLVR 0.731
Puerto Cortes/MSLP - SLVR 0.731	Puerto Cortes/MSLP - SLVR 0.736	Puerto Cortes/MSLP - SLVR 0.724	Puerto Cortes/MSLP - SLVR 0.730
San Lorenzo/MHTG - SLVR 0.719	San Lorenzo/MHTG - SLVR 0.723	San Lorenzo/MHTG - SLVR 0.715	San Lorenzo/MHTG - SLVR 0.713
Puerto Cortes/MSSS - SLVR 0.709	Puerto Cortes/MSSS - SLVR 0.714	San Lorenzo/MHLC - SLVR 0.703	Puerto Cortes/MSSS - SLVR 0.708
San Lorenzo/MHLC - SLVR 0.707	San Lorenzo/MHLC - SLVR 0.711	Puerto Cortes/MSSS - SLVR 0.702	San Lorenzo/MHLC - SLVR 0.701
San Lorenzo/MSLP - SLVR 0.705	San Lorenzo/MSLP - SLVR 0.709	San Lorenzo/MSLP - SLVR 0.701	San Lorenzo/MSLP - SLVR 0.699
Gitmo/MUGM - SLVR 0.696	Gitmo/MUGM - SLVR 0.697	Gitmo/MUGM - SLVR 0.695	Gitmo/MUGM - SLVR 0.692
Puerto Cortes/MHTJ - SLVR 0.687	Puerto Cortes/MHTJ - SLVR 0.692	Puerto Cortes/MHTJ - SLVR 0.681	Puerto Cortes/MHTJ - SLVR 0.686
San Lorenzo/MSSS - SLVR 0.682	San Lorenzo/MSSS - SLVR 0.686	San Lorenzo/MSSS - SLVR 0.678	San Lorenzo/MSSS - SLVR 0.676
San Lorenzo/MHTJ - SLVR 0.657	San Lorenzo/MHTJ - SLVR 0.661	San Lorenzo/MHTJ - SLVR 0.653	San Lorenzo/MHTJ - SLVR 0.651

Figure 4.3. Sensitivity Analysis

In fact, equal weights among all cargo types also provide the same result as shown in the first two columns. For this containerized focus, the port of Manzanillo provides a clear advantage over the other two ports which complete the top five alternatives. Table 4.5 shows the advantage of Manzanillo over the two closest competitors expressed as a relative percentage between the three ports. In this case, Manzanillo has over 70% of the container shiploading and handling capacity, and 40.75% of the container staging capacity. Differences do arise when the weights for roll-on and roll-off as well as breakbulk cargo are changed. For both roll-on and roll-off and breakbulk cargo, the clear preference has changed to the port of Balboa; but in this case, the port of Cristobal actually has the highest measures of shiploading, handling and staging for both types of cargo. Even though the port of Cristobal leads in every category except staging, the additional value that lead to Balboa as the clear winner is attributed to better road quality and the shorter distance between the seaport and airport.

	Container Shiploading	Container Handling	Container Staging	RORO Shiploading	RORO Staging	Breakbulk Shiploading	Breakbulk Staging	Mixed Handling
Manzanillo	23,500	21,600	70,000	8,900	25,700	4,600	64,700	15,600
Balboa	1,900	3,200	32,400	19,600	5,100	7,300	12,500	23,200
Cristobal	6,100	6,000	69,400	24,800	11,000	9,800	15,700	32,300
Sum	31,500	30,800	171,800	53,300	41,800	21,700	92,900	71,100
Manzanillo	74.60%	70.13%	40.75%	16.70%	61.48%	21.20%	69.64%	21.94%
Balboa	6.03%	10.39%	18.86%	36.77%	12.20%	33.64%	13.46%	32.63%
Cristobal	19.37%	19.48%	40.40%	46.53%	26.32%	45.16%	16.90%	45.43%

Table 4.5. Port Throughput Comparison – Short Tons Per Day (STPD)

The final comparison between the original and revised models is conducted with notional data to show the total theoretical range of sensitivity or total error in alternative value that the revised model can account for over the original. Figure 4.4 shows the output for the original model based on notional intermodal alternatives. In this case, three alternatives are created which are comprised of perfect scores, median value scores, and an alternative with the lowest possible scores. This setup is designed to provide the baseline for the revised model to compare against, where all shared measures between the two are not varied from their medium levels.

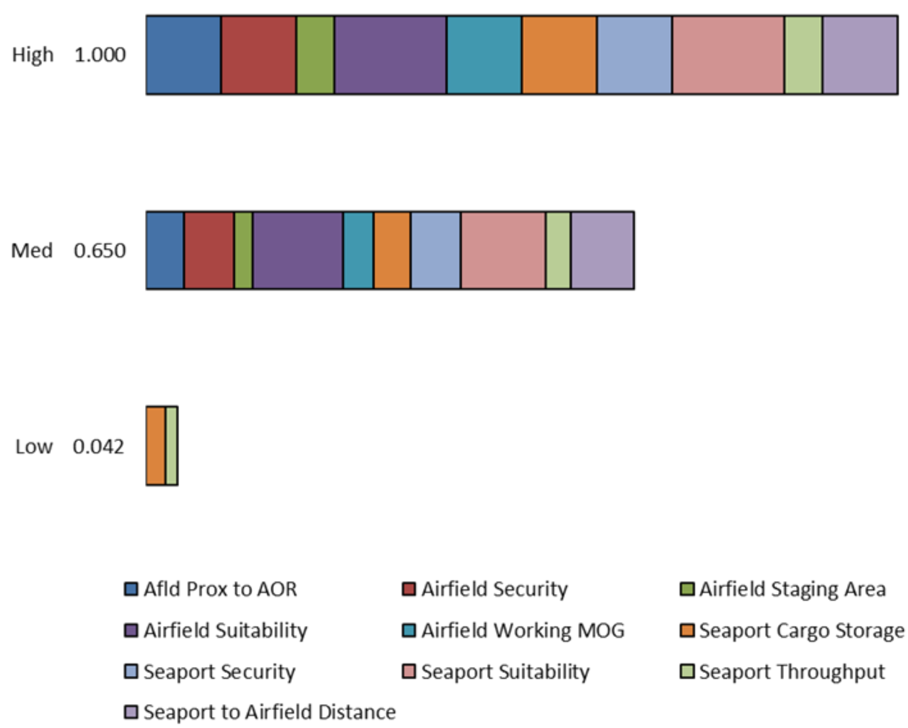


Figure 4.4. Original Model Results – Constructed Data

The next step entails taking the median scores from the original model and inputting them into the revised model. The extra evaluation measures in the revised model that are not accounted for in the original model are set at median 50% value levels as well to generate a baseline for comparison. In this case, the original model scores a median alternative at 65% value, where the revised model scores the same alternative at 63.8%

value. From this baseline, only the measures that differ from the original model are varied from the highest to lowest values based on high (100% value), medium high (75% value), medium low (25% value) and low (0% value for only those unique measures). The output from this comparison is shown in Figure 4.5. The most important take away from the comparison of the notional output is the fact that all of the alternatives from high to low in the revised model would appear identical at 65% value in the original. This comparison clearly shows the additional value the revised model can account for over and above the original.

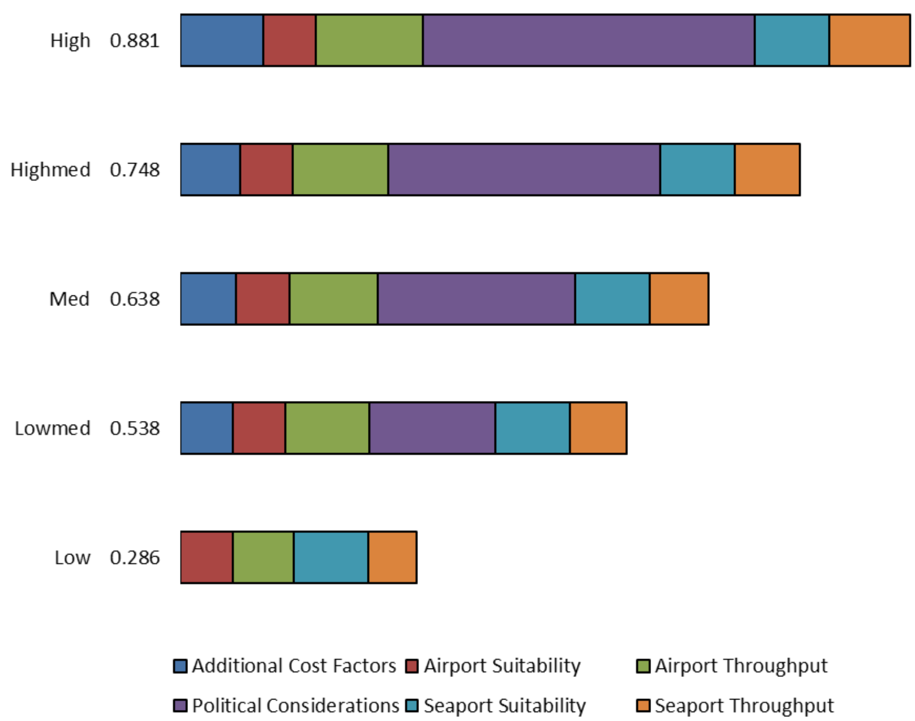


Figure 4.5. Revised Model Results – Constructed Data

V. Conclusions and Recommendations

Conclusions

Overall, comparisons based on real world data show that the revised model holds more value for Panamanian intermodal options based on shorter flight distance required, large cargo capacity, higher levels of political stability, and lower costs associated with cargo handling. Comparisons of the two show the additional value captured by the revised model as demonstrated with real world examples. Further, notional data reveals an additional 60% potential error in alternative value score can be avoided with the revised model. The revised model gives attention to critical issues like political stability, foreign relations, road and rail connectivity, and cost factors which are not addressed in the original. Capturing these additional factors in one forum could avoid the need for additional fact finding analysis after a decision with the original model. Further benefits include the lack of internal scale consistency issues with the revised model and the fact that little additional data collection is required over the current model. This is due in part to the several similar measures between the two, and because the majority of the data sources are the same. The revised model does however require detailed port survey data and throughput simulation to measure short tons per day (STPD). The last major benefit provided by the revised model is the capability of customizing decision maker preference by cargo type in terms of Containerized, Roll-On Roll-Off, and Breakbulk.

Future Research

As stated at the outset, the specific ports chosen for analysis in this study do not represent the full range of choices within the SOUTHCOM area of responsibility (AOR), but alternatives among the available data used may represent choices not previously considered and may therefore benefit from a value focused approach. Expanding this revised model with additional data port analysis tools will enable the comparison of all available alternatives within an AOR, and ultimately the ability to choose the most attractive intermodal choice for specific purposes. Future research could include combining this model and its evaluation measures with appropriate tools to measure them on a wider set of seaports and airports. By combining new tools to measure the attributes of this revised model, a much wider set of alternatives could be considered to yield the optimal intermodal choice for any theater. This choice could include intermodal port pairs for which there is limited formal SDDC TEA Port Operational Performance Simulation (POPS) data available. In addition to a port efficiency simulator, an airfield throughput model could be developed to measure throughput where limited airfield survey data is available. Combining the increased alternative set together with distribution network modeling for specific theaters could provide intermodal network planning with optimal capability and lowest overall system network costs.

Other opportunities to improve this model could incorporate decisions with uncertainty through decision maker utility functions. As Kirkwood notes about uncertainty, "When there is no uncertainty about the outcome of a decision alternative, the primary complexity in evaluating alternatives comes from the need to consider tradeoffs among the evaluation measures" (15:129). On the other hand, evaluations with uncertain outcomes require the use of utility functions to measure the decision maker's risk aversion; "Once the risk tolerance is determined, the resulting exponential utility function can be used to calculate expected utilities for more complicated alternatives, and we can rank the alternatives based on the results of these calculations" (15:139).

Future research to expand this decision model will increase the available intermodal alternative set for operational planning by U.S. TRANSCOM, U.S. SOUTHCOM and Theater Combatant Commanders worldwide. Using this VFT approach and objective measures of value will allow improved decision making even in the face of multiple competing objectives.

Appendix A. Current U.S. TRANSCOM Model

	Criteria	Measure	Scale	Source*	Weight
Seaport	Port suitability	LMSR/FSS feasibility	All, most, limited, restricted	TEA assessment	15%
	Port Security	Type/amount of security	Secured, mostly, somewhat, unsecured	TEA assessment	10%
	Port Proximity to airfield	Distance (one way)	Miles (0-200 – continuous)	NGA/TEA	10%
	Port Throughput	TEUs/STPD	High, medium, low	TEA assessment	5%
	Port Cargo Storage Yard	Square footage	Very large, large, medium, small	TEA assessment	10%
Airfield	Airfield suitability	Type of Aircraft	All (C5), limited (C17), restricted (C130)	GIDE TCJ2 smart sheets	15%
	Airfield Working MOG	# of slots	0, 1, 2, 3 +	GIDE TCJ2 smart sheets	10%
	Airfield Staging area	Square footage	Avail, limited, unknown	GIDE	5%
	Airfield Proximity to Afghanistan FOBs	C17 range (round trip)	Maximum, limited, restricted	618/TACC	10%
	Airfield security	Amount/type of security provided	Secured, mostly, somewhat, unsecured	GIDE AFFID	10%

Seaport Suitability	Seaport Security	Seaport to Airfield Distance	Seaport Throughput	Seaport Cargo Storage	Airfield Suitability	Airfield Working MOG	Airfield Staging Area	Airfield Proximity to AFG FOBs	Airfield Security	Total
15%	10%	10%	5%	10%	15%	10%	5%	10%	10%	100%
All = 100% Most = 75% Limited = 50% Restricted = 0%	Secured = 100% Mostly = 67% Somewhat = 33% Unsecured = 0%	Continuous 0 = 100% 60 = 50% 200 = 0%	High = 100% Medium = 67% Low = 33%	Very large = 100% Large = 75% Medium = 50% Small = 25%	All = 100% Limited = 80% Restricted = 0%	3+ = 100% 2 = 80% 1 = 40% 0 = 0%	Avail = 100% Limited = 50% Unk/none = 0%	Max = 100% Limited = 50% Restriced = 0%	Secured = 100% Mostly = 67% Somewhat = 33% Unsecured = 0%	

