COMPREHENSIVE FRAMEWORK FOR SUSTAINABLE CONTAINER PORTS DEVELOPMENT ON THE US EAST COAST IN THE 21ST CENTURY, YEAR TWO

Thomas Grigalunas, Meifeng Luo and Bong Min Jung
University of Rhode Island

August 2002

URITC PROJECT NO. 536140

PREPARED FOR

UNIVERSITY OF RHODE ISLAND TRANSPORTATION CENTER

DISCLAIMER

1. Report No
URITC FY00-10

2. Government Accession No.
N/A

3. Recipient's Catalog No.
N/A

4. Title and Subtitle
Comprehensive Framework for Sustainable Container Ports Development of US East Coast in the 21st Century: Year Two

5. Report Date
August 2002

6. Performing Organization Code
N/A

7. Authors(s)
Thomas Grigalunas, Meifeng Luo & Bong Min Jung

8. Performing Organization Report No.
N/A

9. Performing Organization Name and Address
University of Rhode Island, Dept. of Env. & Natural Resource Economics,
Kingston Coastal Institute, Kingston, RI 02881
(401) 874-4572
grig@uri.edu

10. Work Unit No. (TRAIS)
N/A

11. Contract or Grant No.
URI 536140

13. Type of Report and Period Covered
Final

12. Sponsoring Agency Name and Address
University of Rhode Island Transportation Center
85 Briar Lane
Kingston, RI 02881

14. Sponsoring Agency Code
A study conducted in cooperation with U.S. DOT

15. Supplementary Notes
N/A

16. Abstract

Building upon the conceptual framework developed during our year one research, a container port and multimodal transportation demand simulation model is applied. The model selects the least-cost (vessel-port-rail-truck) route from sources to markets, where costs are defined as total general costs--costs for using each transportation facility plus interest on the value of investment in containerized goods. The database in the model includes all state and federal highways, the Class I rail system, and oceangoing and near shore shipping routes. For the US, the analysis is at the state level (at the county level for the Northeast). Outside the US, analysis is at the continent level, except for Asia, which is divided into East and West Asia (Singapore and West). Best available data are used as input for economic parameters. Key results show (1) estimated annual demand for 14 major US coastal ports for 1999, (2) the transportation routes for different markets, sources, and cargo values, (3) market areas (the "extent of the market") served by major ports, and (4) interport demand changes due to hypothetical fee changes at selected ports. Then, the model is used to illustrate estimation of (4) the initial demand for a hypothetical new port and (5) the importance of availability of double-stack train rail access and competition from other ports for the hypothetical port. These results then were used, along with other information, to estimate the financial feasibility and risk for the hypothetical port. Limitations, qualifications and refinements and extensions are noted.

17. Key Words
Key words: Transportation economics, container transportation economics, container port demand, multimodal demand, least-cost routing.

18. Distribution Statement
No restrictions. This document is available to the Public through the URI Transportation Center, 85 Briar Lane, Kingston, RI 02881

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	77	N/A

Acknowledgements

First and foremost, the authors wish to thank the sponsors of this research, the URI Transportation Center and the Korea-America Joint Marine Policy Research Center at URI for their generous financial support. Beyond financial support, we deeply appreciate the encouragement and professional interest of Dr. Richard Horn and Professor Wayne Lee over the course of our involvement with the URI Transportation Center.

We are grateful to Ms. Donna David for her valuable secretarial assistance and to Ms. Simona Trandafir, Ms. Gina Shamshak, and Ms. Gabriela Dobrot for their graduate assistance. We also acknowledge the professional and pleasant support by Ms. Gail Paolino of the URI Transportation Center who always reminded us what was due and when, and, in short, kept us on track.

Finally, we benefited substantially from many constructive comments by anonymous reviewers of our proposal and draft final report. Of course, the authors are responsible for any remaining errors.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

I.A. Background and Issues

International trade plays a vital and growing role in the world economy, with container ships serving as the virtual maritime "bridge" used to move goods in a seemingly unending flow across the world's oceans. To carry this vast quantity of containerized goods to and from the United States (some 144 million metric tons 2001 (www.marad.dot.gov/Marad_Statstics/C-Port-Dir.html)), container ships on major routes are increasingly larger and more expensive, driving the need for rapid vessel turnaround times at ports (Cullinan and Khanna, 1999). For US ports hoping to serve as viable hubs, deep water, efficient terminal facilities, and rapid access by double-stacked trains are required. Major investments have been made to upgrade and expand port facilities to meet growing demands, but serious problems in expanding capacity persist and the threat of future gridlock at and around major urban ports remains (MARAD, 2002).

In light of the growth in international trade and the constraints on many existing ports and multimodal links, coastal areas throughout the US face major economic pressures to develop, expand, and improve container port and related transportation facilities. (Hereinafter, port development, expansion, or improvement is referred to as "port development" unless otherwise noted.) Successful container port development can provide significant transportation cost savings and other potential benefits, but success is by no means assured. Port development requires a major investment, imposes risks on many stakeholders, and often raises contentious environmental and economic issues—any of which can delay, modify, or derail planned port development.

Given the array of financial, economic, and environmental issues often raised, many factors must be weighed during the port-planning phase. These factors are inextricably linked, and sound policy assessments for port development can benefit from use of an integrated framework which can capture benefits and costs and the tradeoffs that inevitably arise as different polices are considered.

The research reported on herein is part of a comprehensive framework being developed by the authors and colleagues for assessing container port development. By "comprehensive" we mean that our aim is to consider core financial, economic, and environmental issues in container port and related multimodal development. By "framework", we mean a set of linked concepts and methods all of which are directed toward the same ultimate objective – assessing net benefits to a terminal operator, a host state or region, and the nation as a whole.

An earlier report presented the concepts to be used, summarized illustrative case studies, and provided examples for eventual implementation of the framework (Grigalunas, Luo, and Chang, 2001). Our earlier report also identified future areas of research needed, and began the application of the conceptual framework presented in the year one work.

One critical research need identified in our first-year report was the development of methods to estimate the potential demand for container ports and related multimodal services. Demand analysis -- that is, estimating moves of containers through a port over a period for a given level of fees -- plays a major role in (1) port planning and development, (2) multimodal facility investment, and (3) business decision-making in the container transportation industry (Benacchio, et al, 2000; Hoffmann, 1998; US DOT, 1998). Estimates of port use, therefore, provide the foundation for evaluating not only the financial feasibility of a proposed port, but also for assessing benefits and costs and their distribution to the host state or region and to the nation as a whole.

Demand estimates also provide important information on the need for, and the prospective uses of, multimodal facilities. This information can contribute to evaluating the benefits and costs of infrastructure investments, and also yields data useful for assessing some environmental issues, such as truck traffic on local roads and associated potential external costs like noise and air pollution.

However, port demand analysis is extremely difficult. For one thing, it is derived from international trade in containerized goods. Projecting international trade is hard, but projecting trade in containerized goods in enough detail to be useful in regional port demand analysis is truly daunting. Port demand analysis is also complicated by inter-port competition and the consequences of strategic behavior by ports, shippers, and shipping lines. Difficulties also arise from the many site-specific factors to be considered, major data requirements, and the intensive nature of the computations (Chapter II).

Especially challenging is assessing demand for *new* ports. By definition, historic data do not exist for a new port, and using data from *existing* ports to project potential demand at a *new* port may be problematic at best. This is especially true if a new facility changes the structure of the existing transportation market, as one would expect when major changes are made in the transportation sector.

In short, estimating the demand for a new port or introduction of major new transportation facilities poses many challenges for investors, planners, and policy makers. For the US East Coast, added complications arise from competition with Canadian ports as well as other domestic ports, including West Coast ports, in some cases. Further, port development along the Northeast coast must consider the ramifications of the planned introduction of a Northeast feeder-port system using a network of coastal barges and inland trains to transship containers from the Port of New York and New Jersey to distribution centers in the Northeast (Ellis, 2000)[1].

As the examples given in the above paragraphs illustrate, container port demand analysis for a specific port or area is enormously complicated. We argue that new models and methods can provide valuable insights into the projected demand for container port

---

[1] Also, planned expansion and pricing of the Panama Canal must be considered. Goods from Europe destined for the West Coast, or goods from West Asia being shipped to the US East Coast can use the all-water route through the Panama Canal or be transported by train using the mini-land bridge across the US. The route taken will depend upon the total cost of using all water route compared with the multi-modal route. In our simulation model, the route selected depends upon the value of the cargo and the interest rate, in addition to the freight rate, as explained in Chapter II.

services. Such models also might contribute to decision making from the broader perspective of regional, national, and even international port policy. In this larger setting, a fundamental question is: What configuration of ports and use of related, multimodal facilities will "best" meet the growing demand for containerized goods? To be sure, this question is extraordinarily difficult to answer -- or even to meaningfully pose. Nevertheless, this broad quest is significant, and demand analysis and related analytical tools can provide a framework that can contribute to policy debate and decision making.

In summary, stakeholders facing the complex issues raised by port development can benefit from an integration of concepts, methods, models, and approaches that address key financial, economic and environmental issues. To be useful, the insights available from different disciplines are needed. Among these are environmental and natural resource economics (for resource-valuation and benefit-cost issues), economics (for demand analysis and research on competition and strategic behavior), financial analysis (for discounted cash flow, financing, and tax issues), operations research and computer science (for mathematical modeling and efficient computational algorithms for large-scale problems), and modern visualization methods (allowing user friendly access for stakeholders, as we explain below) in order to contribute to public debate and policy for container port development.

I.B. Overview of the Year One Research Project

In the first year of research, common themes were found to recur in only slightly altered form in coastal areas interested in, and concerned with, prospective port development. These common themes include: (1) concern about the financial feasibility of port development and the role of multimodal access, (2) potential adverse environmental effects and measures that could be taken to mitigate them, and (3) concern about the size and distribution of benefits and costs[2].

To begin to address the above issues, our Year One research project sought to provide an integrated, "comprehensive" framework (Figure 1). It focuses on key financial, economic, and environmental issues and sources of risk in port planning for the US, and particularly for the US East Coast (Grigalunas, Luo, and Chang, 2001).

Because container port issues vary between concerned parties, our Year One report examined benefits and costs from three, very different perspectives:

- a private terminal operator
- the host state (or region)
- the nation as whole.

[2] For example, the recent controversy surrounding the proposed deepening of the Delaware River main federal channel largely had to do to with questions of the size and distribution of economic benefits attributed to the project, as well as concerns about environmental effects and their mitigation (Grigalunas and Opaluch, 2002; General Accounting Office, 2002).

Once this framework is fully operational, a set of methods and "tools" will be available to help better understand who gains, who pays, and by how much. However, even the best technical studies will be of limited use, unless the results can be readily understood by the interested public, stakeholders, and decision makers who may not have a technical background.

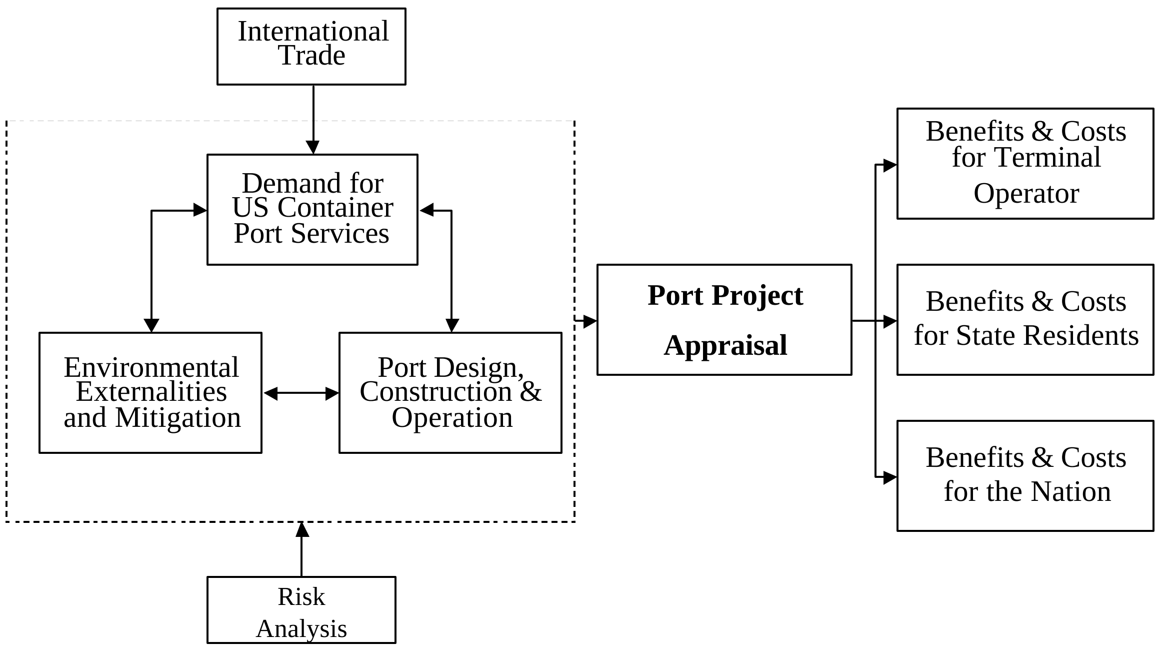
To this end, our ultimate goal is to allow users of the new Policy Simulation Lab at the URI Coastal Institute to assess a variety of container transportation policy issues, drawing upon modern visualization methods (Opaluch, et al., 2002). For example, public users of the framework will be able to simulate the effects on demand for port services, profitability, and public revenues due to a wide range of potential developments. These could include inter-port competition and strategic behavior, including the effects of fee changes. Other issues which could be illustrated include the consequences of a new port or multimodal infrastructure, the effects of selected, new national security policies, or of changes in environmental regulations, or energy costs. Illustrations of fee changes, a hypothetical new port and multimodal infrastructure, and aspects of interport competition are given later in this report.

Specifically, in our Year One research we:

- Developed the *conceptual basis* and identified data needs for a simulation model to estimate the demand for container port and related, multimodal transportation services.
- Applied a discounted cash flow model to assess the financial feasibility and the sources and degree of risk from development of a hypothetical, new container port (terminal) facility. Risk was assessed using sensitivity analyses for important and uncertain variables (start up volume and growth, productivity, and costs) and also using more formal methods (Monte Carlo techniques and a dynamic, discrete event model). *This analysis assumed double-stack rail access between the hypothetical port and mid-west markets were in place.*
- Addressed environmental issues by reviewing potential external costs from container port related development. Concepts for assessing these costs and analyzing the methods for quantifying these non-market effects were examined and illustrated, through examples and case studies. Mitigation or avoidance of adverse environmental effects also was described.
- Set out a consistent, benefit-cost framework for assessing the net economic gains for port development from the viewpoint of a host state (or region) and/or to the nation as a whole from international container shipments.

Among the conclusions of our Year One research was the high degree of financial risk associated with a new container port, at least given the limited information available at the time of the analysis. Major sources of port development risk were identified as the startup volume and annual growth in the number of container moves through the port and the efficiency of port operation, measured as moves/gantry crane/hour. Throughout the analysis of financial feasibility in our Year One study, multimodal transportation to markets via an improved rail and road system were assumed to be in place. Other issues identified had to do with the need to refine and extend our analyses of selected environmental issues.

Figure 42. Simplified Depiction of Comprehensive Framework for Sustainable Container Port Development



I.C. Purpose and Scope of the Year-Two Research Project

Three inter-related analyses are presented in this report. Taken together, these analyses substantially refine and extend the work presented in our Year One report. Major elements of this report include:

- First, we apply the *container port demand simulation model* developed in the Year One report to estimate the potential demand for container moves through 14 major US container ports for the base year 1999 (Chapter II)[3]. These 14 ports handle the vast share (over 90 percent) of containers through US ports.
- Then, a hypothetical new port is introduced in the model, and the *potential initial demand* for this new port is simulated (Chapter III). The model results illustrate the critical role of access to multimodal transportation (particularly double stacked trains) in port profitability. The model results also demonstrate that it is important for port planners to include substitute ports and interport competition when estimating demand for port services.

[3] In fact, the ports of Long Beach/Los Angeles and Tacoma/Seattle are combined due to their proximity. Hence, our model covers 16 major US ports (see Chapter II)

- With the initial new potential container port demand estimate, we go on to reapply the DCF model developed in Year One to provide a new look at the financial risk and uncertainty facing a prospective port developer (Chapter IV). To do this, we project demand for TEU movements through the new port, using preliminary results from an econometric model developed as part of our Year Two research as well as results from container projections from other sources in the literature.

Environmental issues are not considered in this report. These issues were addressed in our Year One report and refined analyses of selected environmental issues (noise and air emissions) are part of our ongoing, Year Three research program.

We believe that the research results described in the chapters that follow substantial extend and improve upon our earlier research on the topics covered. Nevertheless, we emphasize that this is an ongoing project – a work in progress -- and a number of important issues remain. Ongoing and planned research to address remaining specific issues is described in the text.

II. A MULTIMODAL TRANSPORTATION SIMULATION MODEL FOR US COASTAL CONTAINER PORTS

II. A. Introduction

This chapter develops and applies a spatial-economic, multi-modal container transportation simulation model for US coastal container ports. The model is validated and then used to assess the impact on port demand from varying port use fees, i.e., to evaluate the responsiveness (price elasticity) of demand to change in port use fees. Then, in Chapter III the model is used to assess aspects of inter-port competition due to fee changes and introduction of a *hypothetical* new port. Also highlighted in Chapter III is the importance of new multimodal facilities – rail access – to the potential success of the hypothetical new port.

The chapter draws upon results from the Ph.D. dissertation of Luo (2002), which is part of a multi-year study by the authors and their colleagues at the University of Rhode Island and the Korea Maritime Institute from 1999 to now (Grigalunas, Luo, and Chang, 2001). The underlying theoretical framework is based on fundamental microeconomic theory and assumes shippers minimize the total general cost (explained below) of moving containers from sources to markets. We apply the model to estimate *annual* container transportation service demand for major container ports in the United States (US).

First, we outline the model formulation, focusing on the model and the underlying economic reasoning. We also provide a very brief introduction to the assumptions, computational algorithms, and the software architecture. Then, we describe the data used in applying the model, including trade data, transportation networks, and economic variables. After that, the estimated container transportation flow origin-destination (OD) matrix is used to illustrate the model simulation results. All models, including the one presented here, are simplifications, and we stress that the model remains a work in progress. Limitations in the modeling approach, needed refinements, ongoing work, and future directions are briefly described in the final section. Readers not interested in the more technical issues can skip over parts of this chapter.

II. B. The Model

II. B. 1. Introduction

A simulation framework is used, given our research focus on multiple ports and multi-modal shipments of containers in a national and international context. Other modeling approaches have been applied in the literature, using econometric methods (McFadden, 1974; Winston, 1981; Murphy, Daley and Dalenbery, 1992; Jones Qu, 1995; Bolduc, 1999; Garrido, and Mahmassani, 2000; Malchow, 1974), operations research (Hiller and Lieberman, 1974), Emerson and Anderson, 1989) and related techniques (e.g., Hensher and Button, 2000; Kesic, Komadina, and Cisic, 2000). However, the simulation approach is most suited to our work[4]. For a detailed comparison of methods see Luo (2002) and Grigalunas, Luo, and Chang, (2001).

The model is designed to estimate container port demand by simulating the container transportation process through a multi-modal transportation system including ports, rail, highway, and international shipping lines. We distinguish between the purpose of the work reported on in this chapter—to estimate *demand*—and the estimation of the market equilibrium, which includes both demand and supply and is outside the scope of this work.

The model assumes shippers select a route that minimizes the general cost over the whole transportation process; 1999 is used as a base year for trade data, aggregate trade, and its composition; and at this point, we use readily available economic parameters. The rationale for selecting the simulation method and the important implication of these (and other) assumptions are explained in detail in Luo (2002) and in Grigalunas, Luo and Chang, (2002). In ongoing research we will relax some of these restrictive assumptions and improve upon the data used in this chapter.

Next, the economic reasoning and model formulation for calculating general transportation cost are explained. We also discuss the computational algorithm and the simplified software architecture of this model.

Container transportation demand is derived from the demand for international trade in containerized goods. Container routing in the model depends on the origin and destination of the cargo, and how shippers select the route along which to transport the cargo. Many routes could be used for transporting a container between one point in the US and a foreign country. Some routes may use more water transportation but less land transportation (truck and rail), so the transportation cost is low, but it may take a longer time to reach the destination. Other routes use less sea transportation route but longer land transportation, so that the transportation cost is higher, but less time is needed to reach the destination. For the transportation process that is more shipping intensive, the model assumes some savings in lower freight rates will be realized, but it takes longer time, resulting in a higher opportunity cost of capital, higher depreciation cost for some cargo, and higher refrigerated box ("reefer box") renting cost for cargoes that need to be frozen during the transportation process.

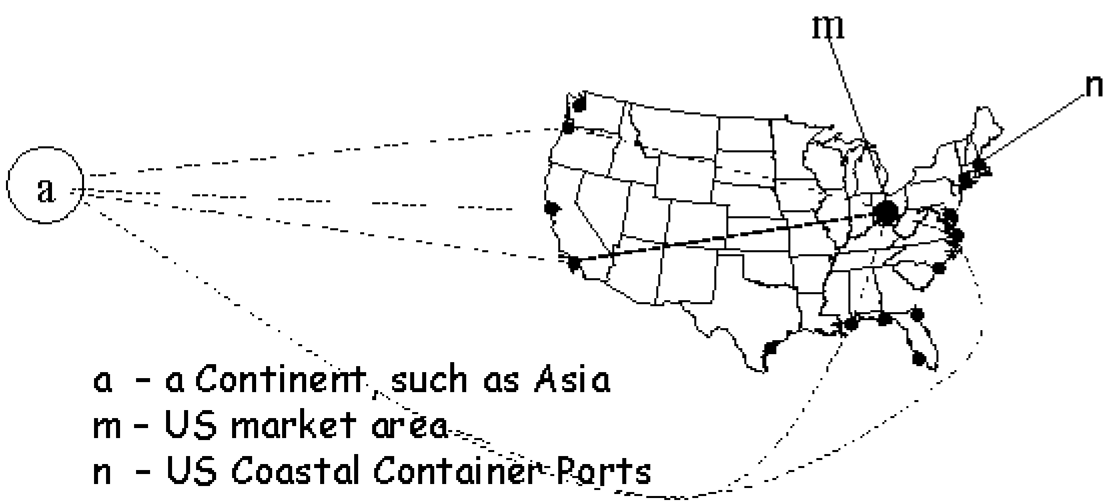
In short, trade offs exist between the transportation cost and the time cost in the route selection decision. In the model, the shipper selects the route which minimizes the total cost in the transportation process from the origin to the destination, where total cost includes the freight rate paid to the transportation facility provider according to usage, and the interest cost on the value of cargo, which varies with the time spent in travel, cargo value, and the interest rate.

[4] Most statistical analyses depend on the observations used, and the generated statistical models are only valid when the market structure remains the same. However, one can not observe anything for a new port before it is built. Therefore, if adding a new port changes the structure of the container port market, simulation methods are more appropriate than regression methods.

In the model, each route is assumed to use only one coastal port. By selecting a least-cost route, the port that a container of typical cargo will go through is also determined in the model. The aggregation of all containers that go through that port gives the simulated container transportation demand for that port.

Next, the basic model for the simulation of container transportation for US coastal container ports is described. A simplified depiction for the transportation process is given in Figure 43.

Figure 43 Simplified Depiction of a Multimodal Transportation Network



Assume there are Q_{ami} containers (in TEU) of cargo category i ($i \in [1, I]$) that are to be imported from world region ***a*** (a continent) to one destination ***m*** in US (exporting is a reverse process of importing). The ship cost is α dollars per mile per TEU. There are N coastal ports to choose from in the US, the distance of region a to the n^{th} ($n \in [1, N]$) container port is l_{an}, The port charge at n^{th} port is p_n per container. The domestic transportation cost from the n^{th} port to the destination m is the sum of the costs of each mode. Assume for mode j ($j \in$ [truck, rail]) the unit cost is b_{nmj} per container per mile, with inland transportation distance l_{nmj}. The sea transportation speed is S_s miles per hour, domestic transportation speed is S_{Lj} miles per hour and the port dwelling time for n^{th} port is H_n days. Also assume the value of container is V_i, and the daily unit cost of capital is r.

- Transportation Costs

Transportation cost is the sum of the fees paid to the transportation facility providers for the use of the facilities (truck, rail, port and container vessel). For some routes, railway may not be used, so rail cost may not appear.

II. B. 2. Mathematical Model

For one container from an origin in a particular world region, ***a***, to a particular place *m* in the US, the transportation cost (C_1) using n^{th} port is:

$$C_1(n) = a * l_{an} + p_n + \sum_j b_{nmj} * l_{nmj} \quad (1)$$

- Time Cost

The time spend on sea leg is: $\frac{l_{an}}{24S_s}$ days, port H_n days, and domestic $\sum_j \frac{l_{nmj}}{24S_{Lj}}$ days, thus total number of days spent in transit is $D_n = \frac{l_{an}}{24S_s} + H_n + \sum_j \frac{l_{nmj}}{24S_{Lj}}$.

For cargo *i*, the opportunity cost of time for the cargo value:

$$C_2(n) = V_i[(1+r)^{D_n} - 1] \quad (2)$$

Other costs that can be expressed as a function of time, like cargo depreciation, refrigerated container rental, can also be included in this part.

- Total cost in the transportation process

The total cost in transit by using n^{th} port is the sum of the costs in the above two part:

$$TC_i(n) = a * l_{an} + p_n + \sum_j b_{nmj} * l_{nmj} + V_i[(1+r)^{D_n} - 1] \quad (3)$$

Assuming the shipper selects least-cost route, the selected port is the one that minimizes $TC_i(n)$. i.e.,

$$\min_n \{TC_i(n)\} \quad (4)$$

Assume through the selection of the least cost route, Q^n_{ami} containers of cargo *i* move from ***a*** to ***m*** will use port ***n***, then the annual demand of port ***n*** ($Q(n)$[5]) is:

$$Q(n) = \sum_a \sum_m \sum_i Q^n_{ami} \quad (5)$$

As can be seen from the above discussion and equations, changes in sources, speed of transportation facilities, availability and/or costs of different ports or multi-modal facilities, and in markets will affect the demand for port services. The model can be used to examine changes in these (and other) factors.

[5] As a conditional demand estimation, this research focuses on conditional demand and does not consider any constraints which may exists on Q(n) for each existing port n. Of course, port throughput is constrained by natural or legal factors. These constraints need to be addressed in a port equilibrium analysis planned for subsequent research.

II. B. 3. Shortest Path Algorithm

The core of the simulation model is the shortest path algorithm, which has been widely applied in economic analysis transportation engineering (Bank,1998; Ertl, Gerhard, 1998, Beuthe, et al., 2001; Fowler 2001; HDR Engineering, Inc, 2001), operations research (Hillier and Lieberman, 1974), and computer network routing (Kurose and Ross, 2000). It is one of the dynamic programming approaches described by Bertsekas, (1995).

Shortest-path problems can be stated in many ways. Here, we adopt the common notation used in the dynamic programming method. Assume the multimodal transportation network consists of a set of nodes $\boldsymbol{V}=\{v_i|i\in[1, n]\}$, then the shortest path from one node (assume node 1) to all other nodes can be formulated as a deterministic dynamic programming problem as follow (Kronsjo and Shumsheruddin, 1992; Bertsekas, 1995):

$$d_1=0 \tag{6}$$

$$d_i= \min_{k\in E_i}\{c_{ki}+d_k\} \quad \text{for } i = 1, \ldots, n \tag{7}$$

where n is the number of nodes in the network; di is the total cost from the starting node to node i; E_i is a subset of nodes that has a direct connection to node i, $E_i=\{v_i|i\in[1, k]\}$; c_{ki} is the general cost from one of these nodes to node i.

In implementing the simulation model, we use one efficient version of the shortest path algorithm for the single source, multiple destination problems – the Dijkstra Algorithm. This has been classified as "Best First Search" algorithm (Bertsekas, 1995).

II. B. 4. Overview of the Simulation Software

To apply the model, the simulation software used is developed using Java programming language. It is designed so that the users can interact with the simulation software and do simulation analysis using a Graphical User Interface (GUI). The GUI is designed using Java Swing technology. To facilitate the visualization of simulation data, this simulation software also included the design and implementation of a GIS data graphical representation using Java.

The software allows users to set up the simulation environment. Among the many options available are: selection of ports, port fees, and queuing time at each port; economic parameters such as the opportunity cost of capital, the unit cost or transportation speed of rail, trucking and shipping; the trade data to use (e.g., if the user has new trade data), and the transportation network data to apply (e.g., when the user has new transportation network data). Examples provided later in this chapter illustrate the range of results, which can be generated.

II. C. Data

Application of the model requires three different kinds of data: (1) container trade flow

OD data between each state to each continent, (2) economic parameters, and (3) transportation networks. The data sources and the data estimation process are outlined below. Given the importance of each data source for development of the model, each is described in some detail.

II. C. 1. Containerized Trade Flow OD Matrix

To apply the model, data is needed on containerized cargo imports and exports, measured in TEUs, and on the total value of cargoes per TEU. This data is needed for movements between origins and destinations (OD).

The best source of OD data, the Port Import Export Reporting Service (PIERS: www.piers.com) database, is very expensive to acquire and not available for this research. Therefore, we start from estimating a container OD flow matrix from available data – 1999 National Waterborne Trade Database from US Maritime Administration, Department of Transportation (MARAD).

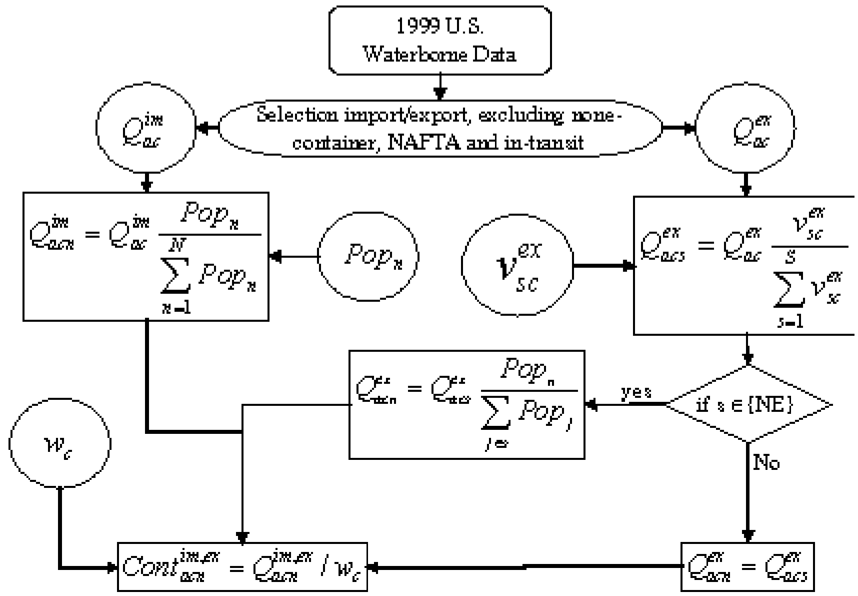
This database contains trade information between the US and foreign countries in weight and in value, but not in TEUs. Further, the data is given for detailed cargo categories (Standard International Trade Classification (SITC) and Harmonized System (HS)), which could roughly be converted to an SIC (Standard Industrial Classification) category (Table 0).