Figure 1. U.S. TRANSCOM model

Appendix B. Revised Model Local and Global Hierarchy Weights

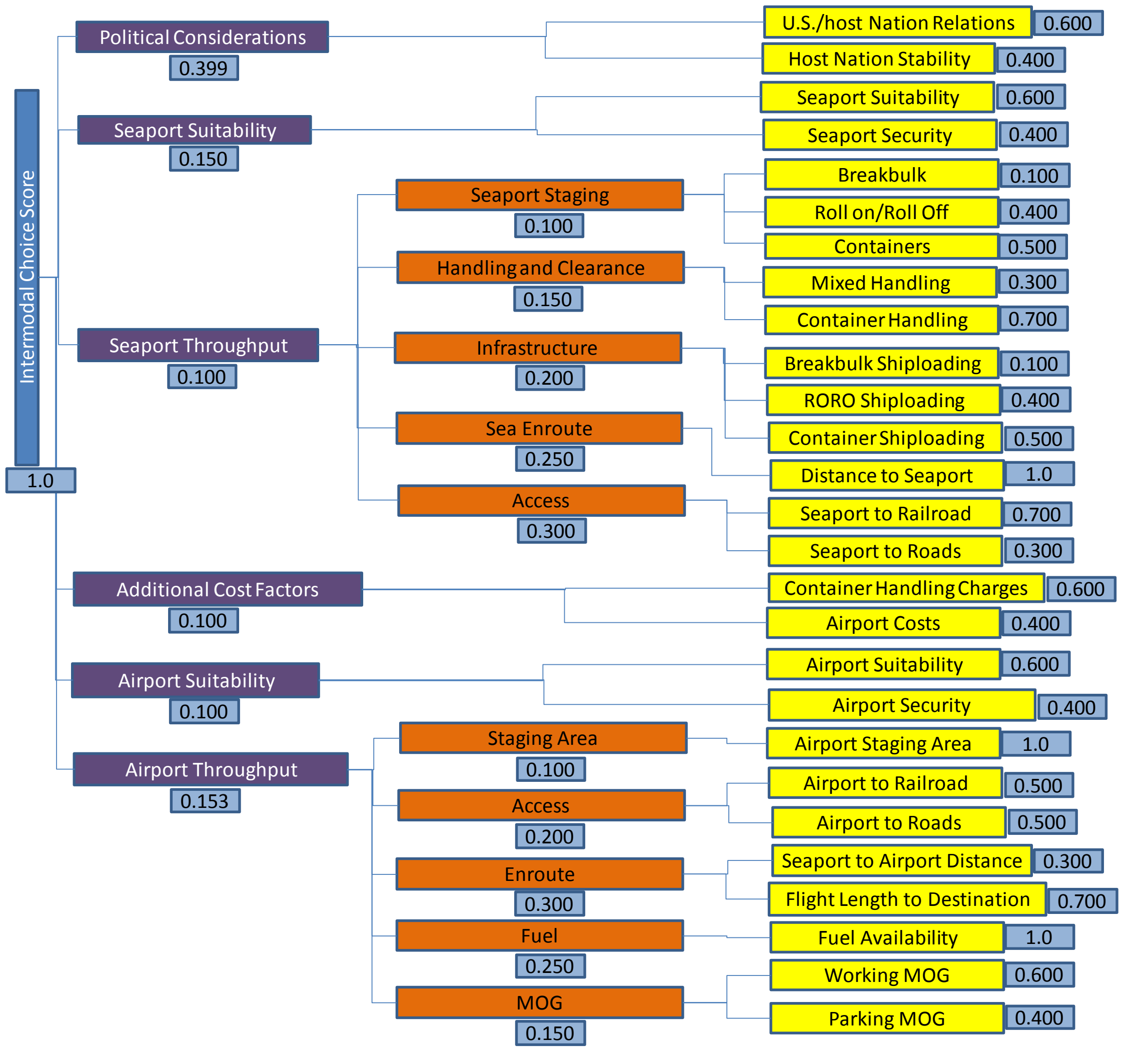


Figure 1. Local Hierarchy Weights

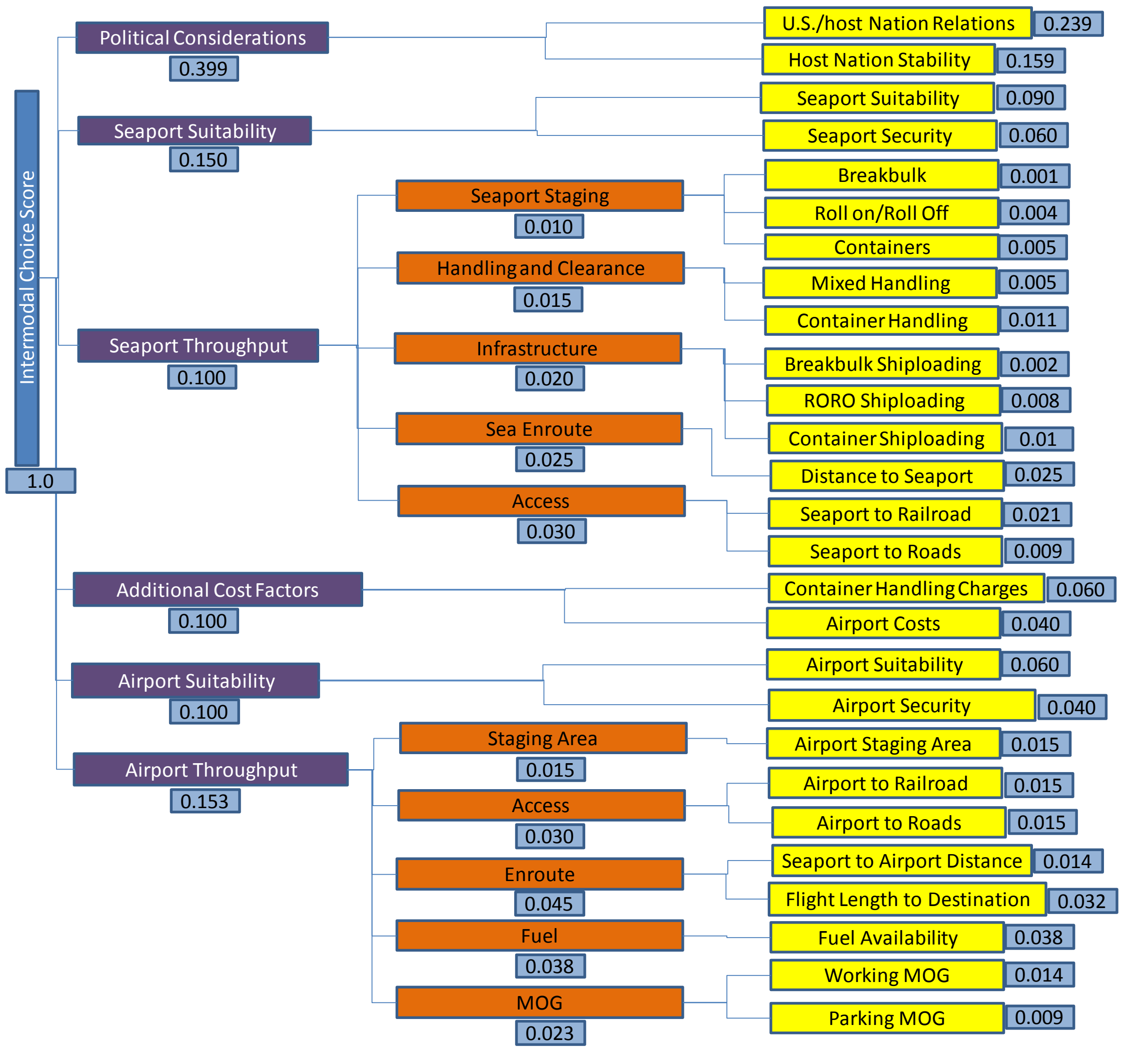


Figure 2. Global Hierarchy Weights

Appendix C. Scenario Airfields and Seaports

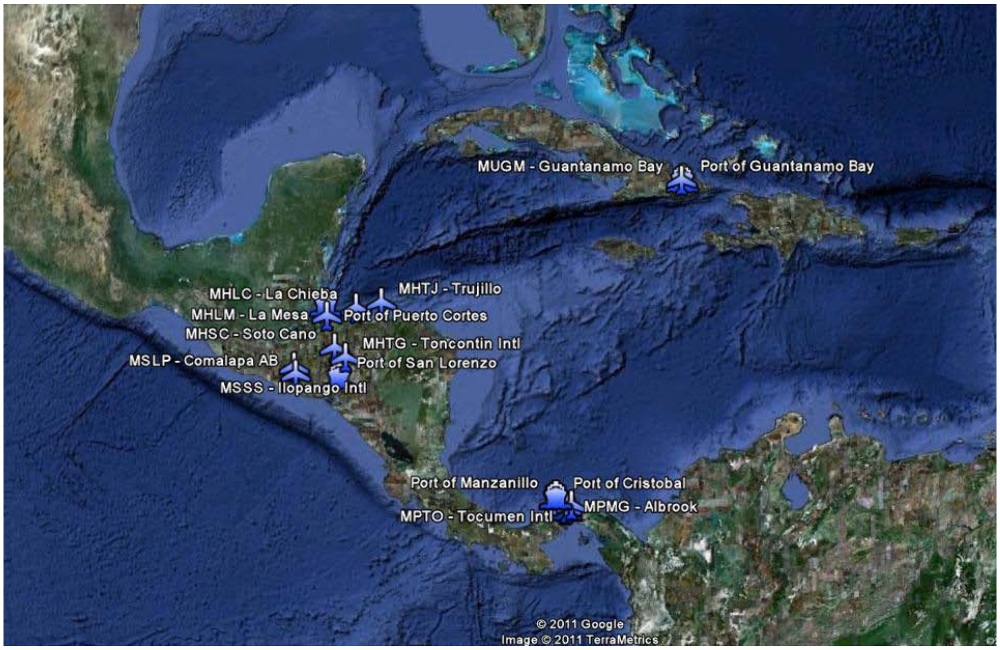


Figure 1. All scenario ports

Figure 2. Cuba ports

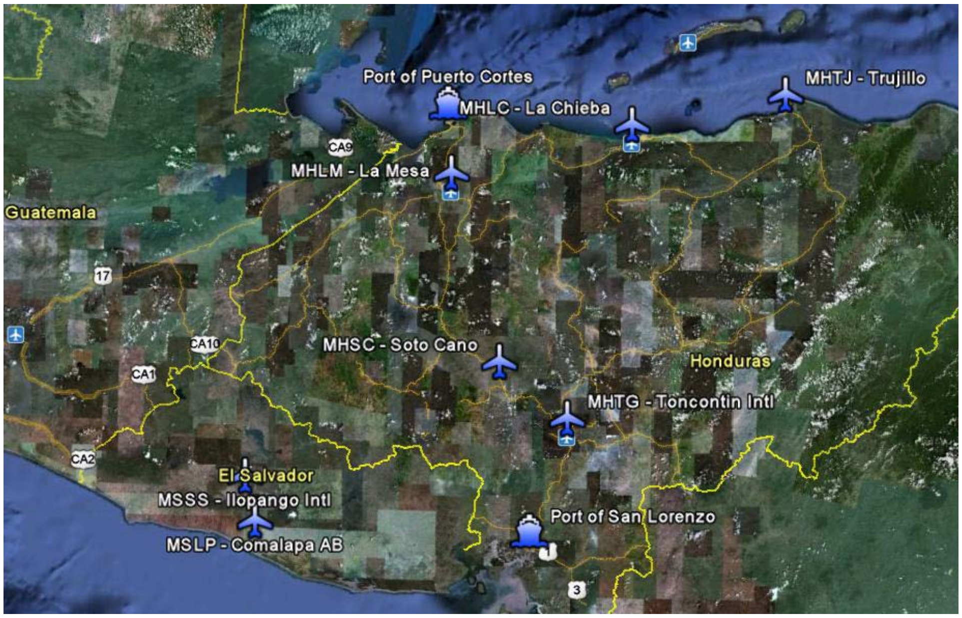


Figure 3. Honduras and El Salvador ports

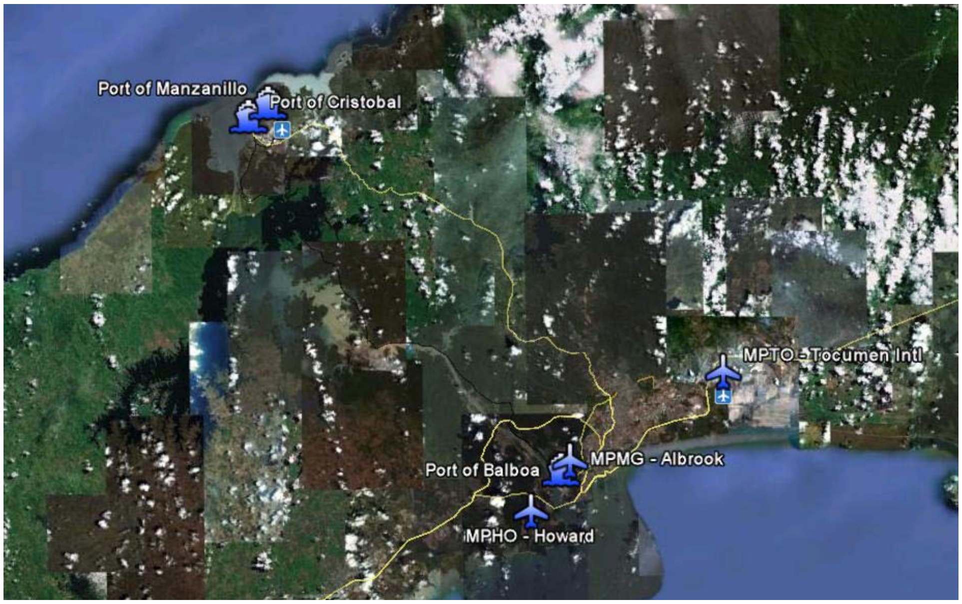


Figure 4. Panama ports

Appendix D. Revised Model Single Dimensional Value Functions