Table 0 Two-digits SIC Codes and Names of US Containerized Cargo

Code	Name	Code	Name
01	Agricultural Products	28	Chemicals and Allied Products
02	Livestock and Livestock Products	29	Petroleum Refining and Related Products
08	Forestry Products, NSPF	30	Rubber and Miscellaneous Plastics Products
09	Fish, Fresh or Chilled; and Other Marine Products	31	Leather and Leather Products
10	Metallic Ores and Concentrates	32	Stone, Clay, Glass, and Concrete Products
12	Bituminous Coal and Lignite	33	Primary Metal Products
14	Nonmetallic Minerals, Except Fuels	34	Fabricated Metal Products, Except Machinery and Transportation Equipment
20	Food and Kindred Products	35	Machinery, Except Electrical
21	Tobacco Manufactures	36	Electrical and Electronic Machinery, Equipment, and Supplies
22	Textile Mill Products	37	Transportation Equipment
23	Apparel and Related Products	38	Scientific and Professional Instruments; Photographic and Optical Goods; Watches and Clocks
24	Lumber and Wood Products, Except Furniture	39	Miscellaneous Manufactured Commodities
25	Furniture and Fixtures	91	Scrap and Waste
26	Paper and Allied Products	92	Used or Second-Hand Merchandise
27	Printing, Publishing, and Allied Products	99	Special Classification Provisions, NSPF

Apart from the ordinary imports and exports cargoes, it also includes in-transit cargoes that are not originated or terminated within US. To convert this data into the container flow OD matrix, we developed a conversion algorithm [6](Figure 44).

Figure 44 Conversion from 1999 US Waterborne Trade Data to Container Flow OD Matrix



First, the total US waterborne trade is separated into import (Q_{ac}^{im}) and exports (Q_{ac}^{ex}) for trade with different continents (subscript a∈{Europe, South America, South Africa, East Asia, West Asia, Australia}) and each cargo category (subscript c- cargo categories as in Table 1).

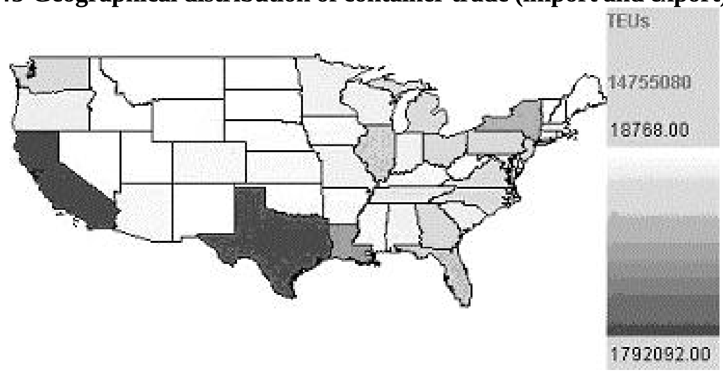
Then, the national imports were distributed to the state level by population (Pop_n, n here is the state number, or county number if it is in Northeast Region), with Northeast region detailed to the county level. Other methods for distributing national cargo import and export will be explored in future research.

The national export data was distributed to the state level by MISER (Massachusetts Institute for Social and Economic Research) state export data (MISER (2000)) (v_{sc}^{ex}). For the Northeast region, the state exports were further detailed for the county level. Finally, all the weight data were converted to number of TEUs, using the research result on estimating weight of containers (w_c) by Hancock *et al.*, (2001)). The MARAD database also has information on the percent of the cargo that is containerized.

[6] US Waterborne data indicates the percentage of cargoes in weight and value which are containerized. For each sector, only the containerized part is counted in our model. We work at the 2-digit level due to the availability of data and of current research on the average weight per TEU, data which is necessary for converting weight to number of TEUs. More detailed data is always helpful in model simulation, but hard to get. Empty and in-transit containers are not included in our model. This leads to an under-estimate for port demand measured in moves of all containers (full, empty, and transshipments) as we describe later in the text.

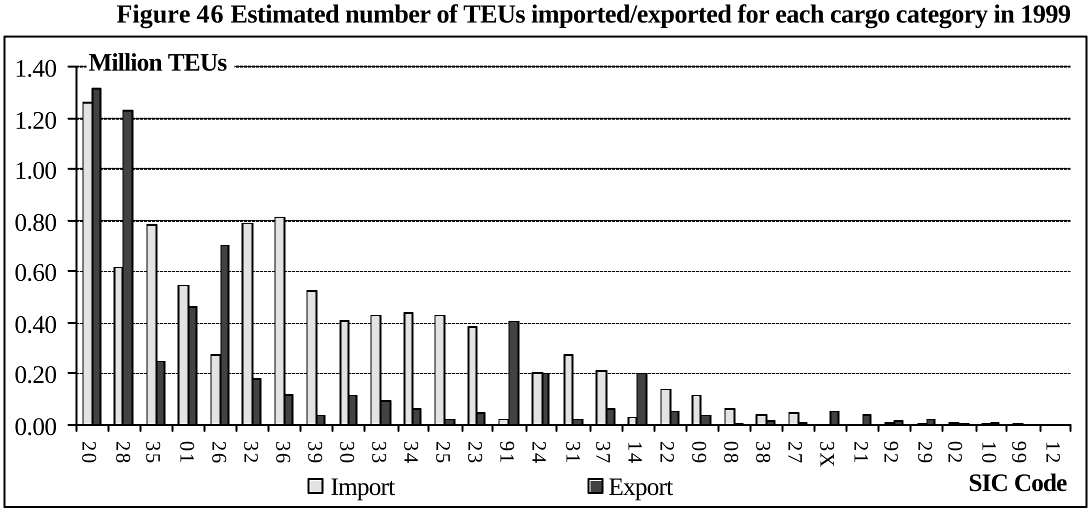
The total converted number of TEUs for US container imports and exports in 1999 is about 15 million (Figure 45).

Figure 45 Geographical distribution of container trade (import and export) in 1999



Container trade by state ranges from 18,768 (state with white color) to 1,792,092 TEUs (state with dark color). Four states, California and Texas, followed by New York and Louisiana, dominate in TEUs. By cargo, four cargo categories prevail: Food and Kindred Products, Chemicals and Allied Products, Paper and Allied Products and Agriculture Products (Figure 46). These four categories alone account for an estimated 3.08 million TEUs, about 53% of the total export containers.

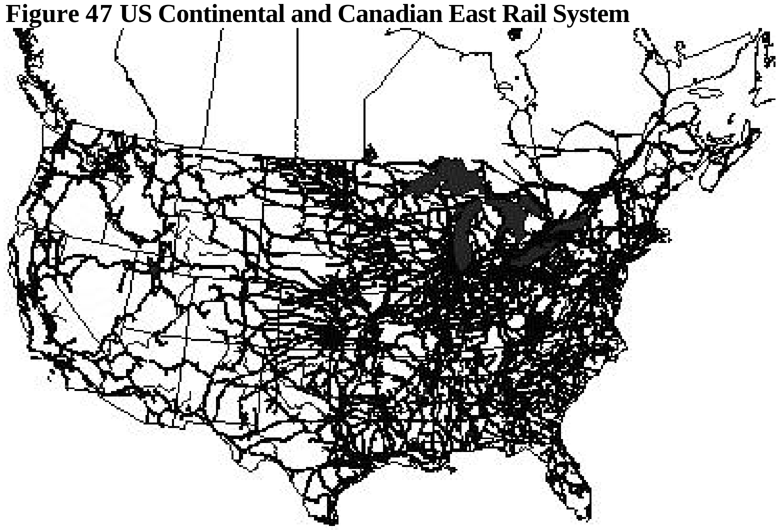
Figure 46 Estimated number of TEUs imported/exported for each cargo category in 1999



II. C. 2. Multi-modal Transportation Network

The multi-modal transportation network in the model contains rail, highway and international shipping line sub-networks, which are extracted from multi-modal transportation network maintained by the Center for Transportation Analysis of the Oak Ridge National Laboratory (ORNL). The rail sub-network includes not only the railways system in Continental US, but also the rail system in the Eastern part of Canada (Figure 47).

Figure 47 US Continental and Canadian East Rail System

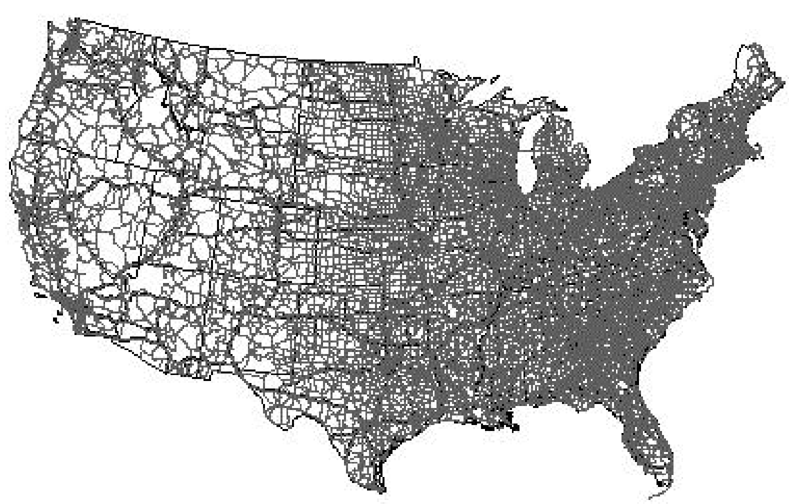


The Canadian part is included because of the need to simulate competition of Canadian ports (Halifax and Montreal) for US East Coast cargoes. Since the focus of this research is on East Coast, the Canadian Pacific coast ports were not included but will be added in our future research.

Both interstate and state highways are included in the highway sub-network (

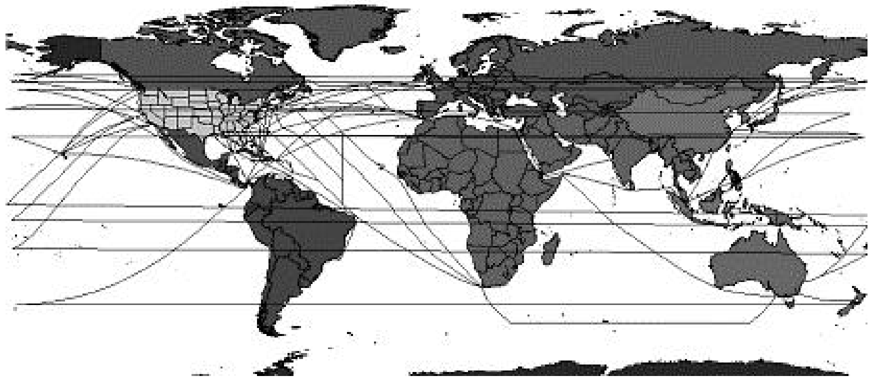
Figure 48). This sub-network overlaps with the rail sub-network, except for Canada; Canadian highways are not necessary to include. This is because our primary concern is the competition of Canadian ports for US cargoes, and most of the US cargoes will not use highways to access Canadian East Coast ports.

Figure 48 Highway Transportation System in the Simulation Model



The international shipping lines are extracted from the ORNL deep-sea sub-network (Figure 49). As foreign countries are aggregated into continents, the international shipping line sub-network is simplified by using the shortest path between each port and each continent directly.

Figure 49 Shipping Route in this Model

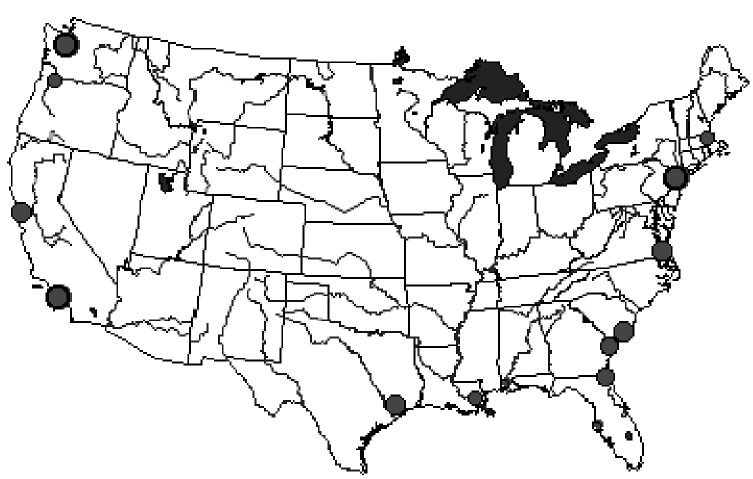


To visualize the multi-modal system used, each modal network (of rail and highway) can be imagined as occupying a horizontal plane, while inter-modal terminals connecting two modes lie between the planes and are attached above and below by vertical access links. The connection of land transportation networks (rail and highway) and sea transportation is at the coastal ports. A unified routable network represents the whole multi-modal transportation network, with a single node list, a single link list, and a topology defined by the links' endpoint nodes. This structure is common to most network analysis program.

II. C. 3. Selected Major US Container Ports

In the model, 14 major US container ports are included: 4 on the West Coast, 4 on the Gulf coast, and 6 on east coast (Figure 50).

Figure 50 Selected US Coastal Container Ports



More ports can be added, according to the issue faced. Table 2 shows the container throughput of selected US container ports, using statistics from the American Association of Port Authority (2002).

Table 1. 1999 TEU Throughput for Selected US Ports in Model

Port	1999 Throughput	Port	1999 Throughput
Houston	1,279,821	Portland(OR)	293,262
NewYork	2,828,878	Seattle**	2,761,059
New Orleans	271,606	Jacksonville	771,882
Long Beach*	8,237,330	Boston	154,175
Tampa	20,273	Savannah	793,165
Norfolk	1,306,573	Oakland	1,703,303
Mobile	16,776	Charleston	1,482,995

*the sum of Long Beach and Los Angeles
***the sum of Seattle and Tacoma*
Source: www.aapa-ports.org

II. C. 4. Parameters and Economic Variables in Simulation Model

To simulate the transportation process and calculate the total cost of transportation, many basic transportation variables must be specified. These include the speed of movement, the unit cost per mile, delays in the terminal and interlink, cost in the rail terminal, and the opportunity cost of time in trucking activities (Table 2).

At this early stage, the economic variables and parameters are selected based on ready availability. The interest rate (15% is used) should be the opportunity cost of capital in the business operation, that is, the *weighted* average of equity and long-term debt. Unit cost per TEU for rail and truck is calculated from average revenue per ton-mile for class I rail and truck, respectively (Bureau of Transportation Statistics, US DOT, (1999), Bureau of Transportation Statistics, US DOT, (2001)). These variables serve to start the simulation process. They all can be changed, for sensitivity analysis or policy analysis, and will be refined in later applications to specific issues.

The TEU statistics include containers loaded with cargoes for import and export, plus empty containers, in-transit containers, and transshipments, as noted earlier. Smaller ports were either neglected, or combined with nearby port. The inclusive nature of the reported TEU statistics becomes important later, when we compare our estimated moves of *loaded* TEUs with actual moves

A Java application is developed to simulate the transportation process, estimate demand for each port according to cost minimization, and graphically represent the data and simulation results. It also allows users to change specific variables through a graphical user interface, which allows users to carry out sensitivity analyses and policy simulations. The detailed structure, design and implementation of the computer model are outside of the scope of this research, so it will not be included. Selected results, described next, illustrate the potential uses of the simulation model.

Table 2. Economic Variables and Parameters Used in the Simulation Model

Name	Value	Notes
IntRate	15%	Annual Cost of Capital
ShipSpeed	20 MPH	From Martin Stepford "Maritime Economics"(*1997*)
ShippingCost	$0.09 /(TEU*mile)	From Cullinane and Khanna (2000)
RailCost	$0.20 /(TEU*mile)	From (BTS, USDOT, 1999, 2000)
railSpeedHigh	64 MPH	The highest rail speed
RailSpeedLow	10 MPH	The lowest train speed
railInterlinkFixCost	$10/TEU	Interlink cost
TruckCost	$2 /(TEU*mile)	From (BTS, USDOT, 1999, 2000)
TruckOCT[7]	$60 /hour	Opportunity cost of trucking
truckToRailCost	$100/TEU	Fixed cost to use rail transportation
truckSpeedHigh	52 mph	The average highest speed of trucking.
truckSpeedLow	10 mph	The lowest speed of trucking
SuezCanalSpeed	5/3 mph	The speed in Suez Canal, for only short length
SuezCanalFixCost	$10/TEU	
PanamaCanalSpeed	5/3 mph	
PanamaCanalFixCost	$10/TEU	

II. D. Selected Results

To illustrate the model, three set of result are presented: (1) simulated transportation *routes* between representative US ports and continents, (2) simulated *conditional demand* of existing major US container ports, and (3) simulated demand curves when one of the container ports changes its *price*.

II. D. 1. Simulated Container Transportation Routes

Simulating transportation routes provides a way to check the validity of the simulation model. Our data on the container transportation OD matrix is converted from waterborne trade, that is, is estimated and, hence, differs from the actual throughput. We can compare our model estimates with actual throughput, but a fully satisfactory comparison between our simulated port demand and actual throughput for validity checking is not possible. A principal reason for this is that actual throughput includes not only full containers but also empty and in-transit containers, while the simulation includes full containers only. Nevertheless, some interesting results and comparisons can be made with the results obtained to date, as we explain below.

US trade with Asia is almost half of all the US international containerized trade and is concentrated in four major states: California, Texas, New York and Washington.

[7] This is an approximation of the net income a truck can earn in one hour by using a high-speed route rather than a low-speed route. It is used to simulate the behavior for truck operations. If a truck has no opportunity cost in this sense, then it will be indifferent between using a high or low speed road. This would be a nonsensical result since, given a choice between traveling 30 miles on a road with a 30 mph speed limit and traveling the same distance on an adjoining road with a 60 mph limit, a trucker in principle could earn twice as much (two trips during the same period) by using the road with higher speed limit.

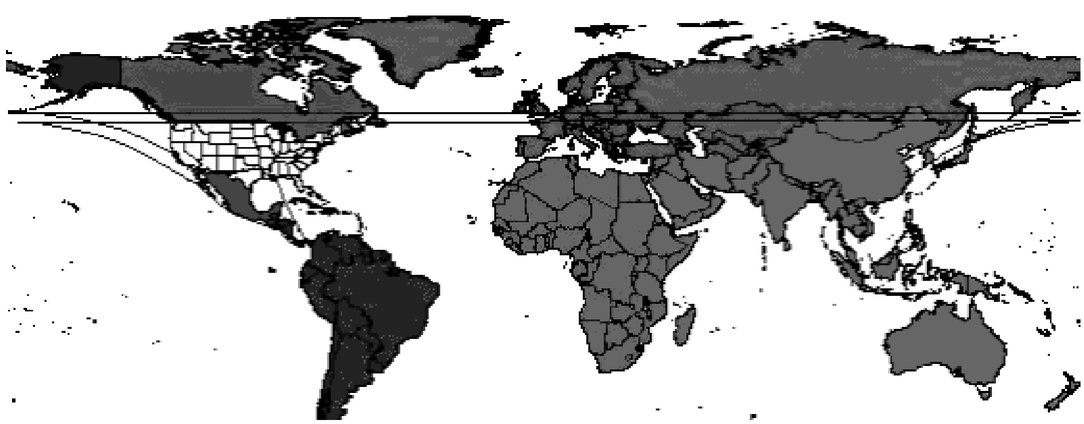
Containerized cargo value for this trade ranges from approximately $1.5 thousand to over $254 thousand per TEU.

The model results show that the decision to use rail or the all-water service depends on which alternative has the lower general cost. Trade between East Asia with West Coast states will always use the direct Trans-Pacific routes, since use of rail will not reduce the general cost. Figure 51 shows the transportation paths between East Asia and the states of Washington and California.

Figure 51. Container Transportation Routes between East Asia and States in Pacific Coast

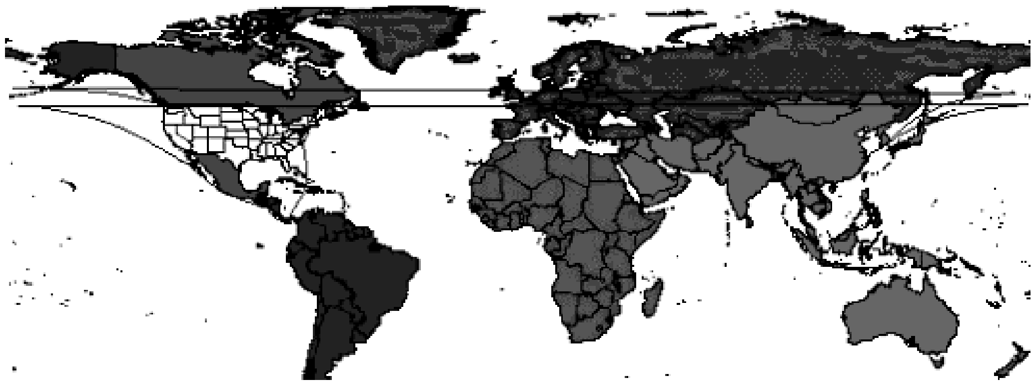
Trade between East Asia and Gulf Coast States (e.g., Louisiana), when the cargo value is low (around $10,000 per TEU), would use as much water transportation as possible, by going through Panama Cannel and using a Gulf Coast container port directly. With high cargo value (around $100,000), trade uses a North Pacific Coast port for import or export and multi-modal facilities to and from the port (Figure 52).

Figure 52. Container Transportation Routes between East Asia and Gulf Coast States



Trade between New York City and East Asia (e.g., China) uses the all-water route through the Panama Canal when the cargo value is low. In contrast, high cargo value imports or exports will move through West Coast Ports and use rail between the port and market area (Figure 53).

Figure 53. Container Transportation Routes between East Asia and New York City



This model groups Asian countries into two sub-continents – West Asia and East Asia. The representative point for East Asia is China. The simulation results shows that the shipping route between East Asia and the US will not take the Suez-Atlantic route, but West Asia trade with the US would take this route.

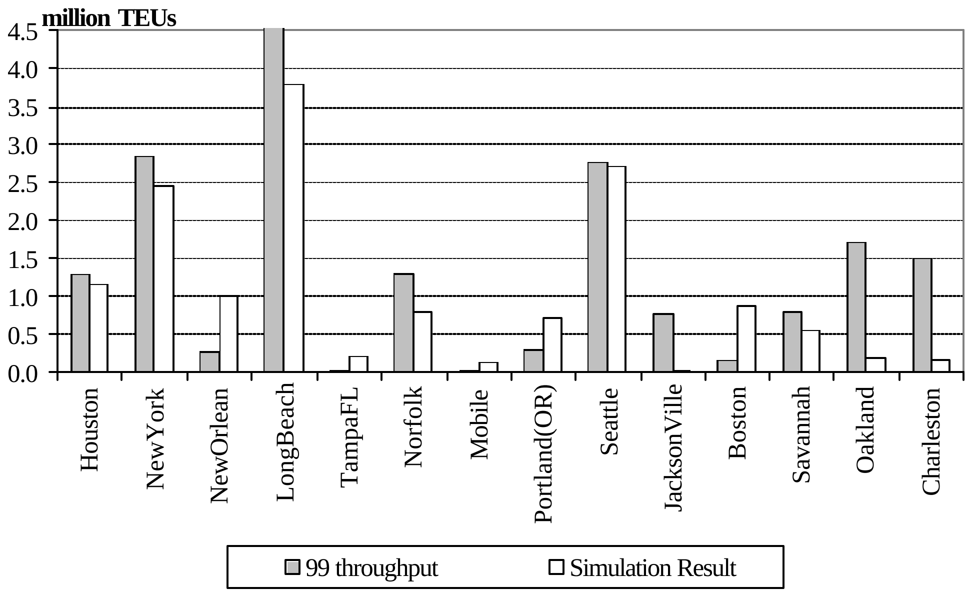
II. D. 2. Estimated Demand for Major Container Ports

Model estimates of the demand for one container port is the *potential* number of containers that will use a port to import and export, conditioned on a given level of fees charged at this port and at all other ports. We re-emphasize that demand is not the same as market equilibrium.

The simulated demand at major container ports is presented in two ways. First, we show the number of containers that will go through each port, for a certain level of charges at every port. The real charge at each port is confidential and hence hard to obtain. At this point, for the purpose of illustrating the model we use a presumed fee of $200/TEU for all ports. Therefore, we estimate a *conditional* demand reflecting the potential for each port, given the assumption that the real costs for a container to go through each port are equal among all the ports. Second, we simulate the effect of inter-port competition, by showing the demand change at other ports due to the fee change in one port, conditional on the fees charged at all other ports (cross-price effects). The demand measured here is a pure substitution effect, which follows from the assumption that international trade is given. To the extent that export or import barriers hinder shippers from switching between ports, our reported substitution effects may be overstated.

Figure 54 presents the model simulation results and actual throughput for selected existing container ports, using the 1999 waterborne transportation data.

Figure 54. Simulated Container Port Demand and the Actual Throughput for Year 1999[8]



Notes: Due to the geographical closeness, some of the ports in West Coast are the sum of two nearby two ports. ***Long Beach*** *throughput is the sum of Long Beach and Los Angeles (about 8.23 million TEUs in 1999).* ***Seattle*** *throughput is the sum of Seattle and Tacoma.*

Generally speaking, the simulated demand (around 15 million TEUs) is lower than the actual throughput for all ports (from AAPA, about 27 million). As noted, the reasons for the observed difference is that reported throughput for ports includes empty containers, domestic movements of containers, transshipments through barge operations, and in-transit cargoes, while the model simulation result contain only fully-loaded import and export containers. Differences in actual costs as compared with the costs used in the simulations also could help explain differences between model estimates and actual throughput.

For example, in 1999 Long Beach handled more than 1 million empty TEUs, and for the Port of Los Angeles 4.76% of inbound containers and 53% of outbound containers were empty. Oakland moved about 400 thousand empty TEUs, while Seattle moved 220 thousand empty containers. Information about empty and domestic containers in other ports is not available. Despite this, the simulated demand of each port reasonably reflects the relative magnitude of actual throughput for major container ports (Figure 54). For example, Long Beach and Los Angeles have the highest throughput of US ports, and this is reflected in the simulated demand. New York is the second largest port, which is also captured in this simulation. Seattle and Tacoma, when added together are comparable with PNYNJ, and this reflects the actual relative order in throughput. Estimated demand for Oakland is very low relative to actual throughput, as we would expect. This is

[8] Note again that "conditional demand" and "throughput" (equilibrium, including both demand and supply) are two different concepts. The fact that the model results excluding supply are reasonable suggess that the results appear to be not much affected by omission of the supply side for this analysis.

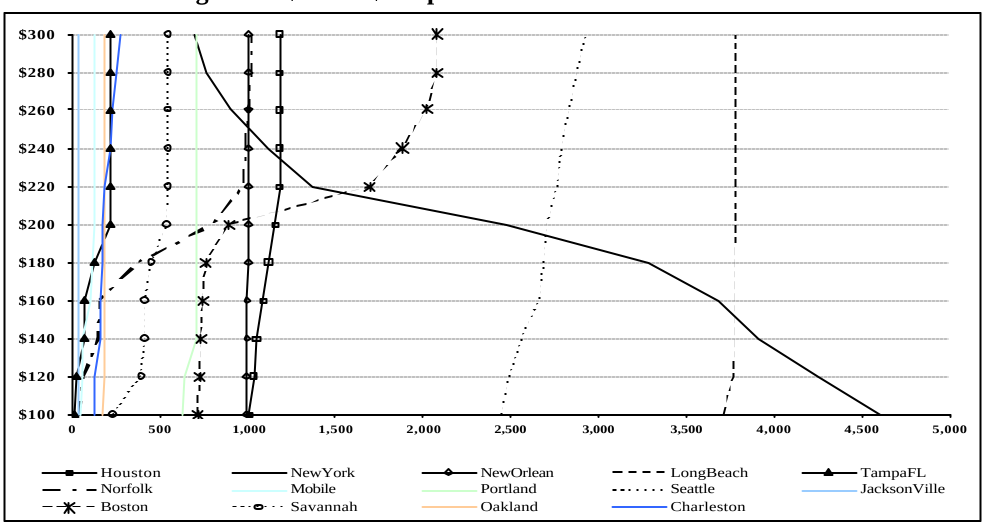
because for each state, the model allocates imports on the relative population of the state. Then, within each state (except for the Northeast, which is at the county level) *all imports* are allocated to one market destination—the metropolitan area with the largest population. Hence, in California the market destination for all CA imports is the LA-LB metropolitan area. Hence, deviations between the simulated result and actual throughput are expected, not only because actual TEUs include empties and transshipments, but also because the current model uses states as the geographical unit (again, except for the Northeast). Use of states is insufficient to distinguish between the ports located in one state, like Long Beach-Los Angeles and Oakland. In future research, states will be desegregated to reflect more realistic markets.

II. D. 3. Demand Change With the Change of Port Use Fees

The previous section presents the simulated results when the port costs are the same for all ports. Many methods can be used to improve the market competitiveness of a port, one common approach being varying terminal charges. Generally speaking, increasing terminal cost at one port will reduce the incentive for shippers to use the port, and shippers may seek a less expensive port. Therefore, the quantity demanded at a port raising fees will decrease while demand in the competing ports will increase.