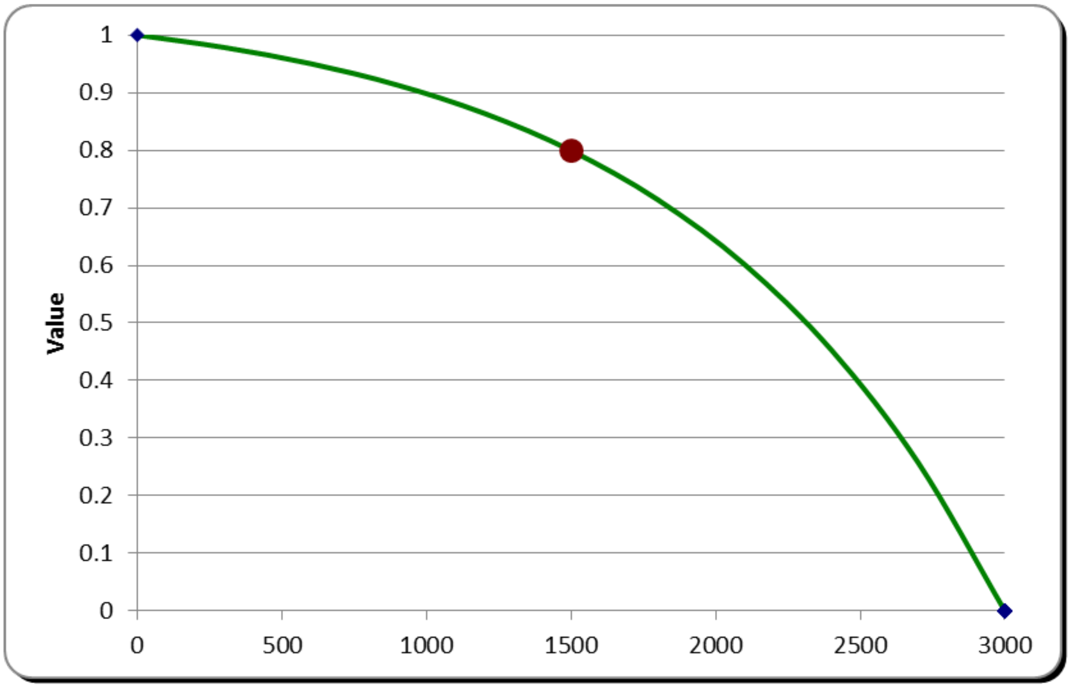


Figure 1. Flight Length to Destination

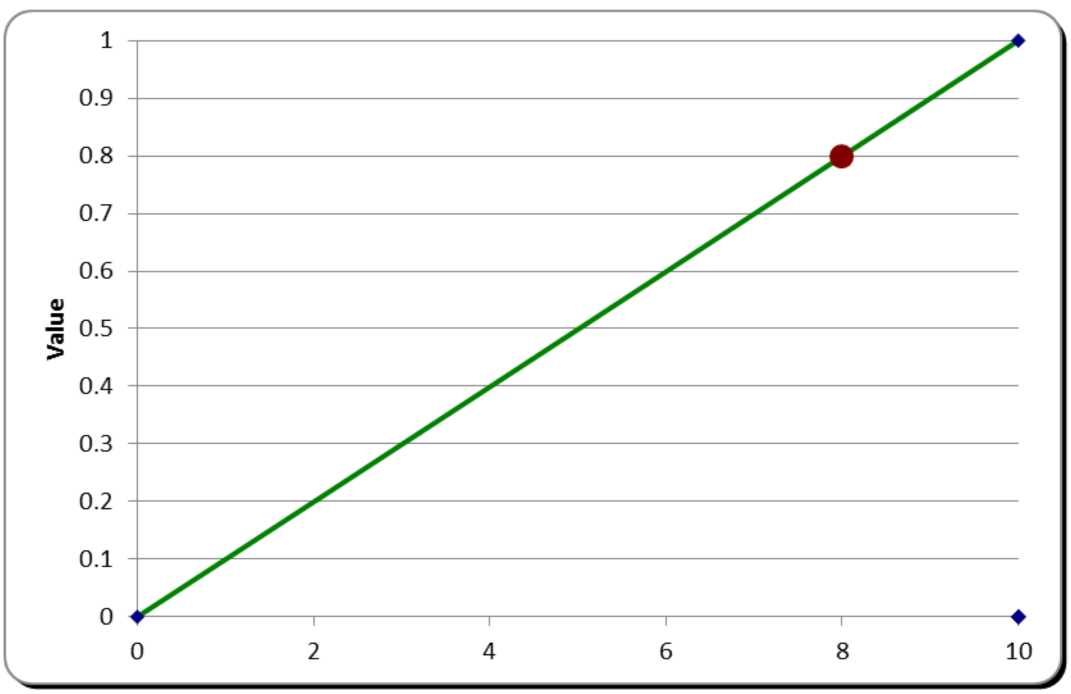


Figure 2. Host Nation Political Stability

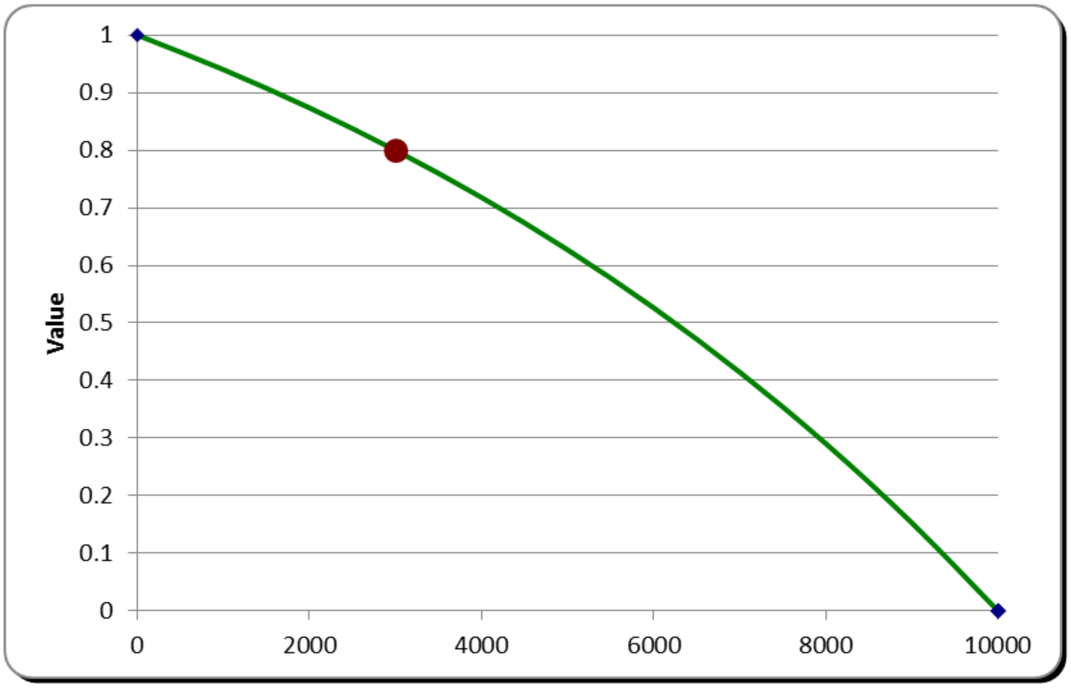


Figure 3. Sea Distance

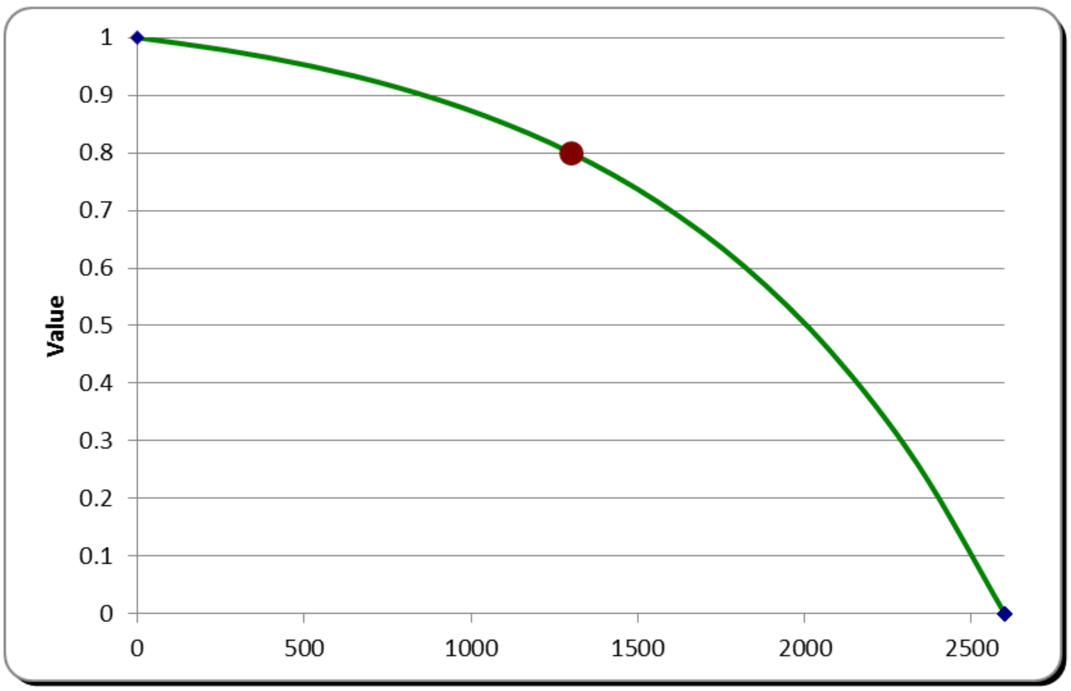


Figure 4. Container Handling Charges

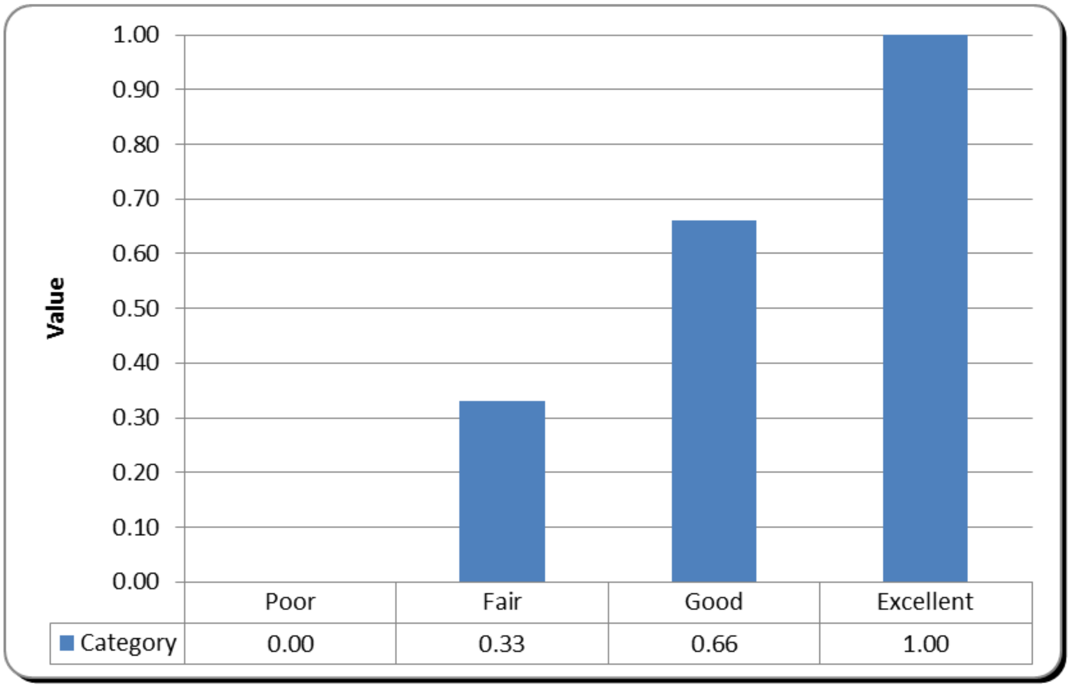


Figure 5. US Relations with host nation

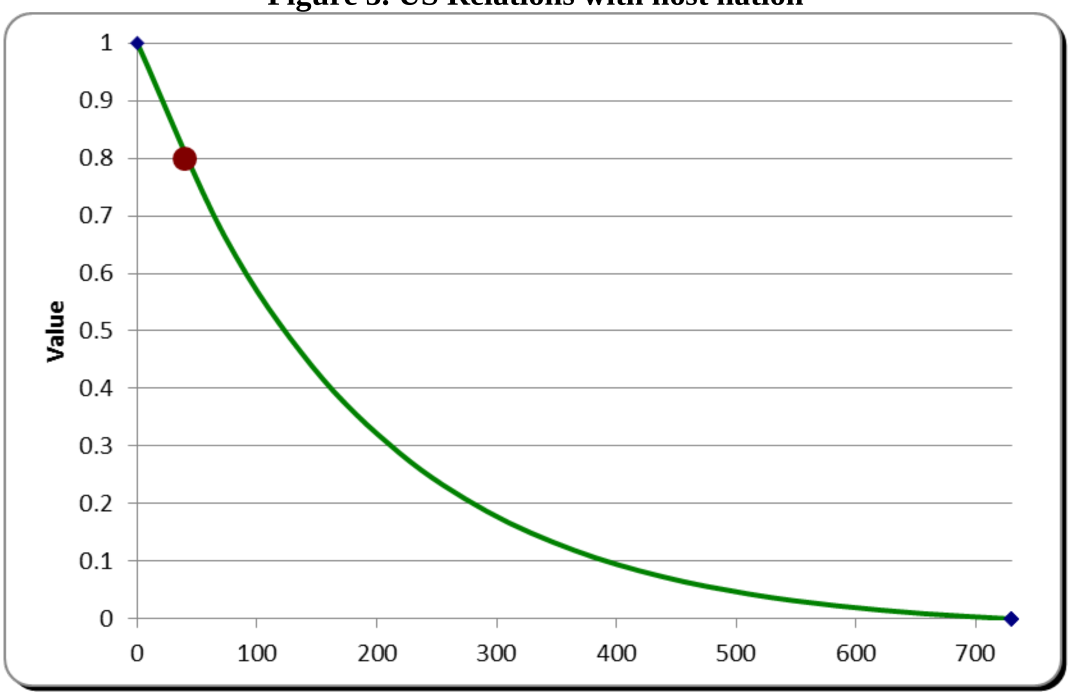


Figure 6. Seaport to Airport Distance

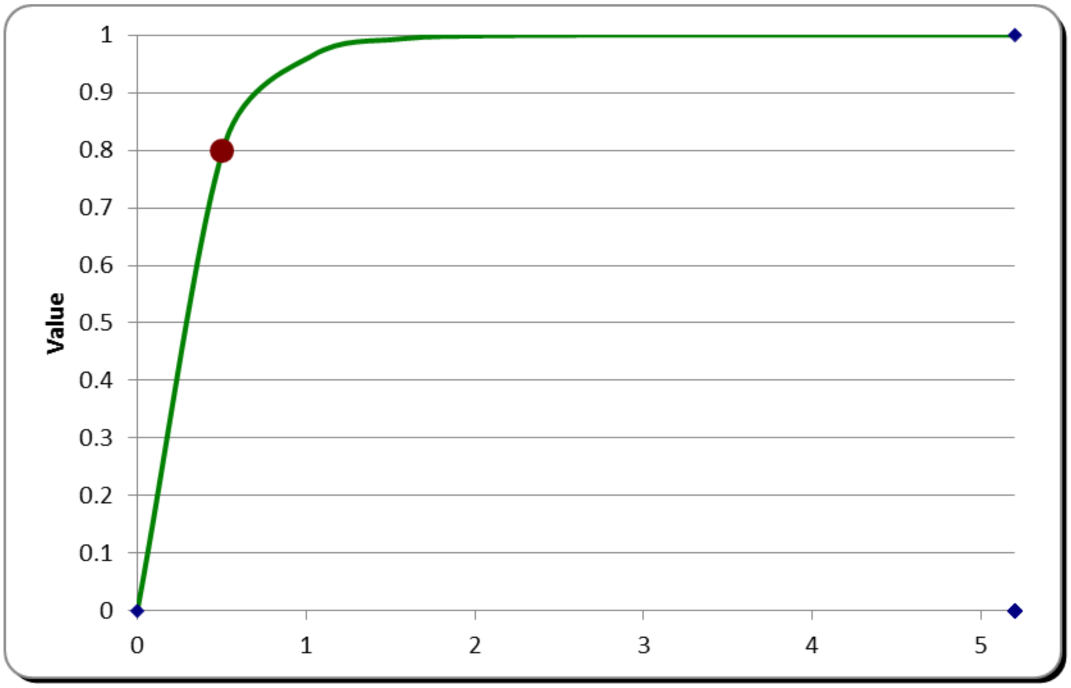


Figure 7. Airport Fuel Availability

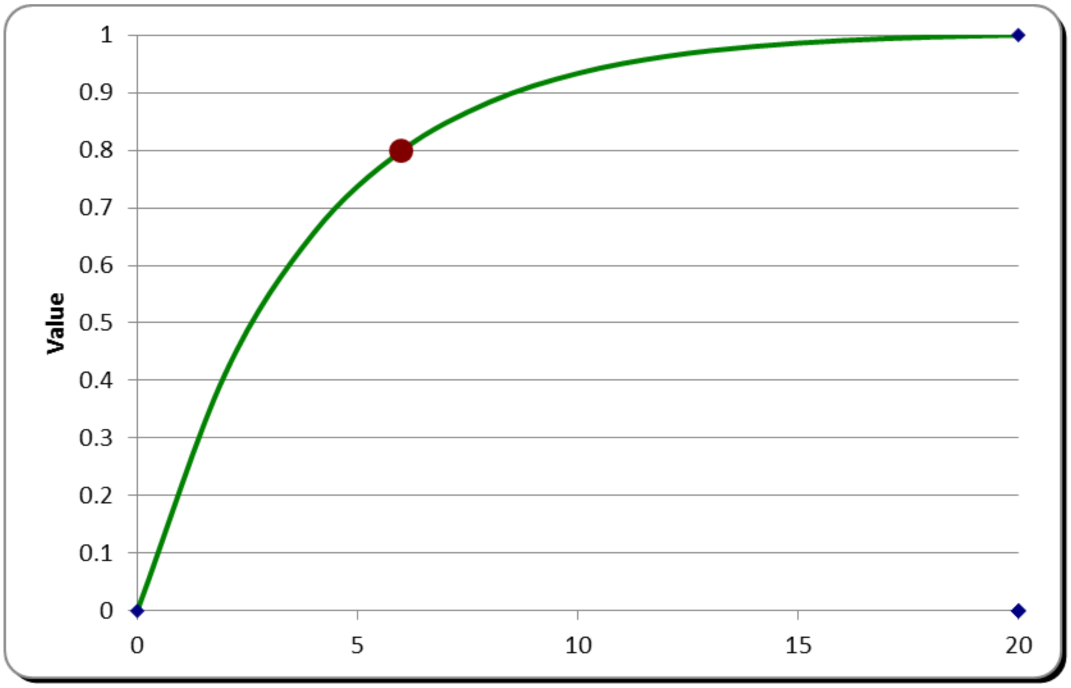