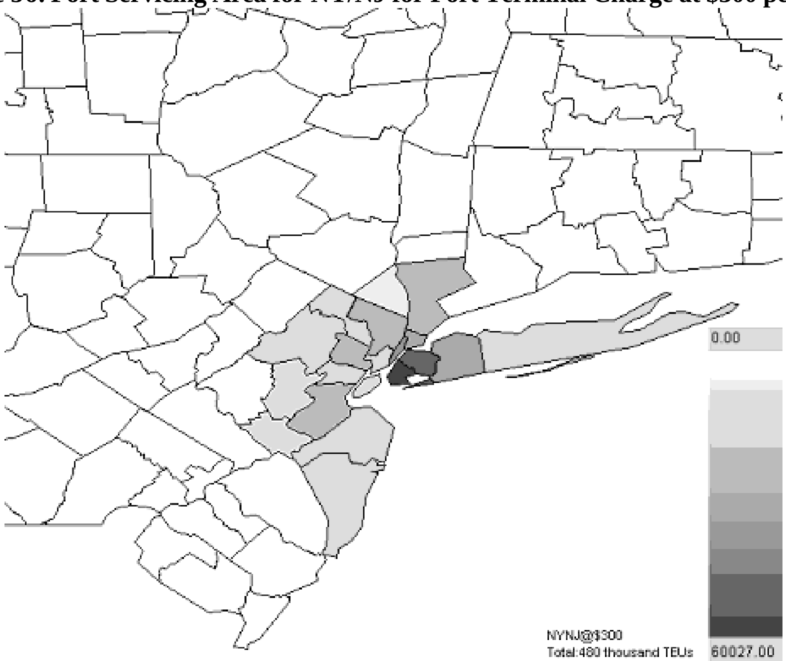
Figure 55 shows the result of simulated demand for each port, assuming the terminal cost at one port (NY/NJ) changes from $100/TEU to $300/TEU. The cost per TEU here represents the overall cost, even include user's preference on the quality of services.

Figure 55. Simulated Demand Change for All Existing Ports When PNYNJ Changes Its Terminal Charge from $100 to $300 per TEU



Several interesting result are found. (1) When PNYNJ hypothetically decreases its terminal price from $300/TEU to $100/TEU, its annual demand will increase from 480,000 TEUs to 4.9 million TEUs, and (2) the $300 per TEU level ($100 more than all other ports, an unlikely case) is near the choke price for *multi-modal* cargo. Also, at $300 per TEU, only local cargoes to and from NYC Metropolitan area will use the PNYNJ (Figure 56). (3) For terminal charges between $220 and $180 at the PNYNJ, the quantity demanded is most elastic. (4) Below $200, a price which is lower than the prices at all other ports in this example, the quantity is less responsive to fee change by the PNYNJ because the PNYNJ cannot capture local markets served by other ports.

Figure 56. Port Servicing Area for NY/NJ for Port Terminal Charge at $300 per TEU



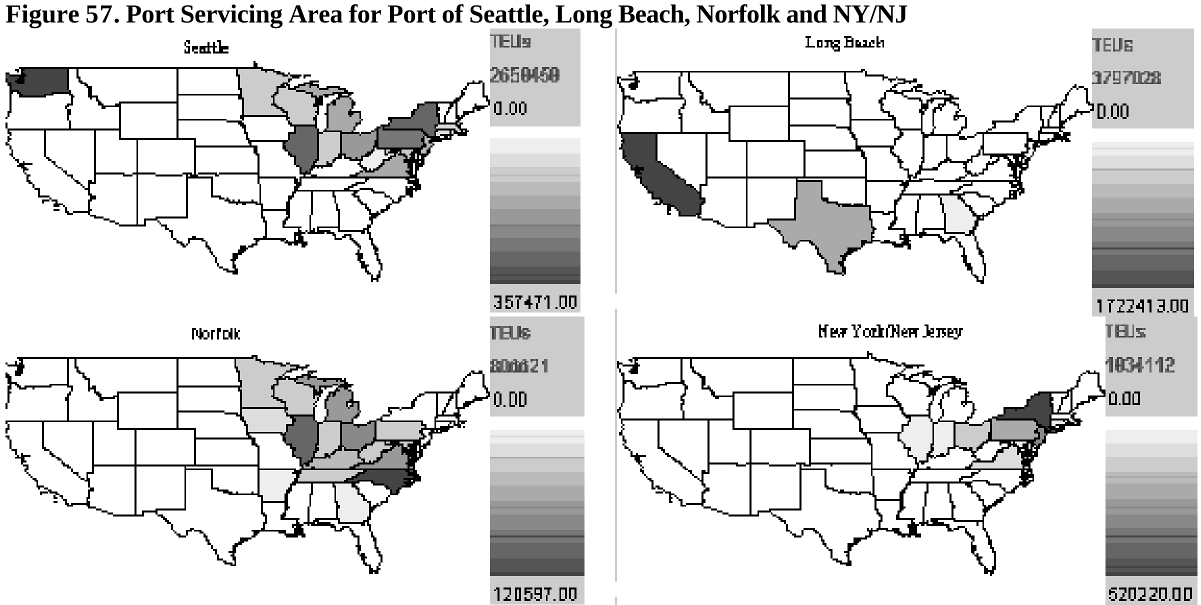
This result also shows the quantity of demand at other ports for different terminal charges at the PNYNJ, with Boston and Norfolk suffering most from reduced fees at PNYNJ. An interesting set of results is that many distant ports also suffer a demand reduction from price decreases at the PNYNJ—not only East Coast ports, but also ports in Gulf Coast and West Coast. When the price is higher than $200, most of the ports in West Coast and Gulf Coast are unaffected. When it continues to drop, the number of affected ports, some quite far from PNYNJ will increase.

II. D. 4. Geographical Distribution of Port Servicing Area

Because of the increasing importance of multi-modal transportation, traditional methods for port demand estimation using hinterland delimitation are no longer valid for container port demand estimation. The import and export of containers at the port will serve not only nearby markets, but also will compete for more distant markets, through use of high-speed, low-cost rail connection.

The simulation of port servicing areas (the "extent of the market") is one of the important results of this research. It is the origin of export containers, or the destination of import containers, which go through a particular port. It supplements the demand estimation, as illustrated in the previous sections, by providing detailed information on the spatial composition of the simulated demand. This will help in understanding the demand change with port competition, not only among nearby ports, but also the ports in other side of the continents. It will also help in identifying the important market areas for container ports and for estimation of the geographic distribution of the benefits from potential transportation cost savings. Figure 57 depicts the port servicing areas for Port of Seattle, Long Beach, Norfolk and PNYNJ. They are simulated assuming that all ports charge the same terminal cost, which is the same assumption used in generating the conditional demands estimated in previous section.

Figure 57. Port Servicing Area for Port of Seattle, Long Beach, Norfolk and NY/NJ



The above figure reveals the vast geographic markets areas serviced by major ports on both coasts, and hence demonstrate the potential for national competition between ports. For example, the Seattle/Tacoma market extends as far as the East Coast, US South Pacific Coast ports compete with South Atlantic ports and Gulf ports, and Norfolk competes with the PNYNJ over containers in the Mid-East region.

In sum, even using very basic economic variables and many simplifications, the simulation model can still provide a number of interesting insights into container transportation demand. The graphic user interface (GUI) of this model enables the user to specify many different scenarios, which could be assessed by suitably altering the model. These potential scenarios include adding a new port at a specified location, improving the rail connections of the proposed port, changing shippers' port choice sets by including Canadian ports, or changing the opportunity cost of capital, the unit trucking cost and rail line-haul rate due to, for example, higher energy costs or environmental regulations, etc. Only a subset of results generated are presented in this chapter; and interested readers are referred to Luo (2002), or Grigalunas, Luo, and Chang, (2001). Forthcoming articles by the authors will address many of these issues.

In closing, we emphasize that the underlying assumptions of this simulation model must be taken together when weighing the results from this chapter and their use for port development policy. For example, the conditional demand estimated from this model is based on the assumption that all port charges are the same. The demand should be understood as the potential number of containers that a port could get if the port does the same as all other ports. The implications of the assumptions in the model will be explained in detail in next section.

II. E. Summary, Conclusions, and Future Directions

Container ports development proposals raise difficult economic issues and present major societal challenges (PNYNJ Press Release, 2001; Preston, 2001). Attempts to resolve these issues require development of new methods and extensions of existing approaches drawing upon advances in simulation techniques and their integration with environmental and natural resource economics and economic theory more generally. Many models are available for transportation modeling in general, but much less work has been devoted to demand estimation for container ports (Hensher and Button, 2000), due to the many national and international issues which must be addressed, the detailed data required, and the high computational complexity involved in solving the model.

This chapter summarized the development of a container port and multimodal transportation demand simulation model for major US coastal container ports and illustrated the model by estimating the demand for 14 major existing US ports. To do this, best available data was used to estimate a container flow OD matrix for different cargoes. The model can be used to simulate container transportation routes for different cargoes between the US and other continents, the conditional demand at each port, and port service areas. It can also simulate changes in the transportation route, port demand, and demand changes due to different policies or developments, such as higher trucking, rail, or shipping costs, changes in the opportunity cost of capital, or due to new ports or multi-modal facilities. The model also could be employed to assess the effects of energy cost changes, of new environmental regulations, and certain national security concerns (such as facility disruptions).

This research reveals that (1) the composition and pattern of international trade, (2) the geographical location of a port with respect to sources and markets, (3) the availability of multi-modal transportation networks, and (4) the associated general total cost, are all major factors influencing container transportation demand at ports. Further, the results demonstrate that competition among container ports is not limited to the vicinity of the port. The service area of individual ports and the cross-price demand curve shows that policies at a given port may affect distant ports. At the same time, demand for port services near major coastal population centers is high, since most container trade is imports, and most US imported cargoes are consumer goods.

We believe this work demonstrates the potential of using simulation methods to provide considerable insights into the demand for container port services, service areas, and multi-modal use and routing. However, the work is still in its early stages and many simplifications have been used, and of course the simulation results presented are limited within the range of the basic assumptions used in the analysis.

Potential refinements include improving important economic parameters used, disaggregating large states (e.g., California) into sub-areas, and use of alternative approaches and assumptions for developing the OD matrix. Extensions include building upon an existing simulation of a hypothetical new port proposed for the Northeast to better evaluate this proposed project as an illustrative case study. Such an analysis should include consideration of a major new initiative by the PNYNJ to develop a port inland distribution system using barges and trains to transship containers to major distribution centers throughout the Northeast.

This simulation provides estimates of demand for the port and the effects of substitutability, including expanding the port "choice set" facing shippers. Ongoing research will model strategic behavior, drawing upon modern game theory. Also, the detailed treatment of multi-modal transportation will allow us to carry out several with-versus-without analyses. For example, we can assess the value of new or improved infrastructure facilities, or analyze selected net environmental effects, for example, truck usage and miles, net air emissions, and vehicle-related noise around a hypothetical new port as compared with the without-port case. National security issues, such as temporary interruption at a port or key infrastructure facility can also be examine.

In the longer run, several basic factors must be considered. Fundamentally, port and multimodal investment are long-run propositions with planning periods of at least 20 years. Hence, it is important to examine how anticipated population and economic growth within the US might affect the relative demand for ports and multimodal facilities. Port expansion which seems pressing today may be less urgent in the future; and of course the opposite can be true. It also is vital to consider major trade developments in terms of trading partners and commodities, especially trade with East Asia -- notably, China -- and, for the East Coast, with Europe. This suggests the need to draw upon or develop, as appropriate, demand analyses for containerized commodities. Also, the proposed major capacity expansion to handle more and larger vessels at the Panama Canal and different pricing structures make it important to refine the way the Canal is included in our simulation model.

Finally, the model as it now stands is a demand model. It is important to build in the supply side to reflect, for example, constraints at ports and multimodal facilities and to make the model an equilibrium model and not just a demand model

Our ultimate goal, noted at the outset of this report, is to link container transportation economic and environmental analyses with a new Policy Simulation Lab ("SimLab") at the University of Rhode Island (Opaluch, et al., 2002). The SimLab will be used by stakeholders, policy makers, businesses, and other interested parties. The software developed to apply the model (and other work, not reported on in this chapter) is designed to lend itself to such efforts.

III. ESTIMATING THE DEMAND FOR A NEW CONTAINER PORT: THE IMPORTANCE OF INCLUDING SUBSTITUTE PORTS AND MULTIMODAL ACCESS

III. A. Introduction

To this point, we have stressed the importance of demand estimation for proposed container port developments for weighing financial feasibility, benefits and costs, and some potential environmental issues, such as traffic, noise and air emissions. As illustrated in Chapter II, demand for a port depends not only upon the fees charged but also upon its relative location with respect to sources and markets for particular goods, shipping lanes, the availability of multimodal facilities, the relative fees charged, and other aspects of performance, such as reliability and frequency of carrier service.

This chapter takes a different tack and uses the simulation model to estimate potential demand for a *new* container port. Simulation can provide a useful methodology for this purpose. For one thing, information which might be used to estimate demand statistically will usually be unavailable for a new port. Also, even if data are available, a new port or major multimodal investment almost certainly changes the structure of the transportation market for the affected area, by that making it problematic at best to rely upon the use of past observations to estimate statistically demand for the new port. Finally, a simulation model has the virtue that it can capture many important features, such as distance to markets, access to multimodal facilities, location with respect to shipping lanes, sources and markets, etc.

In this chapter, we apply the simulation model to provide insight into several important issues when planning for possible investment in a new port. What might be the initial demand for such a facility? How critical are multimodal facilities to the success of a new port? And how would the competition posed by other, existing container ports affect demand at a new port – and vice versa?

Fundamentally, interport competition has to do with the potential substitutability between ports. The availability of substitutes is a fundamental concept both in economic theory (e.g., Silberberg, 1978) and in the applications of theory to a wide range of market, non-market (environmental) commodities, and quasi-market goods (see, e.g., Rosenthal 1987; Smith and Kaoru, 1990; Whitehead and Bloomquist, 1991; Walsh and Johnson, 1992; Freeman, 1993 Emerson, 1989). A considerable body of research shows that the demand for, and the value of, the item being studied likely is overstated (biased upward) when analysts fail to consider substitutes (see, e.g., Rosenthal, 1987; Walsh and Johnson, 1992; Smith and Kaoru, 1990). Port investment raises major financial and other risks. Hence, biased estimates of demand have important consequences for investment decisions, in general, and for port investment in particular. Thus, methods that contribute to a better understanding of interport competition can be very useful in port planning.

For this analysis, we simulate *potential* annual demand for a proposed new container port at Quonset Point, on Narragansett Bay, Rhode Island, under three conditions. First, demand is estimated assuming (A) the port has no connection to a Class I rail system and (B) shippers ignore the Canadian ports of Halifax and Montreal, both of which compete for (are substitutes for) containerized cargoes destined for the US Midwest. Then, potential demand for the new port is simulated assuming a connection to a Class I rail system, while still omitting consideration of the two substitute Canadian ports. Finally, demand for the new port is simulated with a rail connection *and* consideration of the two substitute Canadian ports.

As no formal proposal exists for the proposed port used as our case study, and since the model used is still in its development stage (as we described in Chapter II), our application must be regarded as illustrative and hypothetical. Nevertheless, the case study provides considerable insight into the issues involved -- the importance of including substitute ports and multimodal facility availability -- when assessing demand for a new port -- and methodologies available to address these issues.

The remainder of the chapter is organized as follows. First, the container port transportation demand simulation model and the key data and assumptions used to apply it are outlined for readers who may have skipped the technical details given in Chapter II. Then, the model is used to assess initial, potential demand for a new port being considered for Quonset Point, Rhode Island. Two types of inter-port effects are considered. One involves assessment of the effects of adding the new hypothetical port, with all port fees held constant; the second estimates of how changes in port pricing can affect other ports. We also show the estimated service area for the hypothetical new port.

Throughout the chapter, the initial demand estimates are referred to as a "conditional" demand in that key economic parameters used in the model and competing ports are assumed not to respond to introduction of the new port or to changes in prices. In an ongoing research project, we will relax these assumptions and consider possible strategic behavior by competing ports.

III. B. Background

Demand estimation for container ports is complicated due to the inherent complexities of international trade and its determinants, competition from substitute ports, and potential strategic behavior by substitute ports, shippers, and shipping lines (see, e.g., Jones and Qu, 1995, Gilman and Williams, 1976, Klein and Kyle, 1997; Tsamboulas and Kapros, 2002; Fagerholt, 2000). Difficulties also arise from the multiplicity of factors to be considered, major data requirements, and the computationally intensive nature of the problem (see e.g., Luo, 2002).

As an initial effort to use simulation method for container port demand estimation, the model presented in this chapter uses several assumptions to simplify the simulation process. These assumptions enables the establishment of the simulation model that links the demand at container port with the geographical location of ports, the unit transportation cost by truck, rail, and vessels, and the development in the multimodal transportation system. The reasonableness of these assumptions, the economic reasoning involved, and the model development are given in (see, e.g., Luo, 2002) and (see, e.g., Grigalunas and Luo, 2001), and will not be repeated in detail here. Ongoing work wil exted and refine the model (see chapter II)

Nevertheless, it is important to give a theoretical account of container port demand simulated through this model, because it will give insights on the importance of considering substitution set on demand estimation. Hence, we first explain the nature of the demand estimated through the simulation model. Then, we explain the effect of substitution on demand for a new port.

III. B. 1. Conditional Demand

The simulation model finds the transportation route for each cargo category and each cargo origin and destination by minimizing the general cost in the total transportation process (see, e.g., Luo, 2002). Then, the demand for a port is derived by the total number of loaded containers (in TEU) that will move through the port.

Therefore, the simulated demand from one port is a function of the international trade pattern, the costs for using container transportation facilities (include truck, rail, inland container yard, container port, and vessel transportation), and the complete transportation network. Since the opportunity cost of the capital involved in the containerized cargo is also a very important element in the total general cost, the discount rate is also involved in the demand function.

The general demand model is summarized as follows. Assume there are N coastal ports, the demand for i[th] port can be written as:

$$Q_i = Q_i(Q, p_s, p_r, p_t, p_i, p_{\bar{i}}, Z, r) \tag{1}$$

and $$\sum_{i=1}^{N} Q_i = Q \tag{2}$$

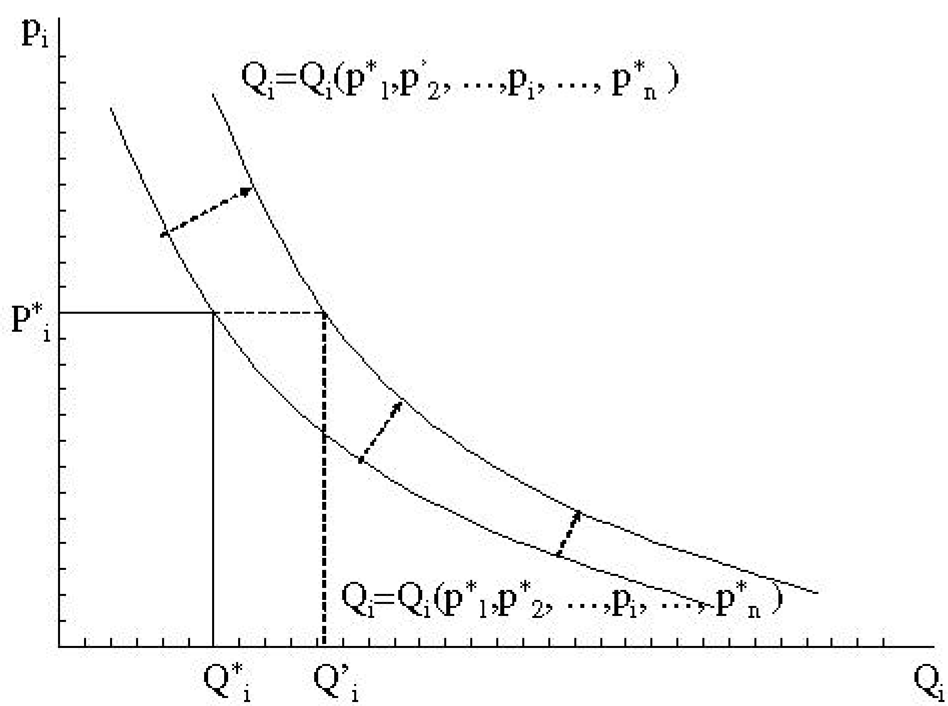
Where:

Q_i: Quantity of demand at port i
p_s, p_r, p_t: unit cost per TEU*mile by shipping, rail and truck, respectively

p_i, $p_{\bar{i}}$: Port cost at port i and all other port, respectively
N: The number of ports under consideration
Q: Total demand
Z: all other attributes for transportation network
ρ: the interest rate

If we consider the effect of only port charges (p_i, $p_{\bar{i}}$) on port demand, port demand is not only a function of its own price pi, but in principle also the prices at all other ports ($p_{\bar{i}}$) (Figure 58). Given information on charges for all ports, then the simulation result is conditional demand *point* estimate (conditional on the price and characteristics of all ports). This case is illustrated by Q^*_i in Figure 58 which shows the conditional demand *function*, Q_i, for the i^{th} port – the relation between quantity of demand and its service charge is conditional on the charges at all other ports. The function $Q_i=Q_i(p^*_1, p^*_2, \ldots, p_i, \ldots, p^*_n)$ in Figure 58 refers to this conditional demand function. Change at any one of them may shift this conditional demand curve. Figure 58 shows that if price at port 2 increases from p^*_2 to p'_2, then the conditional demand function for port i will increase – i.e., shift out. In this case, the conditional demand point estimate will be Q'_i.

Figure 58 Illustration of conditional demand point estimate, conditional demand function, and shift of conditional demand function for a container port



Market competition among geographically dispersed ports enables each port to charge different prices. Therefore, to simulate the throughput, it is necessary to have actual port charges at all ports. At present the primary objective of the simulation model is to estimate the demand, not market equilibrium. For this analysis, for simplicity, a price of $200 per TEU is used at all the ports, which eliminates the effect of port competition on port demand. Therefore, the demand estimated using the simulation model is conditional demand. We emphasize that we are estimating demand – not throughput, which involves equilibrium (i.e., demand and supply) in the market. Later research may simulate market throughput, if further research can incorporate port supply functions in the simulation process.

This model is applied using waterborne trade and other data for 1999. This implies that the demand change due to port construction or facility development at one port will always accompanied by the opposite change in demand at all other ports, i.e.,

$$\frac{\partial Q_i}{\partial p_i} + \sum_{j \neq i} \frac{\partial Q_j}{\partial p_i} = 0 \qquad (3)$$

This property can be easily derived by differentiate the equation (2). It shows that the demand increase at port *i* due to a price decrease at this port will always equal to the sum of demand reductions at all other ports. If port i is the new port, then the estimated demand at this port is a mere shifting from other existing ports.

III. B. 2. Brief Introduction to the Simulation Model, Assumptions and Data

The simulation model, data, and assumptions used in the model are given in Chapter II and in Luo (2002) and Luo and Grigalunas (2002). To economize on space, we provide below only a brief summary of aspects of the model useful for understanding the background for the analysis in the present chapter.

The purpose of the simulation model is to provide a new tool to estimate demand at US coastal container ports. Although it is focused on the demand estimation, this model provides a necessary step toward market equilibrium analysis, or throughput estimation, by incorporating port supply functions in the future.

The basic idea of the model is to simulate the container transportation process over rail, highways, and international shipping line, assuming shippers select the least-cost transportation route to move their containerized cargoes from origin to destination. The cost considered in the model includes the freight rate as well as the opportunity cost of capital on the containerized cargo. The least-cost route is selected using Dijkstra's shortest-path algorithm (see, e.g., Bertsekas, 1995). The multimodal transportation network is adopted from Oak-Ridge National Laboratory (ORNL) (see, e.g., Southworth and Peterson, 2000), and the routing algorithm is implemented using Java Programming Language.

As container transportation is a very complicated process, as a first step the model make several assumptions to simplify the simulation process. First, we assume that shippers are the decision maker and seek to minimize the (general) cost. Second, we assume the unit transportation fees per TEU per mile are the same everywhere for trucks, rail and shipping, respectively. Third, we grouped the foreign countries into continents, and assume there is always a direct shipping line between each US container port and each continent. Some of these assumptions will be relaxed in ongoing research.

To illustrate the use of the simulation model, we used the 1999 US Waterborne transportation Database (see, e.g., Marad, 2000), converted it to the container transportation OD flow matrix for each cargo category (in 2 digit-SIC code). This chapter will illustrate the application of this model in demand analysis of a new container port development project at Quonset Point, Rhode Island. An application of the model to estimate potential demand at existing US container ports is illustrated in Luo (see, e.g., Luo, 2002), Luo and Grigalunas (see, e.g., Luo and Grigalunas, 2002).

III. C. Application of the Simulation Model to the Hypothetical New Port at Quonset Point

This section illustrates the application of the developed model to estimate container transportation demand at a hypothetical, new container port at Quonset Point, Rhode Island. The application proceeds, in sequence, along the following lines.

We start from the status quo – no port handling containers currently exists at the proposed site. Then, the model application is expanded by adding a new hypothetical port at Quonset Point without a rail connection, in order to see how many containers potentially would move through the new port in this case. Next, the model is used to simulate the demand change at the new port, when a Class 1 rail connection to the new hypothetical port is available. Finally, the Canadian North Atlantic container ports of Halifax and Montreal are included in th choice set, recognizing that these ports compete for handling US containerized cargoes to the mid-West.

III. C. 1. Brief Introduction of the Hypothetical Port at Quonset Point

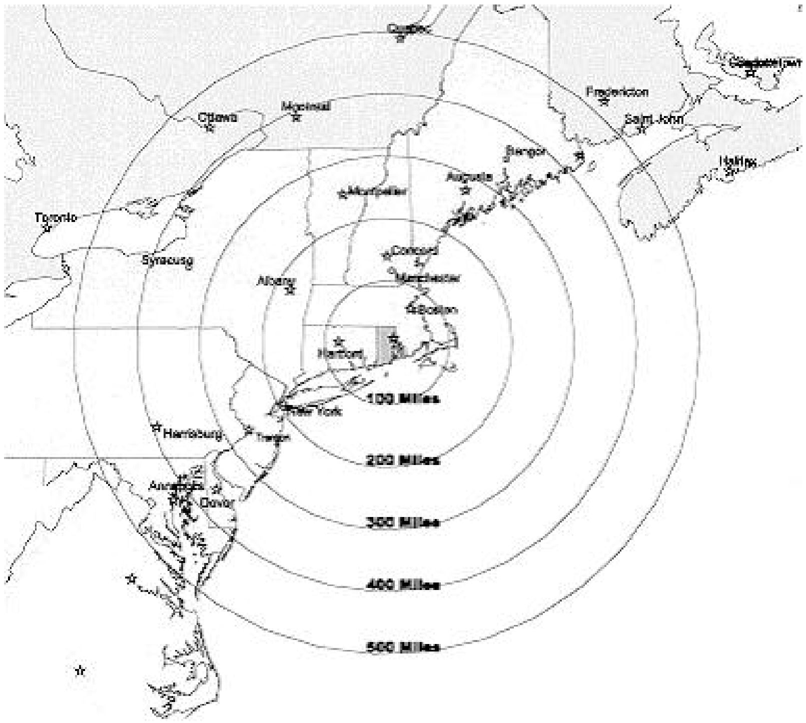
The hypothetical new container port analyzed in this report is based on the container port development proposal by Rhode Island Economic Development Corporation (RIEDC) with its consultants (see, e.g., RI Economic Development Corporation, 1999*)*. Faced with economic issues after the closure of former navy base and transfer the facility under civilian control, RIEDC issued a Request for Proposal in the summer of 1994 as a means of formulating and executing a comprehensive plan for the redevelopment of Quonset Point-Davisville as a major port and intermodal transportation. Since then, a series of activities has followed, including public hearings on the development plan, stakeholder discussions on different alternatives, debate on the pros and cons of different alternatives, and environmental and economic analyses of possible impacts of different proposals. Up to now, no decision about initiation of port development has been made, and a new round of economic analyses of container port development will start very soon.

This chapter takes the development proposal as a "hypothetical" port to illustrate the use of the developed container transportation service demand simulation model. For background, we first introduce the geographical condition and existing transportation facilities of the location for the hypothetical port.

III. C. 1. a. Geographical Condition

The hypothetical port site (Quonset Point) is located on the West Passage of Narragansett Bay, RI. The port of Boston is in the North, and PNYNJ is to the South. According to RIEDC (www.riedc.com), the site has easy access to markets and distribution service and is the center for New England Market. Figure 59 displays the location of the hypothetical container port.

Figure 59 Location of the Hypothetical Container Port in Rhode Island



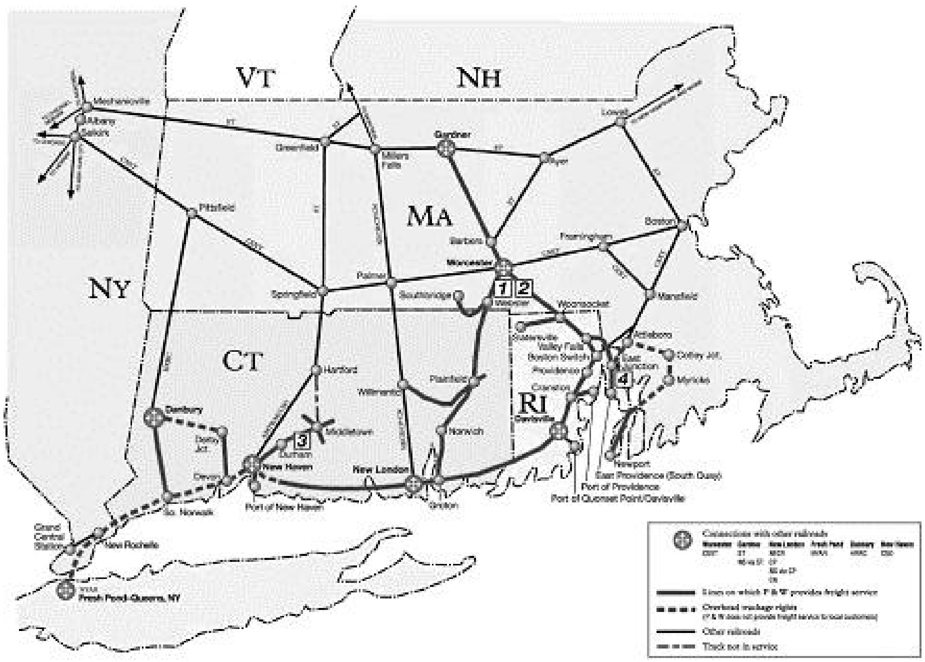
Source:www.riedc.com/qpd/qpdframe.htm (accessed 3/15/2002)

III. C. 1. b. Port Access from Land

An on-site rail system connects the hypothetical container terminal to the local rail services (Providence and Worcester, P&W,

Figure 60), to the New England area.