Figure 8. Aiport Parking MOG

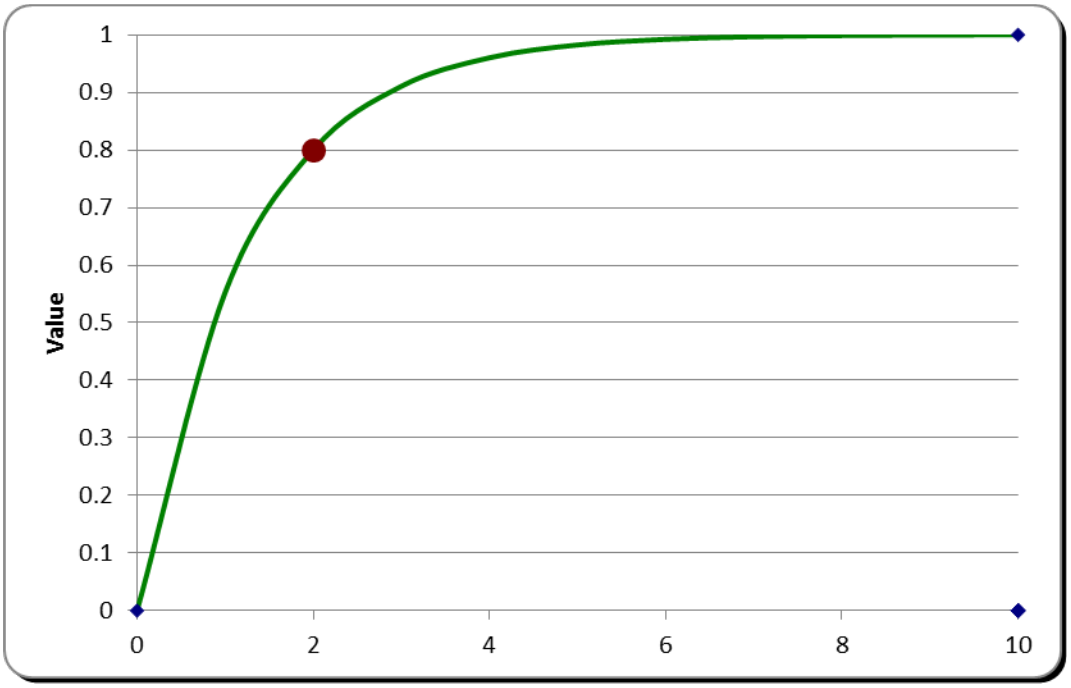


Figure 9. Airport Working MOG

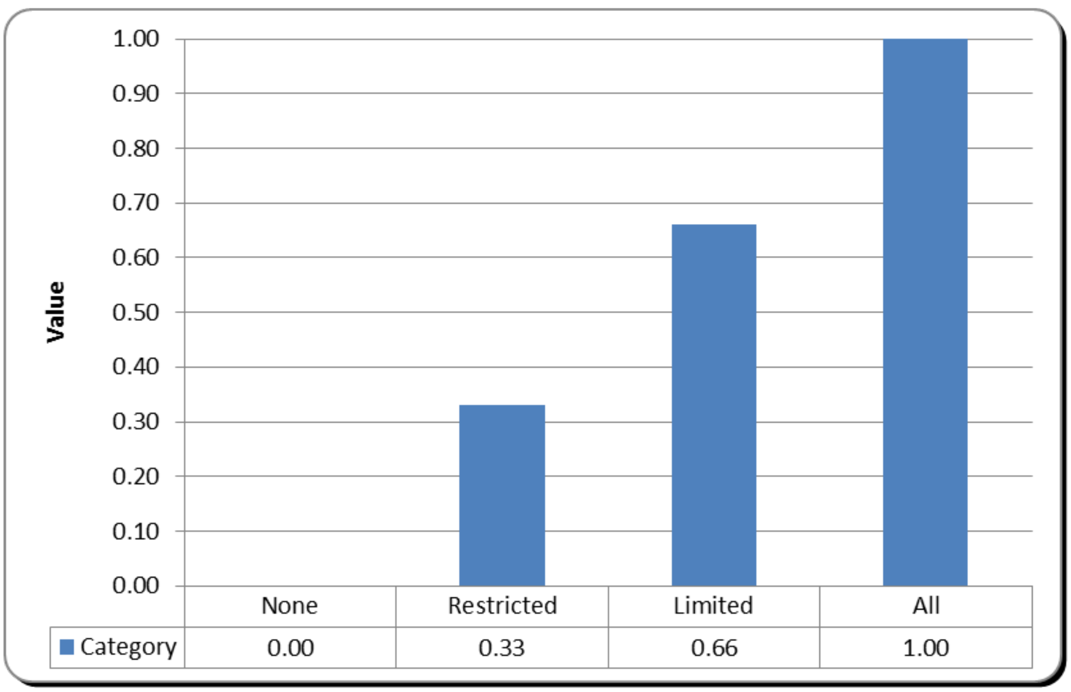


Figure 10. Airport Suitability

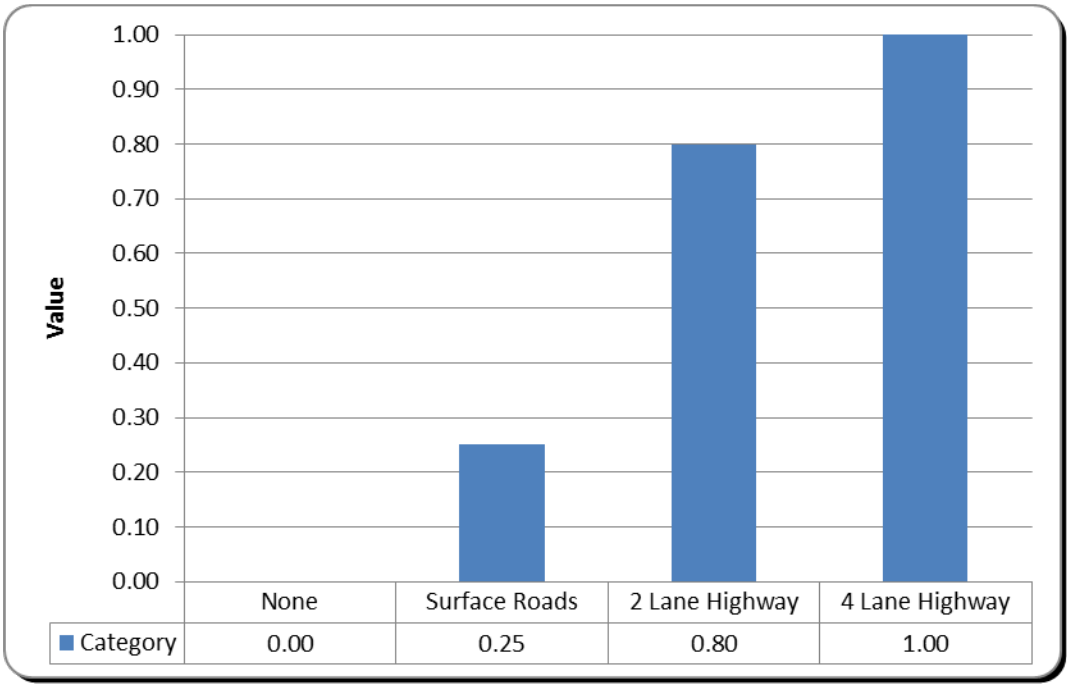


Figure 11. Airport to Road Connections

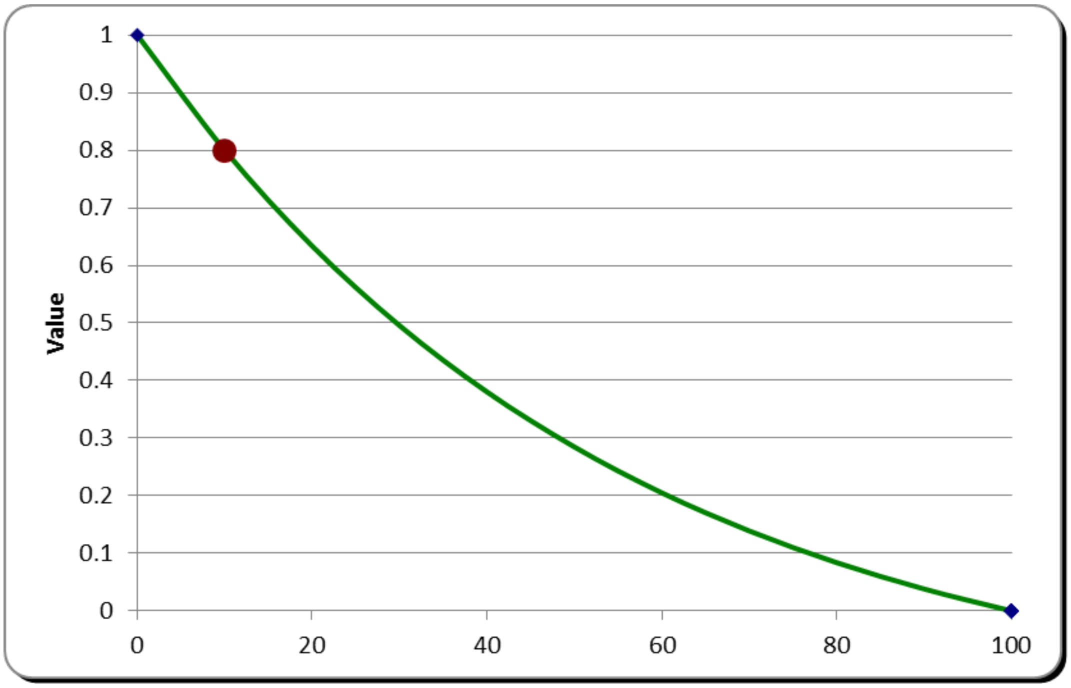


Figure 12. Airport to Railroad Connections

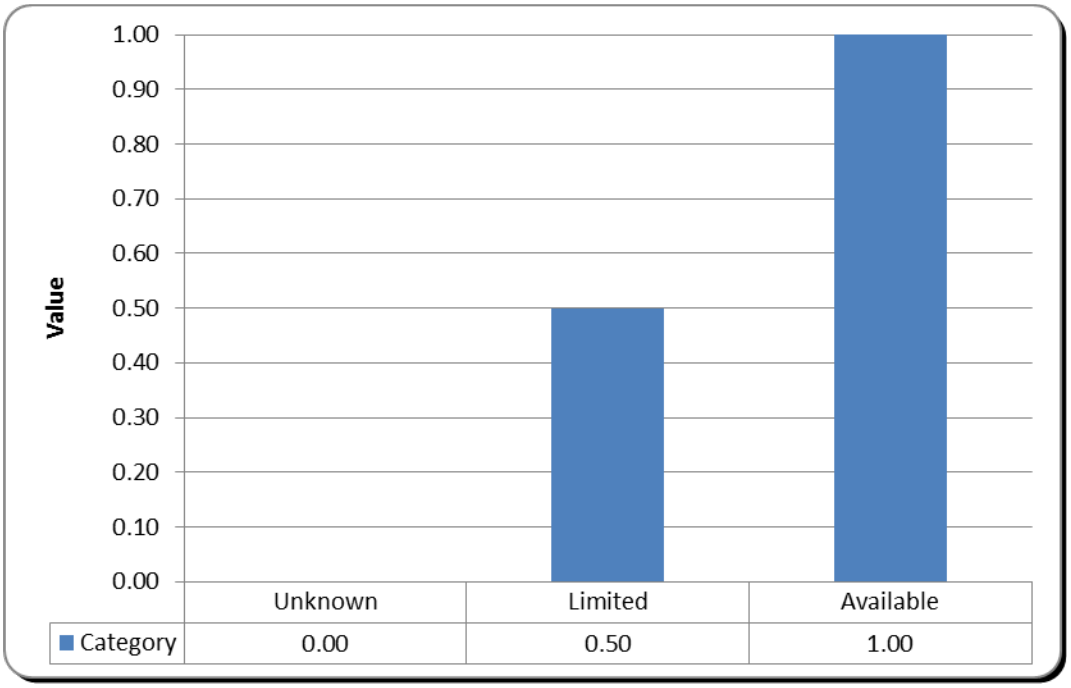


Figure 13. Airfield Staging Area

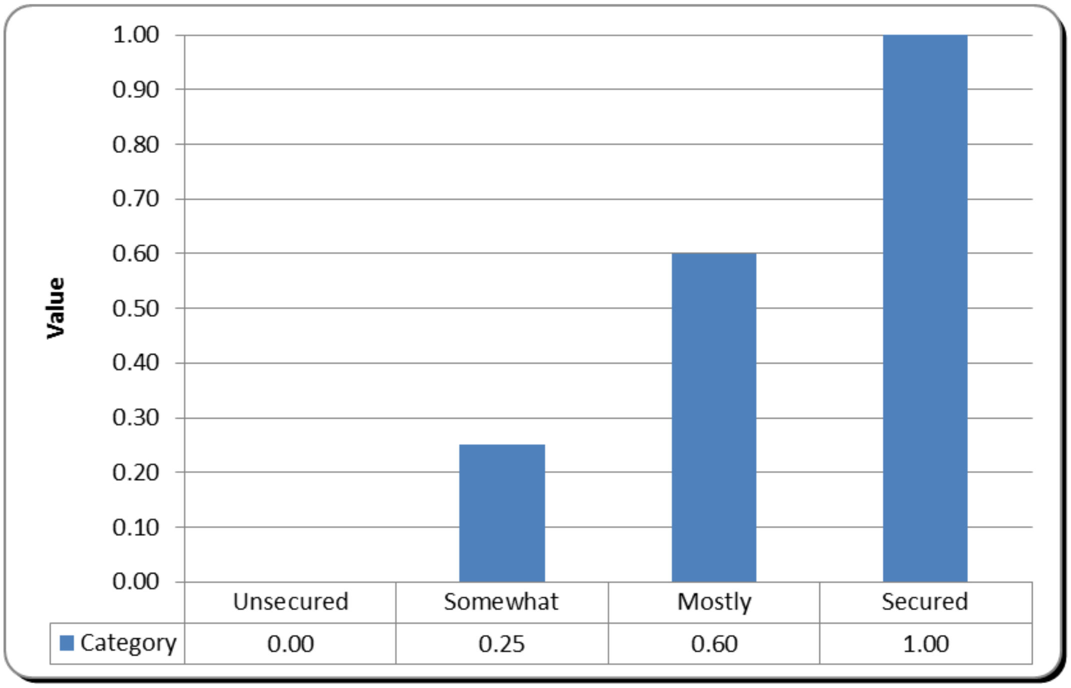


Figure 14. Airport Security

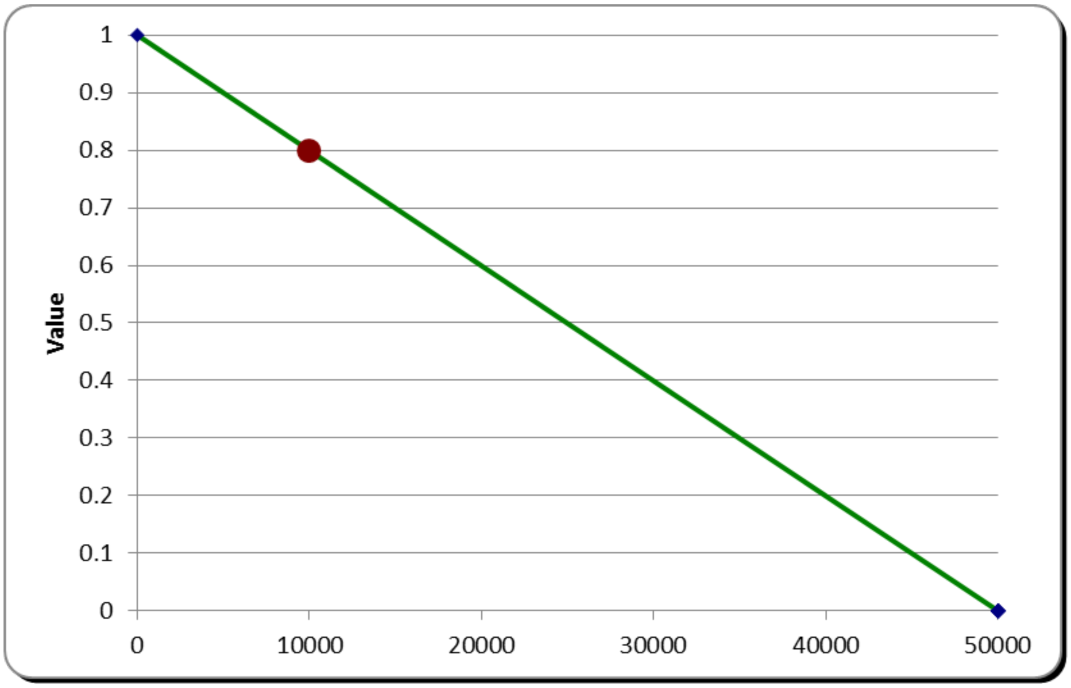
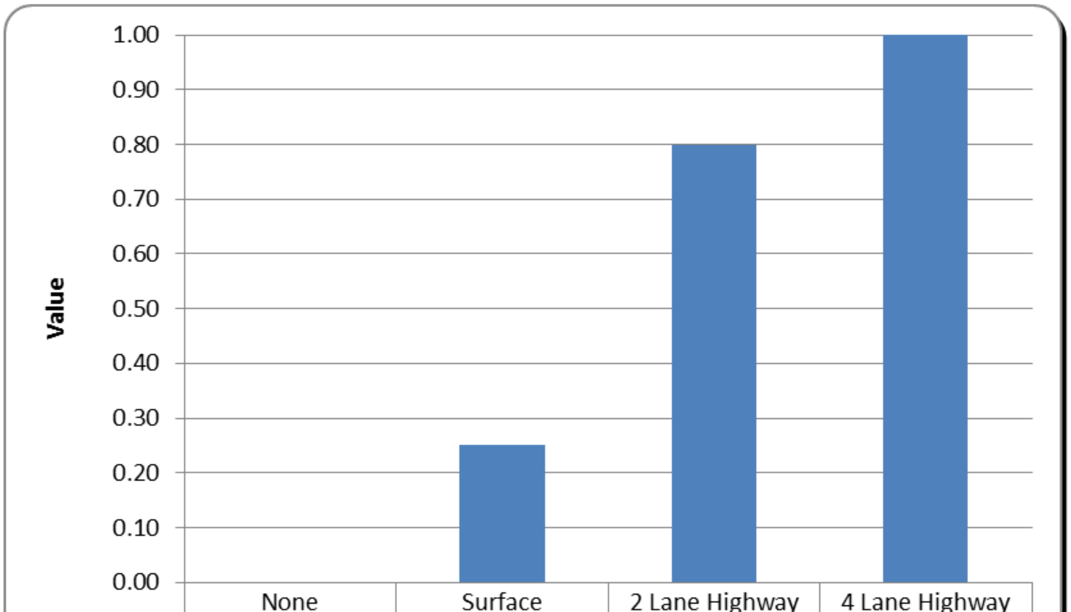


Figure 15. Airport Additional Cost Factors



	None	Surface	2 Lane Highway	4 Lane Highway
Category	0.00	0.25	0.80	1.00

Figure 16. Seaport to Road Connections

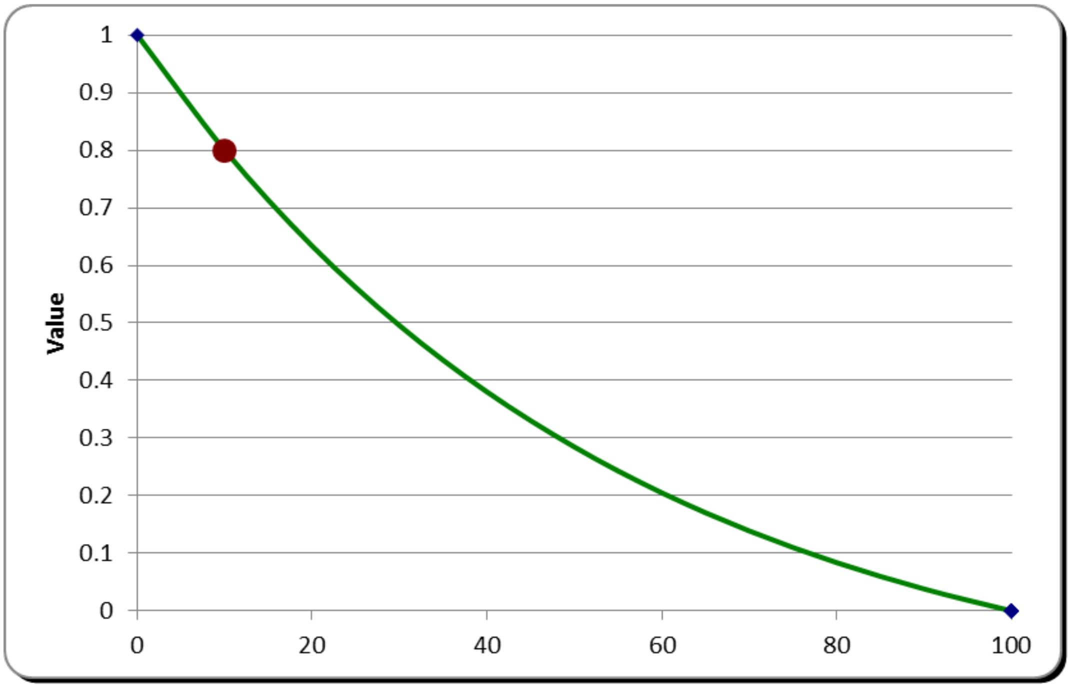


Figure 17. Seaport to Railroad Connections

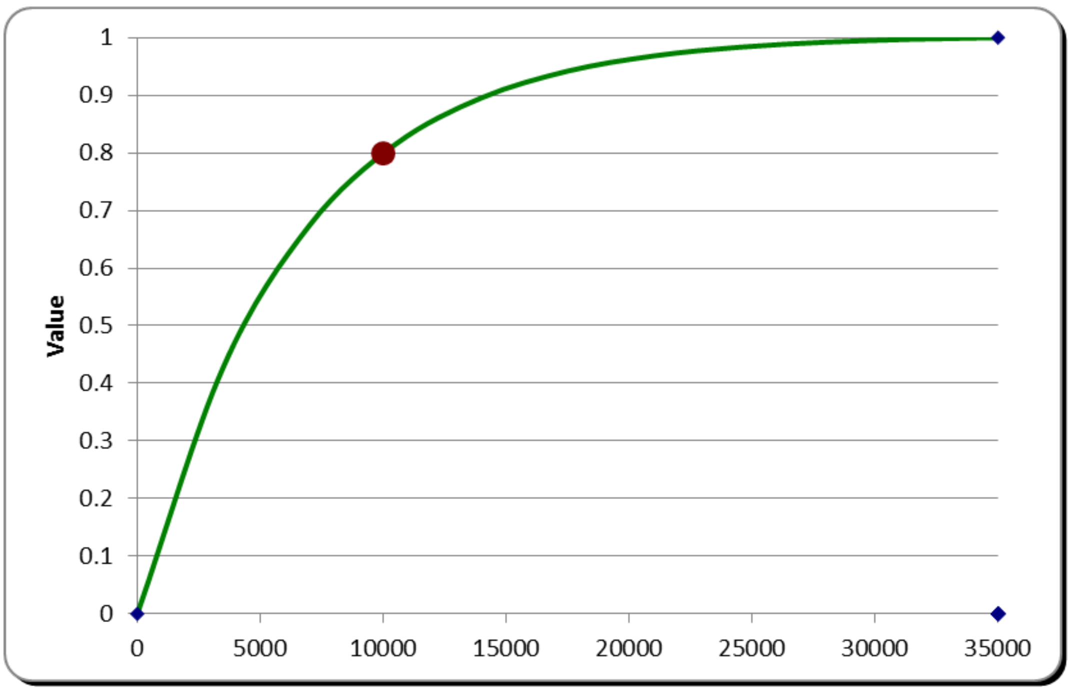


Figure 18. Container Handling Capacity

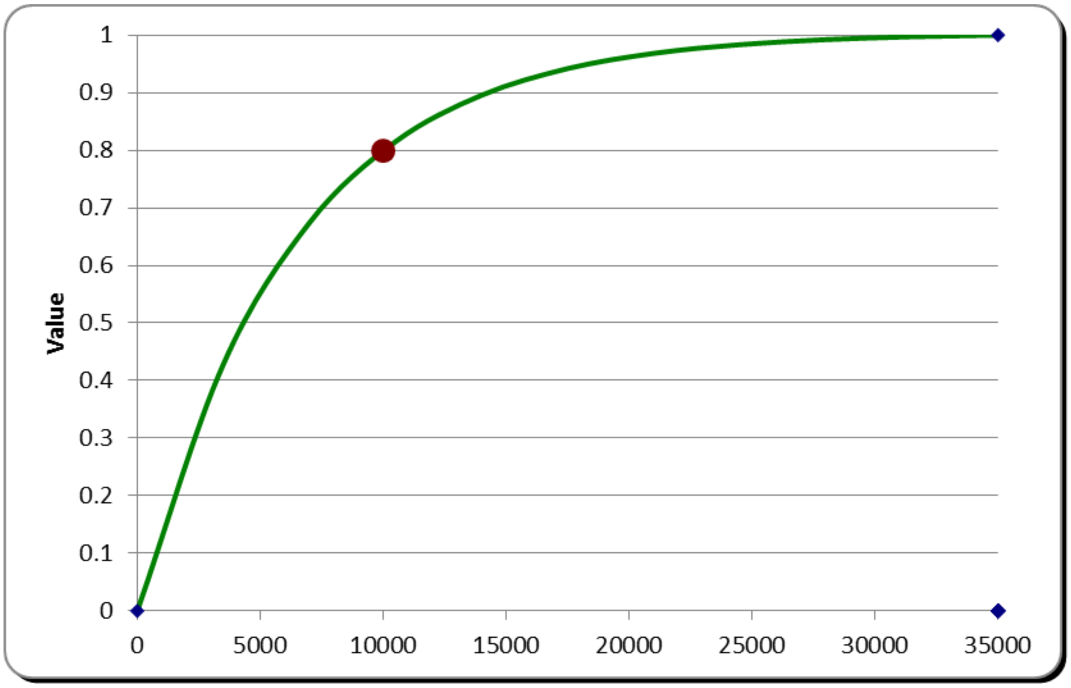


Figure 19. Mixed Cargo Handling Capacity

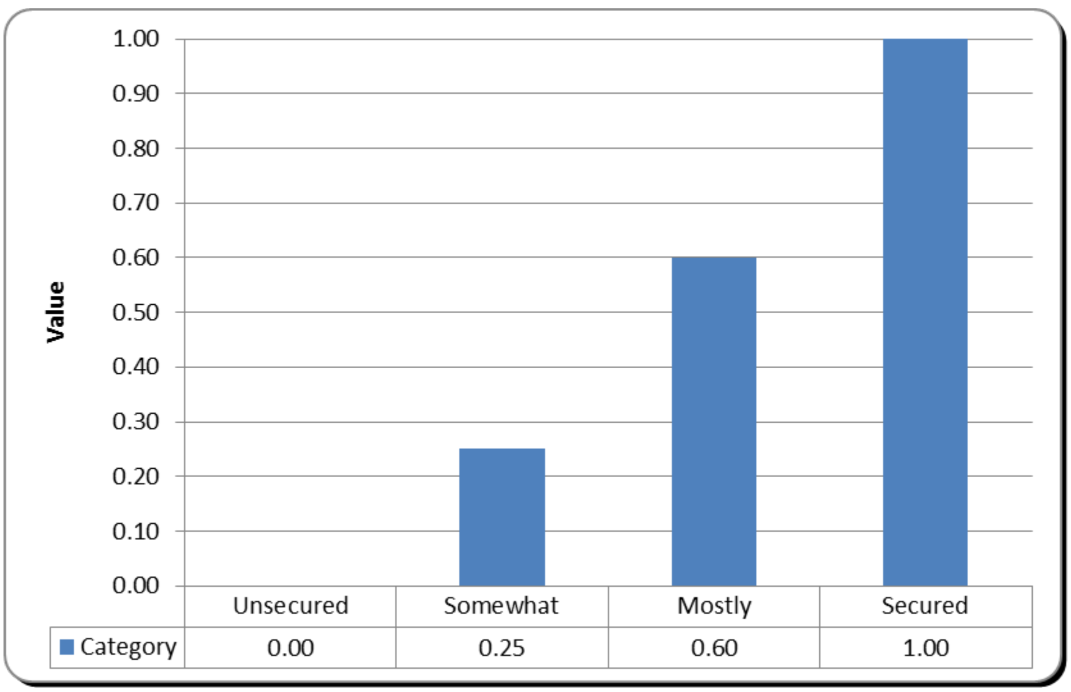


Figure 20. Seaport Security

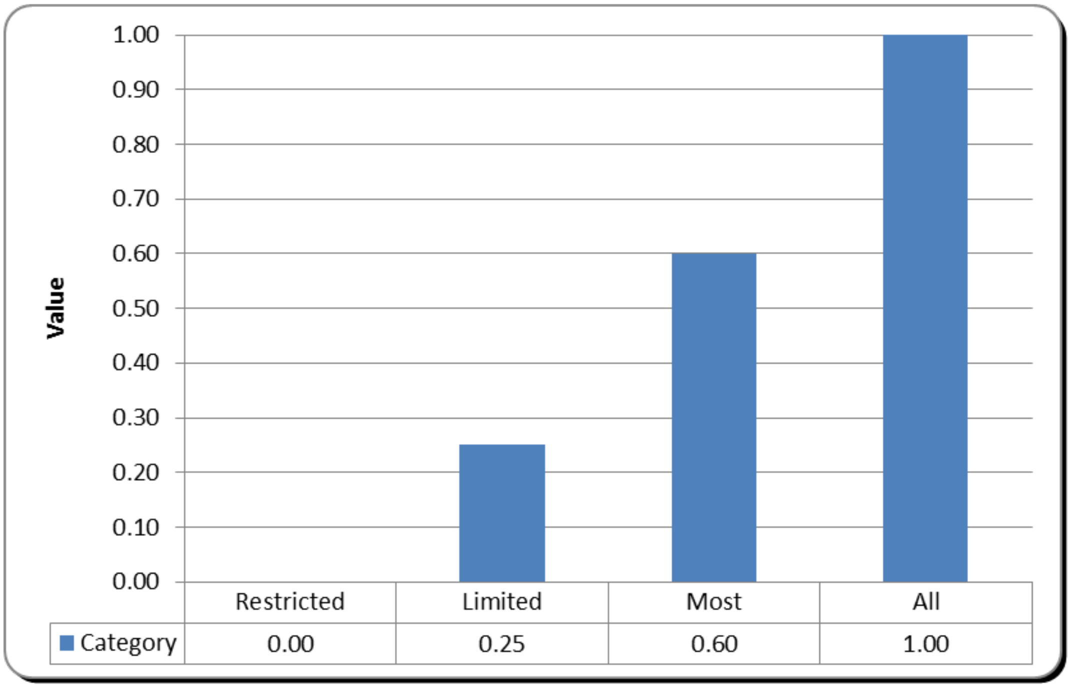


Figure 21. Seaport Suitability

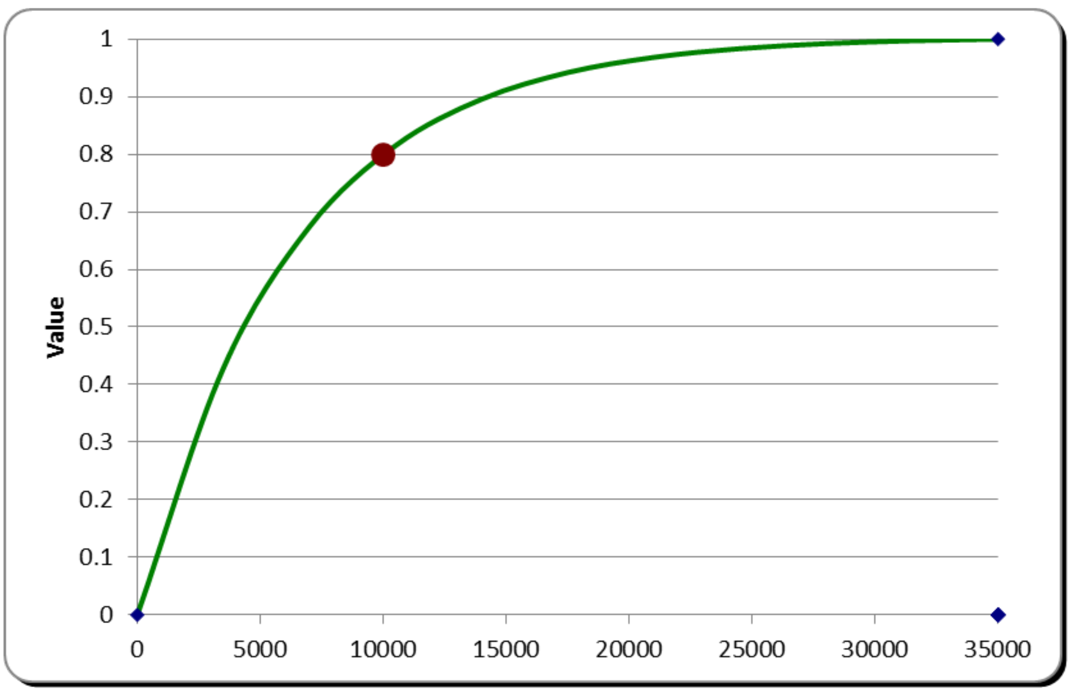


Figure 22. Container Shiploading Capacity

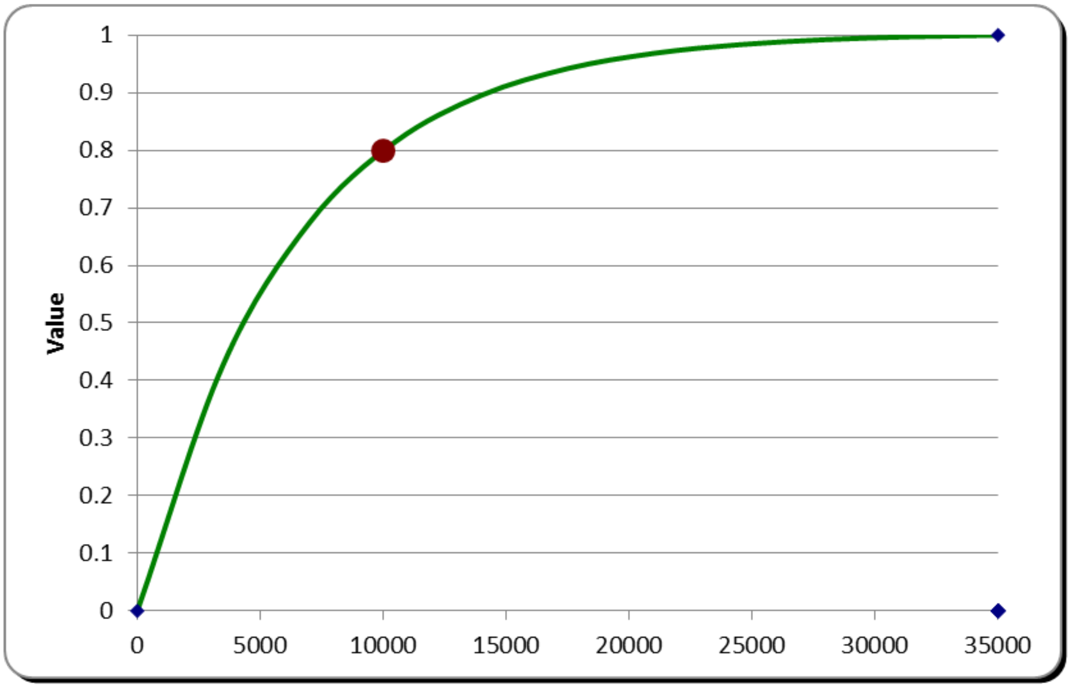


Figure 23. Roll On Roll Off Shiploading Capacity

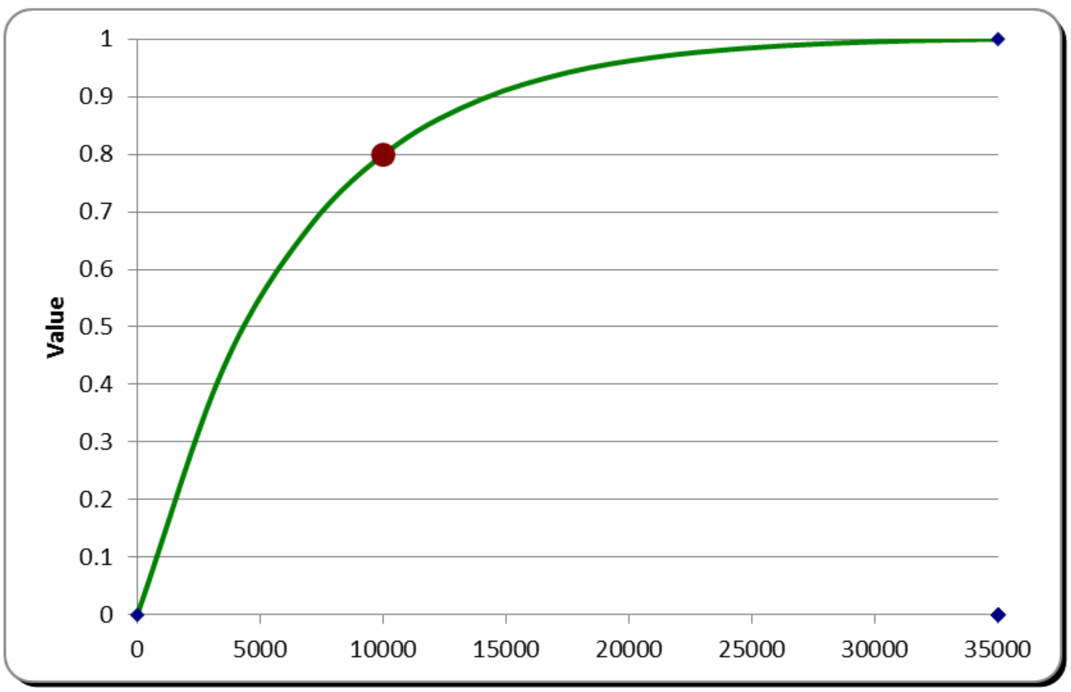


Figure 24. Breakbulk Shiploading Capacity

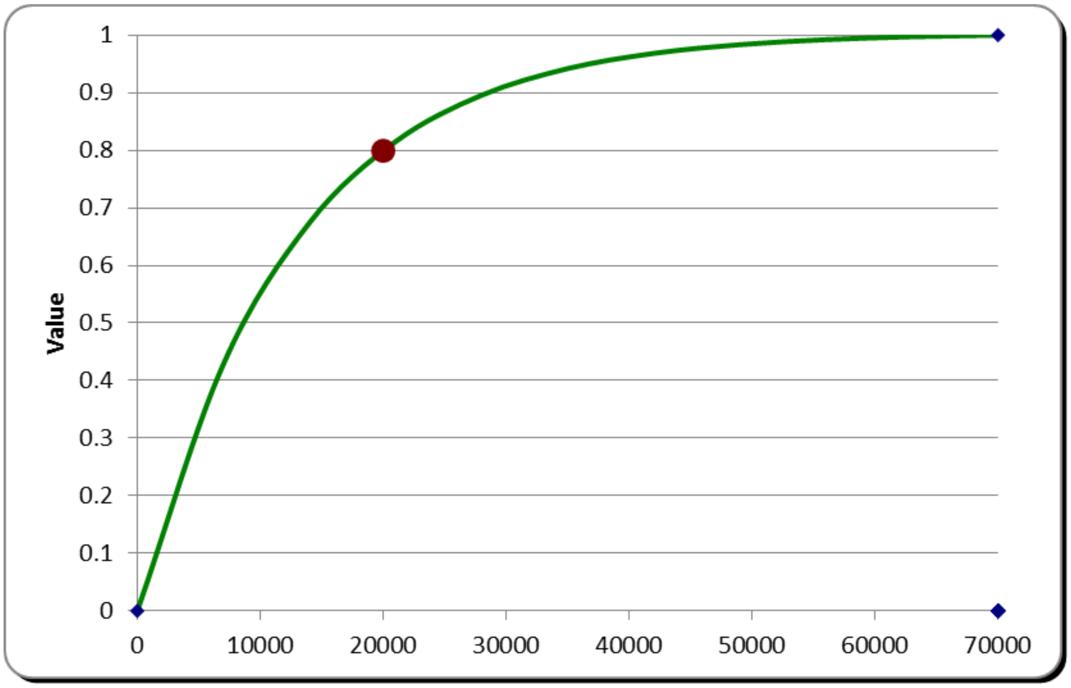


Figure 25. Container Staging Capacity

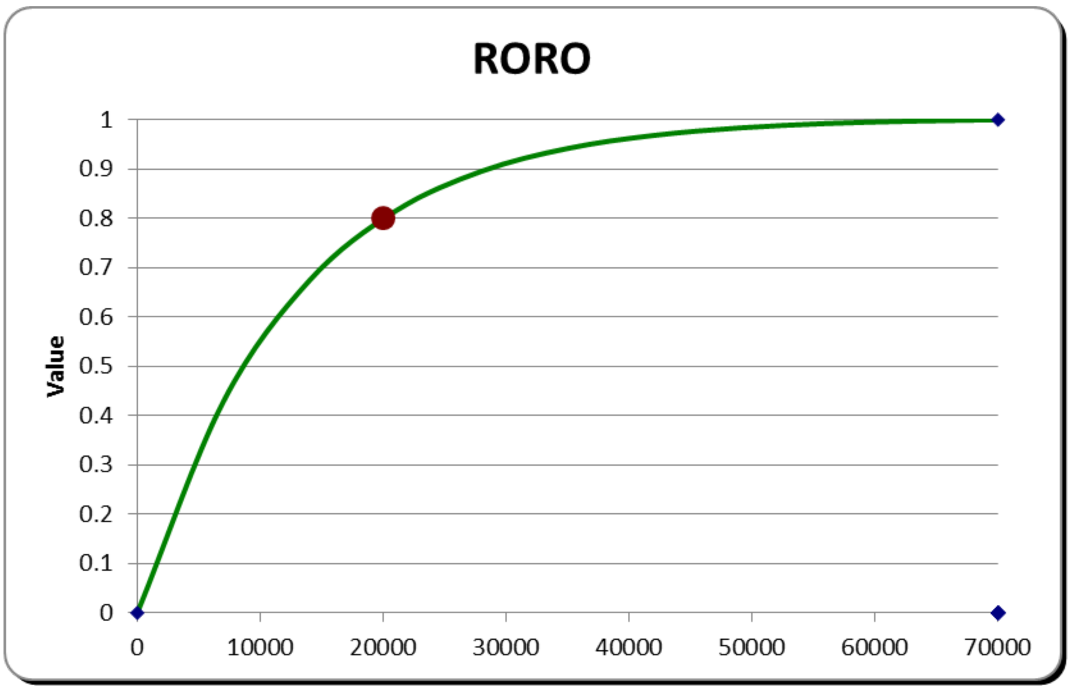


Figure 26. Roll On Roll Off Staging Capacity

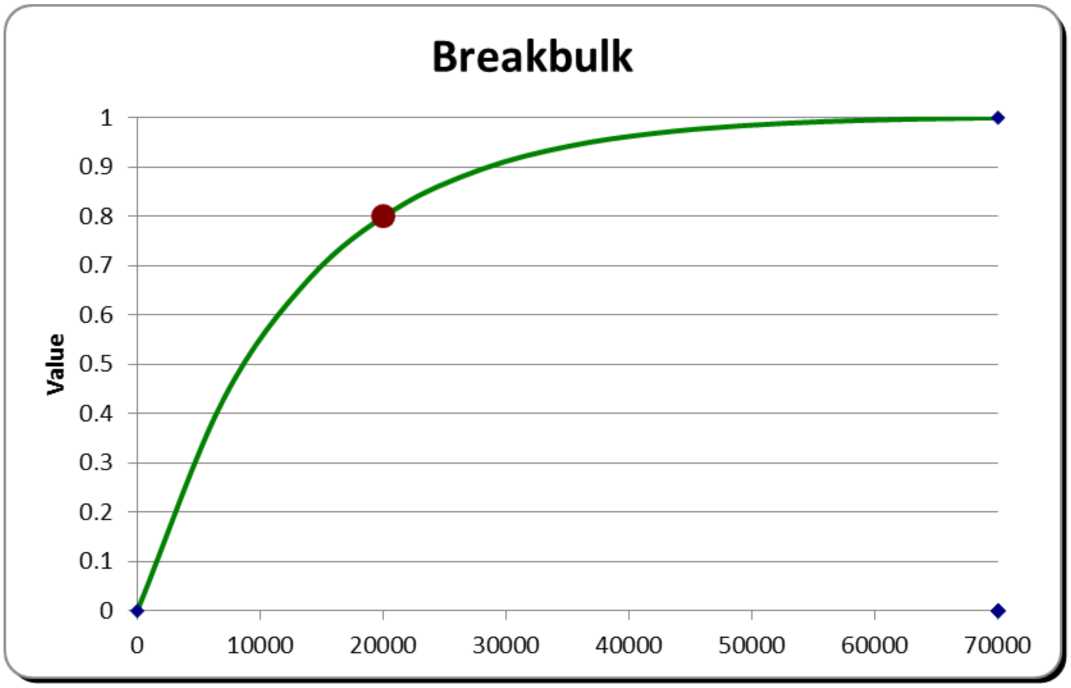


Figure 27. Breakbulk Staging Capacity

Appendix E. Graphic Model Results

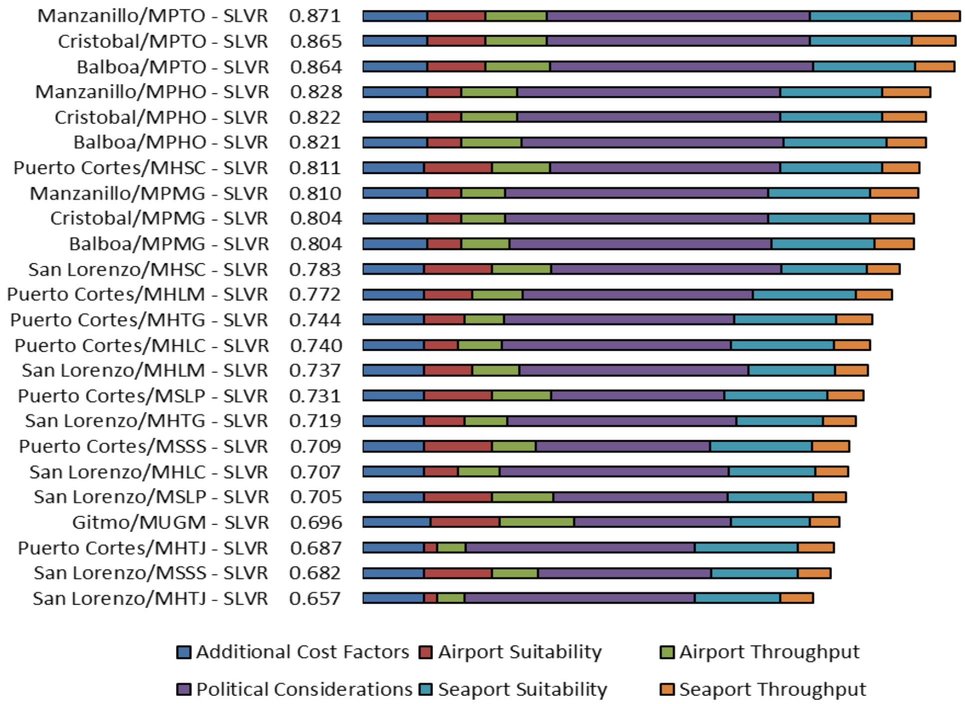


Figure 1. Revised Model Results

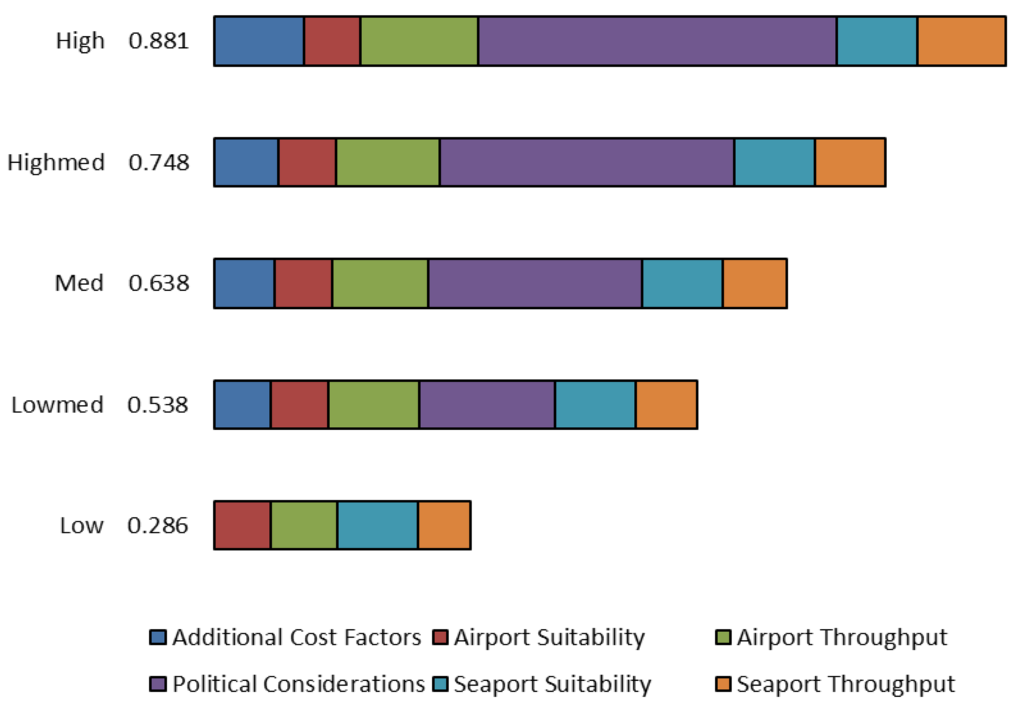


Figure 2. Revised Model Results – Constructed Data

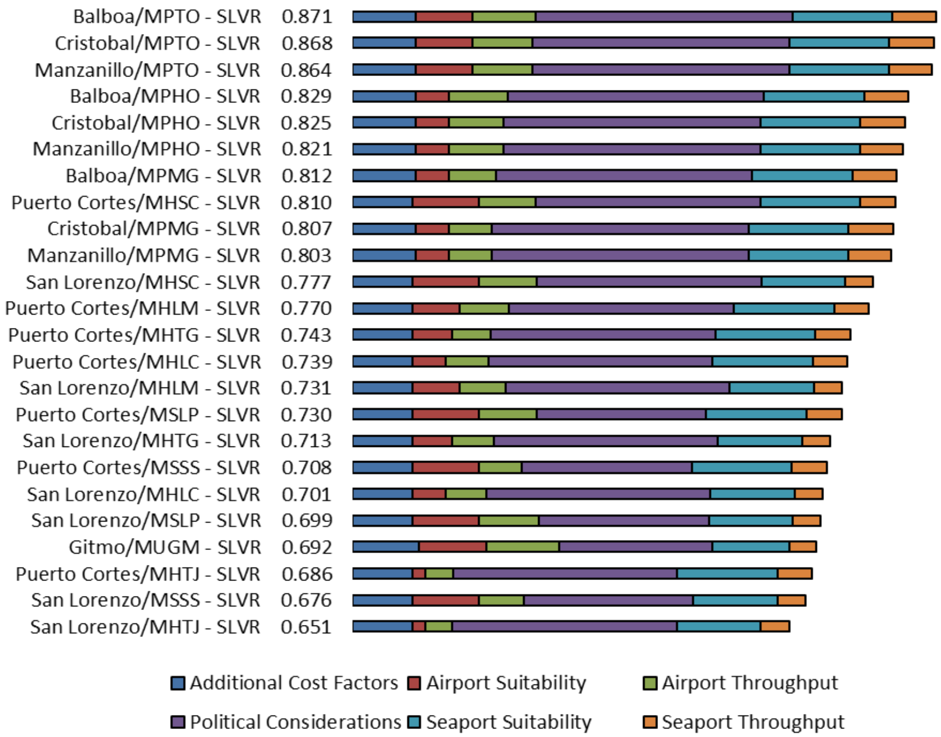


Figure 3. Revised Model Results – Breakbulk Cargo

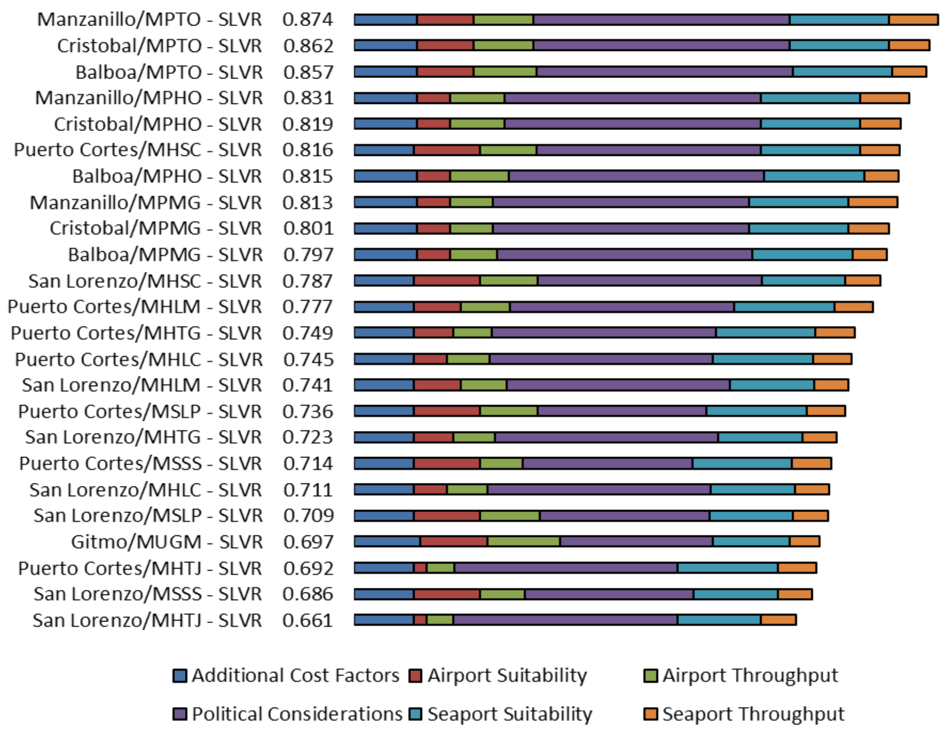


Figure 4. Revised Model Results – Containerized Cargo

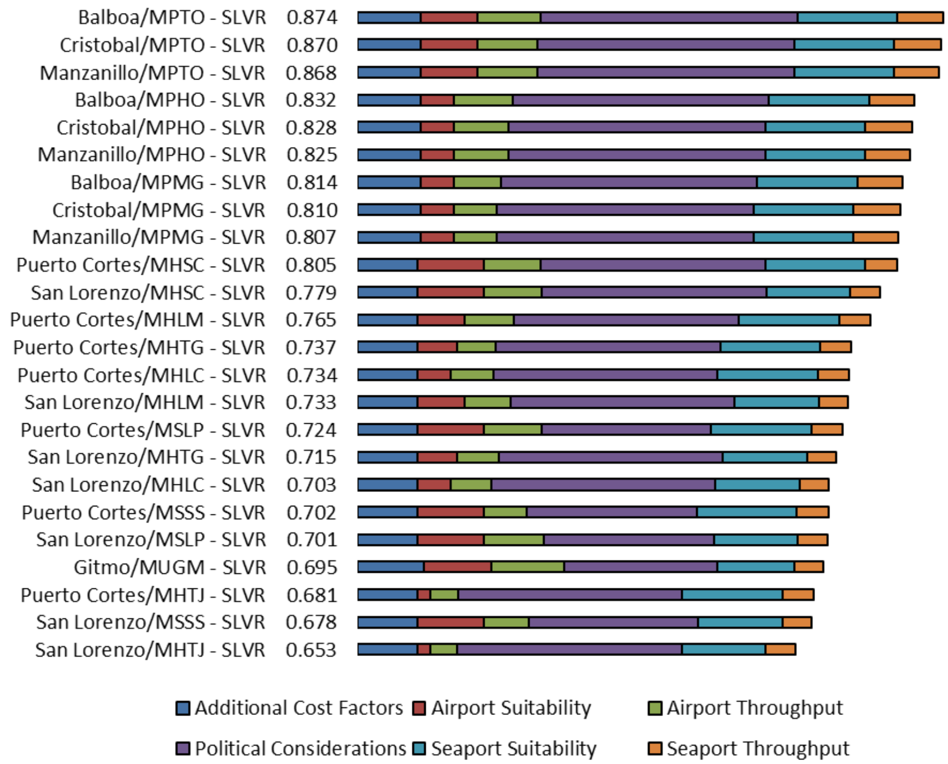


Figure 5. Revised Model Results – Roll On Roll Off Cargo

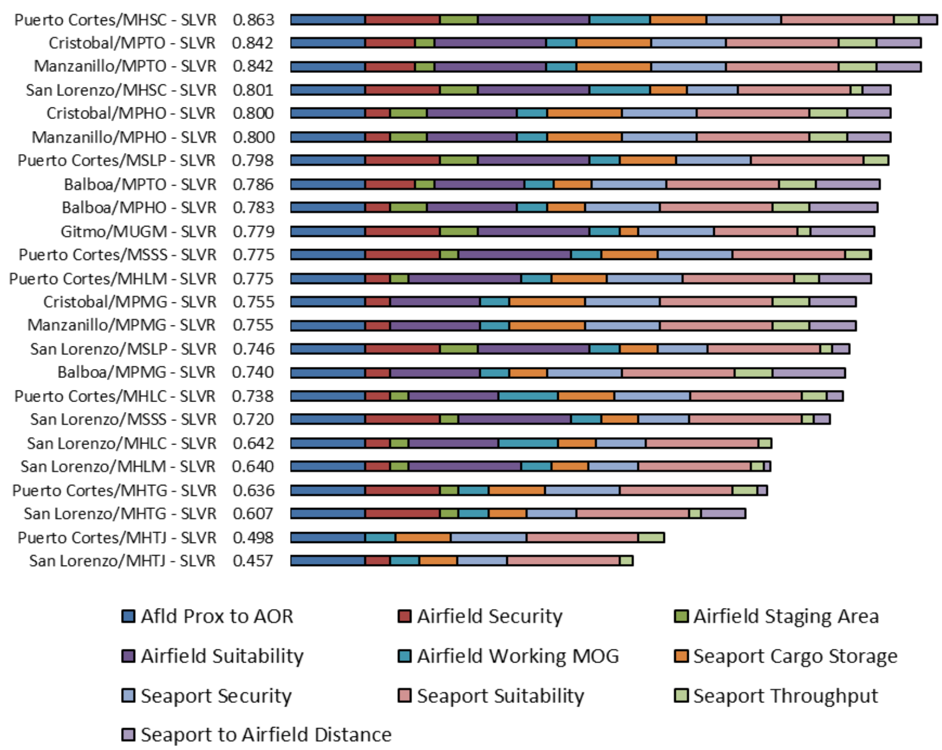


Figure 6. Original Model Results

Figure 7. Original Model Results – Constructed Data

Original model	Revised Model	Revised Model- Containers	Revised Model- Roll On Roll Off	Revised Model- Breakbulk
Puerto Cortes/MHSC - SLVR 0.863	Manzanillo/MPTO - SLVR 0.871	Manzanillo/MPTO - SLVR 0.874	Balboa/MPTO - SLVR 0.874	Balboa/MPTO - SLVR 0.871
Cristobal/MPTO - SLVR 0.842	Cristobal/MPTO - SLVR 0.865	Cristobal/MPTO - SLVR 0.862	Cristobal/MPTO - SLVR 0.870	Cristobal/MPTO - SLVR 0.868
Manzanillo/MPTO - SLVR 0.842	Balboa/MPTO - SLVR 0.864	Balboa/MPTO - SLVR 0.857	Manzanillo/MPTO - SLVR 0.868	Manzanillo/MPTO - SLVR 0.864
San Lorenzo/MHSC - SLVR 0.801	Manzanillo/MPHO - SLVR 0.828	Manzanillo/MPHO - SLVR 0.831	Balboa/MPHO - SLVR 0.832	Balboa/MPHO - SLVR 0.829
Cristobal/MPHO - SLVR 0.800	Cristobal/MPHO - SLVR 0.822	Cristobal/MPHO - SLVR 0.819	Cristobal/MPHO - SLVR 0.828	Cristobal/MPHO - SLVR 0.825
Manzanillo/MPHO - SLVR 0.800	Balboa/MPHO - SLVR 0.821	Puerto Cortes/MHSC - SLVR 0.816	Manzanillo/MPHO - SLVR 0.825	Manzanillo/MPHO - SLVR 0.821
Puerto Cortes/MSLP - SLVR 0.798	Puerto Cortes/MHSC - SLVR 0.811	Balboa/MPHO - SLVR 0.815	Balboa/MPMG - SLVR 0.814	Balboa/MPMG - SLVR 0.812
Balboa/MPTO - SLVR 0.786	Manzanillo/MPMG - SLVR 0.810	Manzanillo/MPMG - SLVR 0.813	Cristobal/MPMG - SLVR 0.810	Puerto Cortes/MHSC - SLVR 0.810
Balboa/MPHO - SLVR 0.783	Cristobal/MPMG - SLVR 0.804	Cristobal/MPMG - SLVR 0.801	Manzanillo/MPMG - SLVR 0.807	Cristobal/MPMG - SLVR 0.807
Gitmo/MUGM - SLVR 0.779	Balboa/MPMG - SLVR 0.804	Balboa/MPMG - SLVR 0.797	Puerto Cortes/MHSC - SLVR 0.805	Manzanillo/MPMG - SLVR 0.803
Puerto Cortes/MSSS - SLVR 0.775	San Lorenzo/MHSC - SLVR 0.783	San Lorenzo/MHSC - SLVR 0.787	San Lorenzo/MHSC - SLVR 0.779	San Lorenzo/MHSC - SLVR 0.777