Figure 60 Existing Rail Connection of the Hypothetical Port at Quonset Point, RI

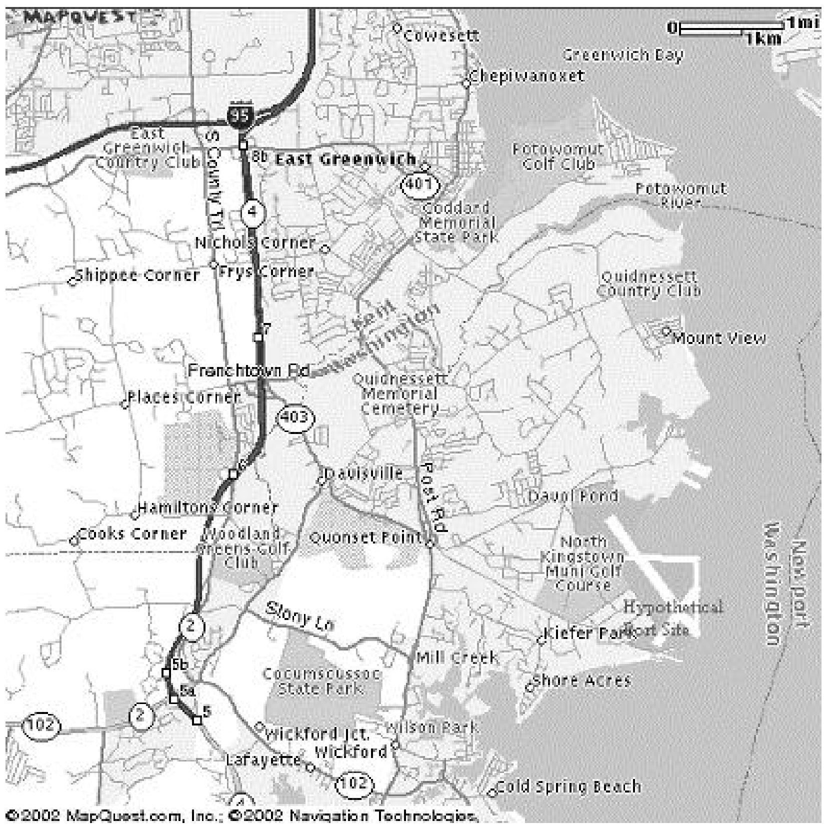


Source: www.pwrr.com

The P&W then connects the hypothetical port to the Class I national rail system of the US (CSXT, ST or CR) for container transportation. Existing rail access to the port and the link to the continental Class I rail system need improvement in order for the hypothetical port to be attractive for multimodal container shipment, as the later results show.

Currently, regional roadway access to the hypothetical port is also inadequate. Interstate highway I-95 (Figure 61) is the major roadway providing regional access to the site, but is over 5 miles away. Hence, existing access to the site from the south is extremely difficult.

Figure 61 Roadway Access to the Hypothetical New Port



III. C. 2. Application for Demand Analysis at Hypothetical Container Port

For the purpose of this application, the cost of using all port facility is assumed to be equal (here, $200 per TEU). This separates the efforts of the port in market competition from demand simulation for each port. Thus, the demand simulated from the model is a result of international trade, and transportation behavior over existing multimodal transportation facilities.

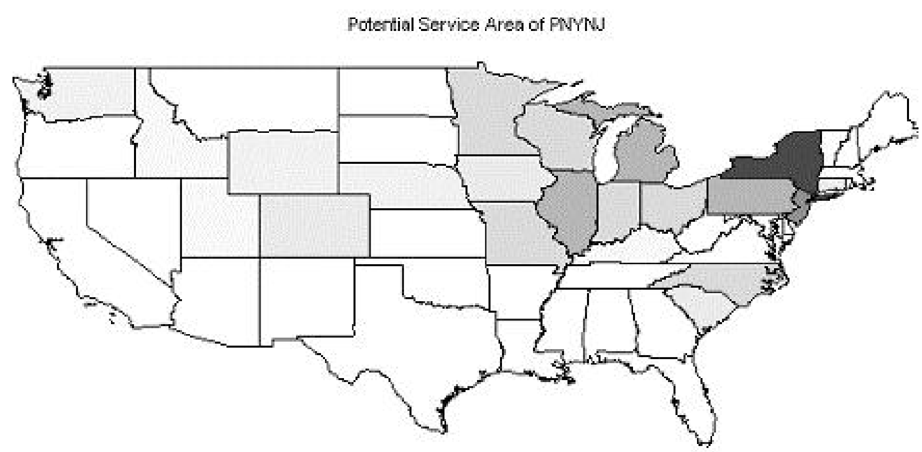
III. C. 2. a. Status-quo

The *status-quo* in this chapter is the simulation result for existing major US container ports, excluding (1) the hypothetical new port in Rhode Island and (2) the Canadian Atlantic coastal ports. The simulation result is shown in Figure 54 adopted from Luo (see, e.g., Luo, 2002) and also presented in Luo and Grigalunas (see, e.g., Luo and Grigalunas, 2002).

Simulated potential demand for New York is about 2.5 million TEUs, and for Boston, 0.9 million TEUs. Both simulation results are comparatively high, reflecting the potential for these ports to attract more containers than they currently handle. The high potential demand is due to the high population density at the vicinity of these two ports and their geographically advantages positions. The throughput is not as high as the estimated demand, because of various port constraints including road, terminal spaces in highly dense metropolitan area, and access channels depth.

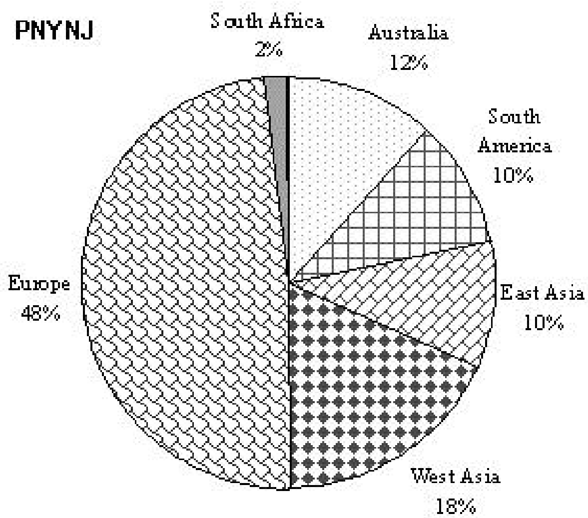
Compared with Boston, the PNYNJ serves a wider geographical area coverings almost all of the middle-to-north part of US states, including some states on the West Coast (Figure 62).

Figure 62 Servicing Area of PNYNJ



An estimated 48% of the containers that go through the PNYNJ involve US trade with Europe (Figure 63). Although US trade with East Asia is very high, only 10% of the demand at PNYNJ is US-East Asia trade. However, 18% of the demand comes from US trade with West Asia, because it is easier to move this cargo through the Suez Canal.

Figure 63 Composition of the Trade Routes for PNYNJ Demand

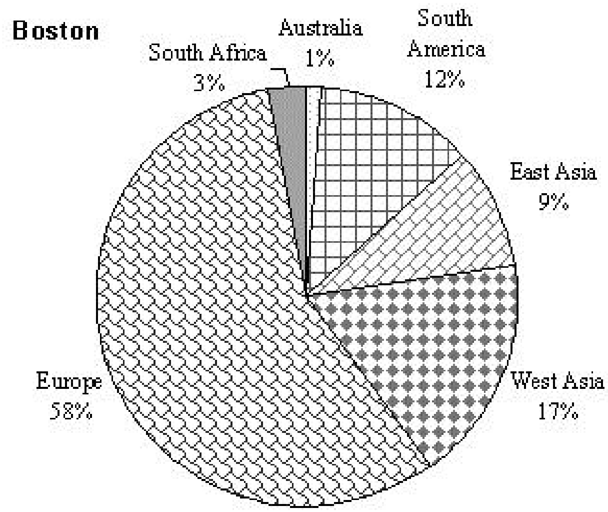


The service area of Boston is much smaller than that of the PNYNJ, as is shown in Figure 64.

Figure 64 Service Area for Port of Boston

For one thing, rail access to Boston less convenient than to the PNYNJ, so Boston captures substantially fewer multimodal containers the PNYNJ. In terms of trade routes (Figure 65), most trade is with Europe (58%) and West Asia 17%. East Asia only accounts for 9% of its demand.

Figure 65 Composition of Trade Routes for Demand at Port of Boston



III. C. 2. b. Adding a New Port at Quonset Point

Next, the potential demand for a hypothetical new port at Quonset Point is simulated, in order to estimate the potential demand for the new port and demand changes at existing ports (Table). For this exercise, the new port is assumed to charge a fee of $200 per TEU.

This simulation results show a demand for the new port at Quonset Point of about 97 thousand TEUs, for the given assumptions of the simulation model. Most of the containers are shifted from the Port of Boston (78,718 TEUs). The second diversion is from Seattle, which loses about 13 thousand TEUs to Quonset Point. Only 5,561 TEUs are shifted from the PNYNJ. Other US ports are unaffected by a new port at Quonset with no inter-modal rail access.

These results can be summarized as follows. First, the potential demand for the new port at Quonset, 97 thousand fully loaded TEUs, is not trivial—but neither would it support a hub port operation. Second, the new port primarily affects Boston, with only a modest effect on the PNYNJ. Third, the new port has a non-negligible impact on Seattle (which serves some Northeast markets), which shows the increased geographical area of port competition due to multimodal transportation.

However, the assumption of no improved rail system means that the hypothetical port at Quonset only has very limited market area, covering only Rhode Island and some counties in Connecticut (Simply stated, limited rail access makes Quonset Point non-competitive for multimodal cargoes. However, it also keeps the containers in the local area from being taking away from the new port. The composition of trade routes by a hypothetical port at Quonset Point is in Figure 67. Most of the containers involve US trade with Europe.

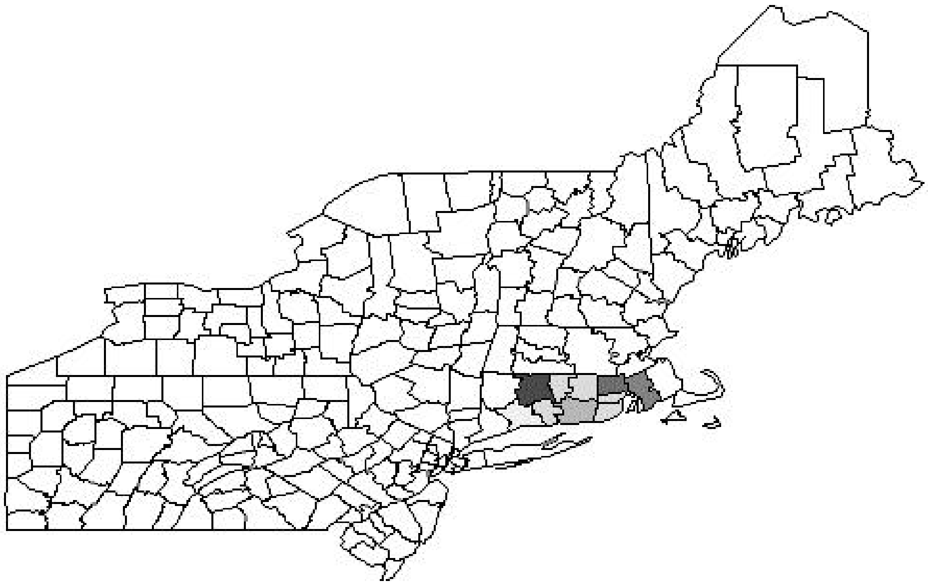
Figure 66), likely due to the inefficient current access for both rail and road transportation.

Table 3 Demand Change in TEU with a New Port at Quonset Point
(assuming no rail connection)

	Status Quo	Adding New Port	Demand Change
Quonset		97,285	
Houston	1,153,573	1,153,573	0
PNYNJ	2,467,057	2,461,496	-5,561
New Orleans	1,005,261	1,005,261	0
Long Beach	3,779,562	3,779,562	0
Tampa	211,850	211,850	0
Norfolk	799,151	799,151	0
Mobile	116,323	116,323	0
Portland	709,664	709,664	0
Seattle	2,703,956	2,690,957	-12,999
Jacksonville	26,520	26,520	0
Boston	889,402	810,684	-78,718
Savannah	539,675	539,675	0
Oakland	181,667	181,660	-7
Charleston	171,419	171,419	0

Simply stated, limited rail access makes Quonset Point non-competitive for multimodal cargoes. However, it also keeps the containers in the local area from being taking away from the new port. The composition of trade routes by a hypothetical port at Quonset Point is in Figure 67. Most of the containers involve US trade with Europe.

Figure 66 Service Area for Hypothetical Port at Quonset Point, Rhode Island



As stated before, lack of a good rail connection to Quonset renders the port not competitive. Virtually all large ports have class I rail access. Thus, there is no demand to use the new hypothetical port to move multimodal cargoes.

Figure 67 Composition of Trade Routes at Quonset Hypothetical Port

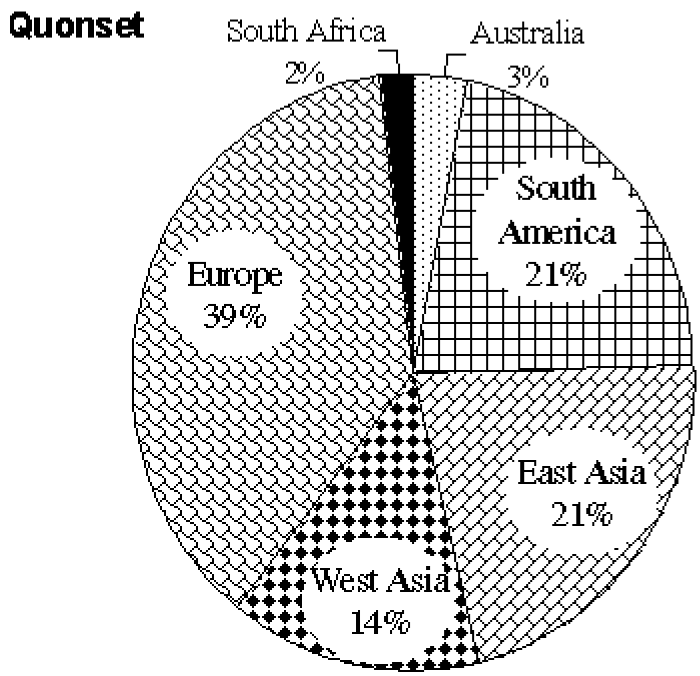


Figure 68 Annual TEUs Movements on RI Roads

As in Figure 68, the thicker lines indicate movement of containers on roads. The closer a road is to the hypothetical port at Quonset Point, the "thicker" it will be because of higher annual container (TEUs per year) movement. Since no easy way exists to turn south onto I-95 south from Route 4, and vise versa, the cargo from the south cannot use I-95 north direction to access to Route 4. There is no container movement to and from the new hypothetical port by rail, since the rail access is not currently available.

III. C. 2. c. Improve the Rail Connection to the Port

As noted, existing rail access to the hypothetical port at Quonset Point is not adequate to attract multimodal cargo, limiting the service area of the new port to the local area. For a new port to survive in the competitive container transportation market, it must compete for multimodal cargo. The developed simulation model can be used to examine the demand change for both a hypothetical new port and all other ports, if the rail connection of the new port is improved.

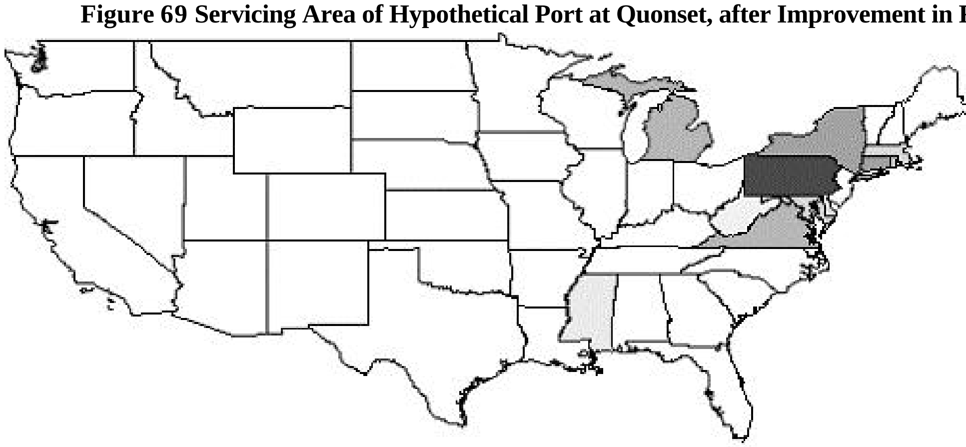
The multimodal improvement considered here involves making the P&W a Class I rail, and making a smooth connection between the internal rail at Quonset and P&W, and the connection of P&W with major Class I rail system at Worcester, MA. Table 11 compares the demand at each port after the rail improvement at Quonset, with the one before rail improvement.