Puerto Cortes/MHLM - SLVR 0.775	Puerto Cortes/MHLM - SLVR 0.772	Puerto Cortes/MHLM - SLVR 0.777	Puerto Cortes/MHLM - SLVR 0.765	Puerto Cortes/MHLM - SLVR 0.770
Cristobal/MPMG - SLVR 0.755	Puerto Cortes/MHTG - SLVR 0.744	Puerto Cortes/MHTG - SLVR 0.749	Puerto Cortes/MHTG - SLVR 0.737	Puerto Cortes/MHTG - SLVR 0.743
Manzanillo/MPMG - SLVR 0.755	Puerto Cortes/MHLC - SLVR 0.740	Puerto Cortes/MHLC - SLVR 0.745	Puerto Cortes/MHLC - SLVR 0.734	Puerto Cortes/MHLC - SLVR 0.739
San Lorenzo/MSLP - SLVR 0.746	San Lorenzo/MHLM - SLVR 0.737	San Lorenzo/MHLM - SLVR 0.741	San Lorenzo/MHLM - SLVR 0.733	San Lorenzo/MHLM - SLVR 0.731
Balboa/MPMG - SLVR 0.740	Puerto Cortes/MSLP - SLVR 0.731	Puerto Cortes/MSLP - SLVR 0.736	Puerto Cortes/MSLP - SLVR 0.724	Puerto Cortes/MSLP - SLVR 0.730
Puerto Cortes/MHLC - SLVR 0.738	San Lorenzo/MHTG - SLVR 0.719	San Lorenzo/MHTG - SLVR 0.723	San Lorenzo/MHTG - SLVR 0.715	San Lorenzo/MHTG - SLVR 0.713
San Lorenzo/MSSS - SLVR 0.720	Puerto Cortes/MSSS - SLVR 0.709	Puerto Cortes/MSSS - SLVR 0.714	San Lorenzo/MHLC - SLVR 0.703	Puerto Cortes/MSSS - SLVR 0.708
San Lorenzo/MHLC - SLVR 0.642	San Lorenzo/MHLC - SLVR 0.707	San Lorenzo/MHLC - SLVR 0.711	Puerto Cortes/MSSS - SLVR 0.702	San Lorenzo/MHLC - SLVR 0.701
San Lorenzo/MHLM - SLVR 0.640	San Lorenzo/MSLP - SLVR 0.705	San Lorenzo/MSLP - SLVR 0.709	San Lorenzo/MSLP - SLVR 0.701	San Lorenzo/MSLP - SLVR 0.699
Puerto Cortes/MHTG - SLVR 0.636	Gitmo/MUGM - SLVR 0.696	Gitmo/MUGM - SLVR 0.697	Gitmo/MUGM - SLVR 0.695	Gitmo/MUGM - SLVR 0.692
San Lorenzo/MHTG - SLVR 0.607	Puerto Cortes/MHTJ - SLVR 0.687	Puerto Cortes/MHTJ - SLVR 0.692	Puerto Cortes/MHTJ - SLVR 0.681	Puerto Cortes/MHTJ - SLVR 0.686
Puerto Cortes/MHTJ - SLVR 0.498	San Lorenzo/MSSS - SLVR 0.682	San Lorenzo/MSSS - SLVR 0.686	San Lorenzo/MSSS - SLVR 0.678	San Lorenzo/MSSS - SLVR 0.676
San Lorenzo/MHTJ - SLVR 0.457	San Lorenzo/MHTJ - SLVR 0.657	San Lorenzo/MHTJ - SLVR 0.661	San Lorenzo/MHTJ - SLVR 0.653	San Lorenzo/MHTJ - SLVR 0.651

Figure 8. Model Output Comparison

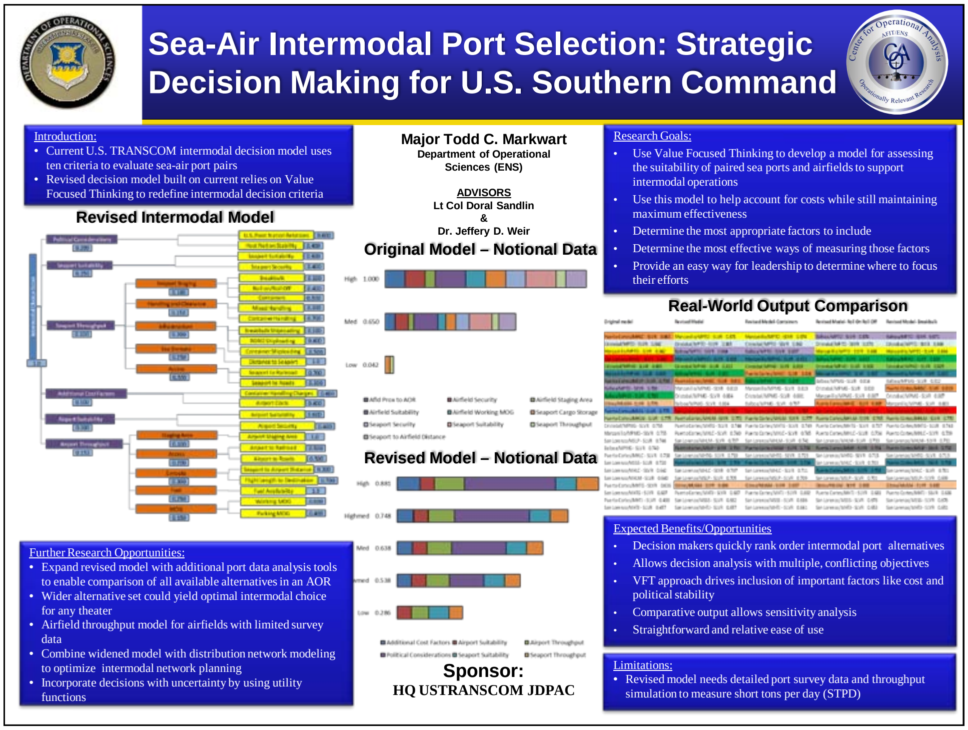
Appendix F. Blue Dart

World events and changes in the expeditionary force structure and strategy of the U.S. military have forever altered the traditional approach to operational employment and readiness under previous paradigms. Greater degrees of flexibility and speed are required to carry out operations, which are aided by the utility of intermodal transport options to quickly and efficiently move large force package rotations in support of geographic combatant commanders' (CCDR) requirements. The United States Transportation Command (U.S. TRANSCOM) is responsible for making decisions on the most efficient mix of sea and airport operations to support U.S. Government and Department of Defense (DoD) movement requirements worldwide, and the selection of the best port pairs is critical in executing that mission. U.S. TRANSCOM has used a decision model which evaluates ten sea and airport factors to prioritize port pairs, but recent humanitarian assistance/disaster relief operations in Haiti brought new attention to United States Southern Command's (U.S. SOUTHCOM) need for constantly evolving logistical planning.

This research uses a "value focused" methodology to identify factors and data sources to broaden the scope of the existing model to help U.S. TRANSCOM remain flexible in supporting worldwide CCDRs including U.S. SOUTHCOM. This revised model gives attention to political stability, foreign relations, road and rail connectivity, and cost factors not addressed in the original, and may avoid the need for additional fact finding after decisions made with the original. Further benefits of the revised model include the lack of internal scale consistency issues and the need for little additional data collection over the original. The revised model can also customize decision maker preference by cargo type in terms of Containerized, Roll-On Roll-Off, and Breakbulk. The only additional needs are detailed port survey data and simulation to measure short tons per day (STPD) for seaport throughput.

Additional sources of alternative value for real world U.S. SOUTHCOM port pairs accounts for significant differences between the two models. Notional port pair data also reveals an additional 60% potential error in alternative value score can be avoided by using the revised model.

Appendix G. Quad Chart



References

1. Bontekoning, Y. M., & Priemus, H. (2004*). Breakthrough innovations in intermodal freight transport*. Transportation Planning & Technology, 27(5), 335-345.

2. Boyd, J. (2011, February). *DOT Issues Strong Intermodal Rail Endorsement*. Journal of Commerce. Retrieved March 1, 2011, from ABI/INFORM Research.

3. Coyle, J. J., Novack, R. A., Gibson, B. J., & Bardi, E. J. (2011). *Transportation: A Supply Chain Perspective*, Seventh Edition, South-Western Cengage Learning, Mason, OH.

4. CountryWatch website, http://www.countrywatch.com. 21 April 2011.

5. Cullinane, K., Toy, N., (2000). *Identifying Influential attributes in freight route/mode choice decisions: a content analysis.* Transportation Research Part E 36. 41-53.

6. DeWitt, W., Clinger, J., *Intermodal Freight Transportation*, Committee on Intermodal Freight Transport, Chairman: Gerhardt Muller, U.S. Merchant Marine Academy.

7. Dobie, Kathryn (2005). *The Core Shipper Concept: A Proactive Strategy for Motor Freight Carriers*. Transportation Journal, Spring 2005. 37-53.

8. [GAO-07-718], *Intermodal Transportation, "DOT Could Take Further Actions to Address Intermodal Barriers,"* U.S. Government Accountability Office, Washington, D.C., 2007.

9. "Intelligent Railroad Systems." Excerpt from website. n. pag. http://www.fra.dot.gov/Pages/779.shtml 8 March 2011.

10. Keeney, Ralph L. (1992). *Value Focused Thinking: A Path to Creative Decision Making*, Harvard University Press, Cambridge, MA.

11. Keeney, Ralph L. (1994). *Creativity in Decision Making with Value-Focused Thinking*. Sloan Management Review, Summer 1994, 33-41.

12. Keeney, R. L. (1996*). Value-focused thinking: Identifying decision opportunities and creating alternatives.* European Journal of Operational Research, 92(3), 537-549.

13. Keeney, R. L. (2008). *Applying value-focused thinking*. Military Operations Research, *13*(2), 7-17

.

14. Keeney, R. L., & Gregory, R. S. (2005). *Selecting attributes to measure the achievement of objectives*. Operations Research, *53*(1), 1-11.

15. Kirkwood, Craig W. (1997). *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets*. Belmont, CA: Wadsworth Publishing Company

16. Kozan, E. (2006). *Optimum capacity for intermodal container terminals*. Transportation Planning & Technology*, 29*(6), 471-482.

17. Landers, J.. (2010). *Federal Surface Transportation Grants Reward Rail, Mass Transit Projects*. Civil Engineering, 80(4), 23. Retrieved March 1, 2011, from ABI/INFORM Research.

18. Leachman, Robert C. (2008). *Port and modal allocation of waterborne containerized imports from Asia to the United States*. Transportation Research Part E, 44. 313-331.

19. Maloni, Michael & Jackson, Eric, C. (2005). *North American Container Port Capacity: An Exploratory Analysis*. Transportation Journal, Summer 2005. 1-22.

20. Military Sealift Command website, https://www.msc.navy.mil. 10 May 2011.

21. Military Surface Deployment and Distribution Command, Transportation Engineering Agency, OCONUS Port Studies. 27 April 2011.

22. Muller, G. (1999) *Intermodal Freight Transportation,* Fourth Edition, Eno Transportation Foundation and Intermodal Association of North America, Washington D.C.

23. Paun, Mark S. (2006). *Intermodal Distribution comes of age in Europe.* Army Logistician PB 700-06-01, Volume 38. Retrieved May 12, 2011, from http://www.almc.army.mil.

24. [SR-252], Transportation Research Board, *Special Report-252,* "Policy Options for Intermodal Freight Transportation," National Academy Press, Washington D.C., 1998.

25. Taylor, J.C., Jackson G.C., *"Conflict, Power, and Evolution in the Intermodal Transportation Industry's Channel of Distribution*," Transportation Journal, Spring 1999.

26. Terreri, A.. (2011, January). *Intermodal Rail Gains Momentum*. World Trade, WT 100, 24(1), 34-38. Retrieved March 1, 2011, from ABI/INFORM Research

27. Thuermer, K.. (2009, January). *Intermodal Grows Up*. World Trade, 22(1), 36-39. Retrieved March 1, 2011, from ABI/INFORM Research.

28. Shoviak, M. *Decision Analysis Method to Evaluate Integrated Solid Waste Management Alternatives for a Remote Alaskan Air Station,* MS thesis, AFIT/GEE/ENV/01M-02. School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 2001.

29. Swartz, K. "Great Circle Mapper Utility Tool." http://www.gcmap.com. 27 April 2011.

30. Tharaldson, M.K.W. *Strategic Airlift En Route Analysis to Support the Global War on Terrorism using a Value Focused Thinking Approach*, MS thesis, AFIT/ENS/GOR/06-19. School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 2006.

31. The World Bank website, http://worldbank.org. 27 April 2011

32. U.S. TRANSCOM briefing slides, "Criteria and Weighting and Suitability Model", no date

33. World seaports catalogue, marine and seaports marketplace, http://ports.com/. 12 May 2011

Vita

Major Todd C. Markwart graduated from Horizon High School in Scottsdale, Arizona. He entered undergraduate studies at the University of Arizona in Tucson, Arizona where he graduated with a Bachelor of Science degree in Criminal Justice in December 1998. He was commissioned through AFROTC at the University of Arizona.

His first assignment was at Laughlin AFB as a student in Undergraduate Pilot Training in November 1998. After pilot training, he was assigned to fly C-17s at McChord AFB in April 2000. After attending the C-17 Weapons School in May 2005, he was stationed at Charleston AFB. In February 2009, Major Markwart was selected to stand up the first ever multinational C-17 airlift unit at Papa AB, Hungary. In May 2010, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to AMC staff at the Advanced Airlift Tactical Training Center in St. Joseph, Missouri.

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