Table 11. Comparison for Container Port Demand in TEU with and without Improvement in Rail Connection

	Existing Rail Access	Improved Rail Access	Change
Quonset	97,285	357,978	+ 260,693
Houston	1,153,573	1,153,573	0
PNYNJ	2,461,496	2,365,706	-95,790
New Orleans	1,005,261	1,005,261	0
Long Beach	3,779,562	3,779,537	-25
Tampa(FL)	211,850	211,850	0
Norfolk	799,151	769,590	-29,561
Mobile	116,323	116,314	-9
Portland	709,664	709,664	0
Seattle	2,690,957	2,690,957	0
Jacksonville	26,520	26,520	0
Boston	810,684	684,575	-126,109
Savannah	539,675	539,675	0
Oakland	181,660	181,659	-1
Charleston	171,419	162,221	-9,198

The simulation results indicate that improved rail access significantly increases the demand of the new port from 97 thousand TEU to around 358 thousand fully loaded TEU. Most of the demand decreases occur at Boston (126 thousand TEU), then New York/New Jersey (96.8 thousand). Norfolk also has reduced demand of around 30 thousand TEU. Some distant ports, like Charleston, also suffer some loss. With rail access, the improved port also has the potential to serve a much wider area than before (Figure 69).

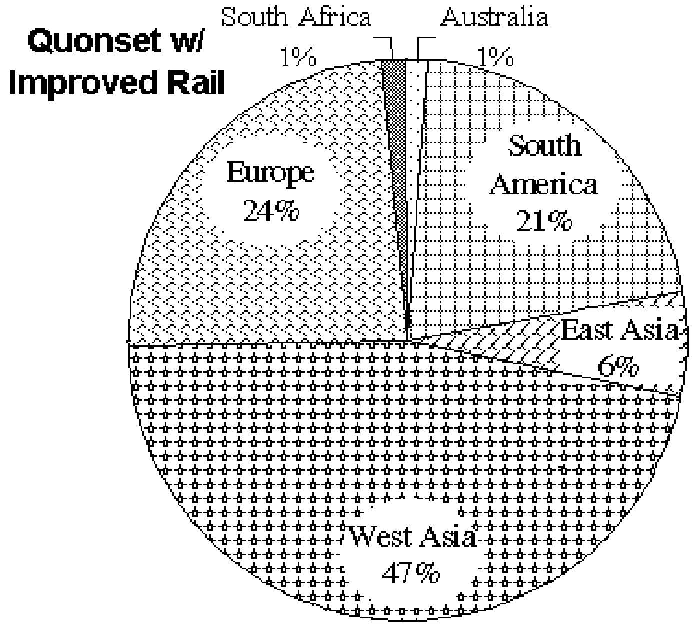
Figure 69 Servicing Area of Hypothetical Port at Quonset, after Improvement in Rail Access



After the improvement in rail access, most of the potential demand at the hypothetical port will be the trade with West Asia (

Figure 70), due to the geographical advantage for the route that using Suez Canal.

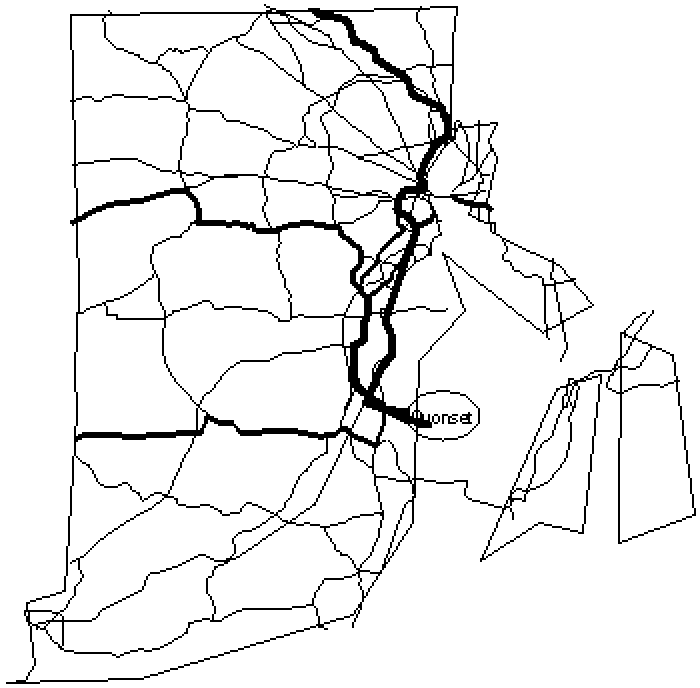
Figure 70 Composition of Trade Route for Hypothetical Port, after Rail Improvement



III. C. 2. d. Adding Halifax and Montreal

Figure 71 shows the distribution of container movement on the Rhode Island road and rail. In this simulation, the number of TEUs transported to the hypothetical port by truck is 97,285 TEU—the same demand before improvement of rail access. This is reasonable because the rail access does not improve road access. (Improvements in road access of course would change this outcome, but is not considered in this chapter.) The number of TEUs transported to the hypothetical port by rail is 260,693: 73% of the demand is for multimodal containers.

Figure 71 Distribution of Annual TEUs on RI Road and Rail

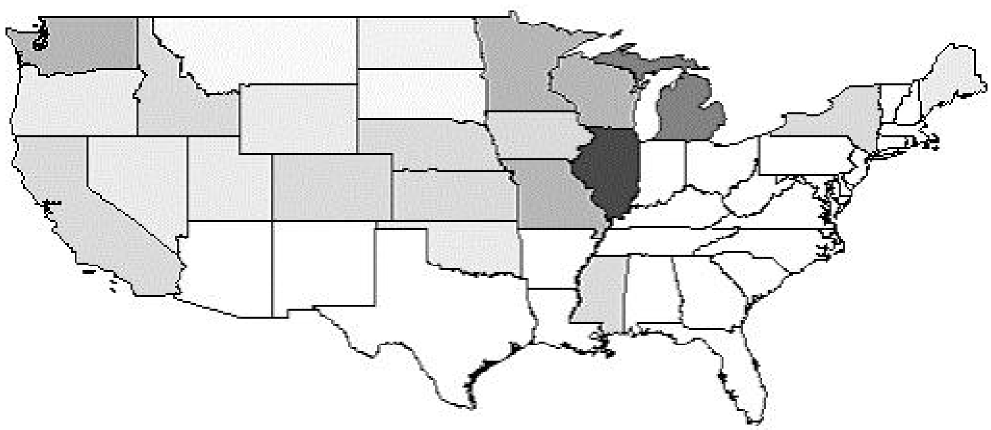


The results show that Canadian Atlantic ports would take away approximately 1 million TEU of US containerized cargo from US ports, including the proposed new port at Quonset. Of these, 66% is from New York, 18% from Boston, 4.5% from Houston, and 4.2% from Quonset. New York suffers the largest losses because Montreal, which is closer to Europe than New York, is also closer to the US market area west of Mississippi than is the PNYNJ. Thus, US - European trade in that region often find it less costly to use Montreal rather than the PNYNJ. Figure 72 shows the service area of Montreal.

Table 12 Comparison of Port Demand in TEU with and without Atlantic Canadian Ports

	No Canadian Ports	With Halifax, Montreal	Change
Quonset	357,978	315,712	-42,266
Halifax		9,199	
Montreal		995,753	
Houston	1,153,573	1,108,671	-44,902
PNYNJ	2,365,706	1,705,024	-660,682
New Orleans	1,005,261	1,005,261	
Long Beach	3,779,537	3,779,537	
Tampa(FL)	211,850	211,850	
Norfolk	769,590	760,448	-9,142
Mobile	116,314	116,314	
Portland(OR)	709,664	701,527	-8,137
Seattle	2,690,957	2,657,134	-33,823
Jacksonville	26,520	26,520	
Boston	684,575	501,406	-183,169
Savannah	539,675	516,849	-22,826
Oakland	181,659	181,654	-5
Charleston	162,221	162,221	

Figure 72 Service Area of Port of Montreal



Due to the competition with Halifax and Montreal for multimodal cargoes, the estimated demand for Quonset moved by rail is 218,427 TEUs. The local container market (that moved by truck) is still 97,285. The percentage of multimodal cargo is about 70%. Figure 73 shows the annual container movement on road and rail at a Quonset Port.

Figure 73 Annual Container Movement on RI Road and Rail

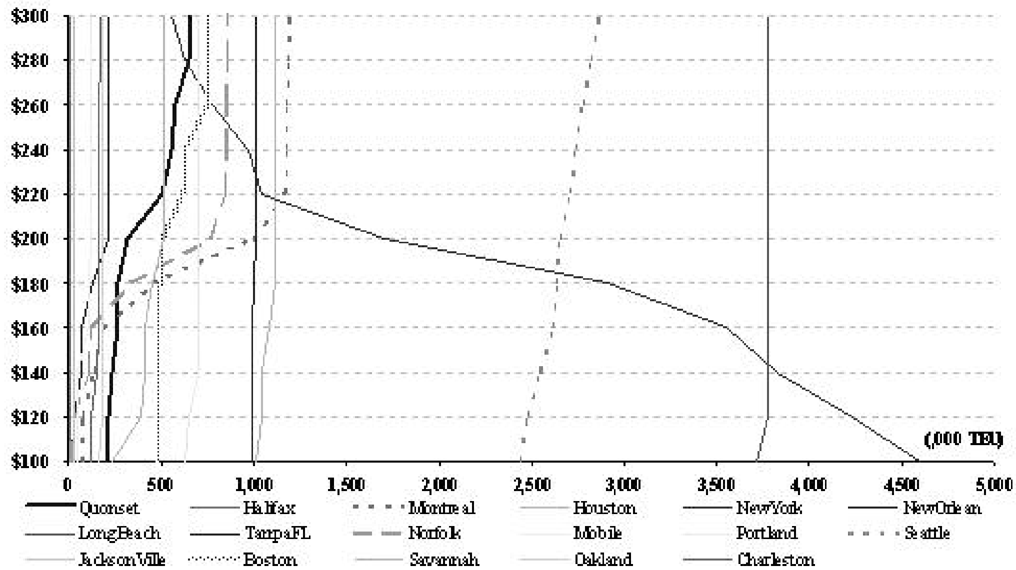
III. C. 2. e. Port Competition Analysis

Up to this point, the analysis of container transportation service demand at the hypothetical new container port assumes that the cost to use port services is equal at all ports. This demand reflects the potential number of containers that a port could expect to handle, according to its location and links to the multimodal transportation system. It is in effect an equilibrium allocation of international trade of containerized cargoes to each port, when all the ports charge the same fee, provide the same service, have same liner schedule, etc.

Next, the simulation model is used to estimates the change in demand if there is a real price (cost per TEU) change at one of the ports. Since this simulation model takes international trade as given (based on waterborne commerce data as of 19990, the estimated demand change is purely a substitution effect. This type of analysis could help identify ports that are close substitutes to each other, and hence could provide a way to analyze port competition.

First, this section analyzes the demand for the PNYNJ and all other ports for hypothetical price changes from $100 to $300 per TEU at the PNYNJ. Figure 74 shows the demand change for each port with such a change.

Figure 74 Demand Change for each Port when Cost per TEU at PNYNJ Changes from $100 to $300



Notes: All ports other than PNYNJ assumed to charge $200/TEU.

This simulation indicates that at a hypothetical unit price per TEU of $300 at PNYNJ ($100 more than all other ports), demand for PNYNJ is only 562,000 TEUs. On the other hand, for price decreases, the quantity demanded at the PNYNJ will increase, while the demand for Seattle, Montreal, Norfolk, Boston, and Quonset will decrease. For the PNYNJ, most of the demand increase occurs for cost decreases from $20 more to $40 less than the charges at all other ports. The biggest decrease occurs at the port of Montreal for this price range. This indicates that Montreal is the closest substitute for the PNYNJ, followed by Norfolk. Boston and Quonset are also substitutes, but they are not as close substitutes as Montreal and Norfolk. Even when the cost at the PNYNJ is $100 lower than that in all other ports, the demand for the hypothetical new port is still at 200,000 TEU per year.

These results suggest that the demand for Quonset Port is not small, even at disadvantageous market conditions, using the 1999 container transportation data. Stated another way, the PNYNJ is not a big substitute for the hypothetical new port at Quonset, despite its proximity.

For the same range of price change in the port of Boston, the impact on demand for all other ports is different (Figure 75). For price changes from $300 to $260 per TEU, almost all of the demand increase at Boston comes from the demand decrease at Quonset Point. This indicates the proposed new port at Quonset Point is almost a perfect substitute for Boston. For further price decreases, more ports will experience a decrease in demand. New York and Montreal are two of the ports that will experience the highest losses due to the competition from Boston, because these two ports are close substitutes for Boston for multimodal containerized trade between the US and Europe and West Asia.

Figure 75 Demand Change for each Port when Cost per TEU at Boston Changes from $100 to $300.

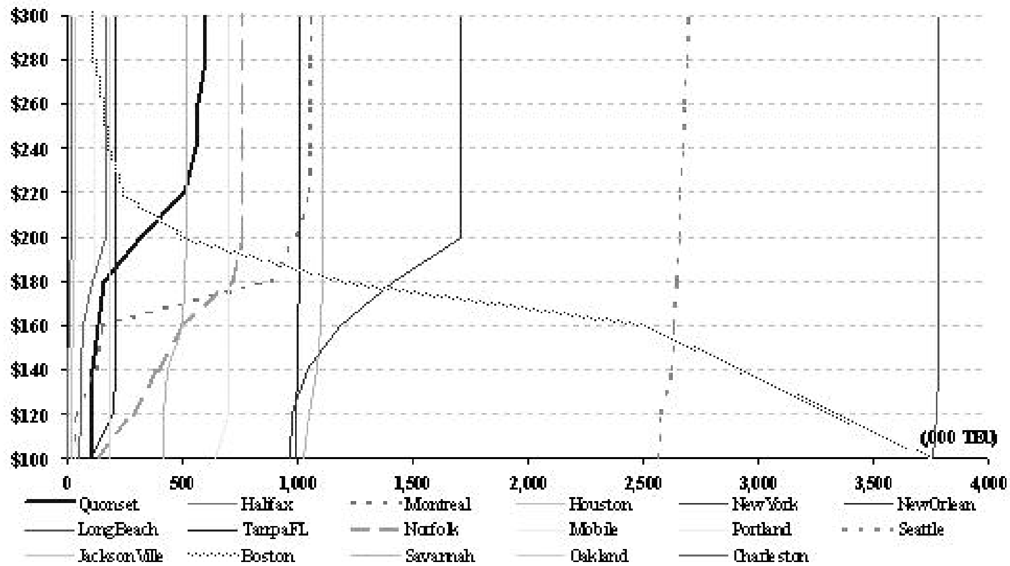
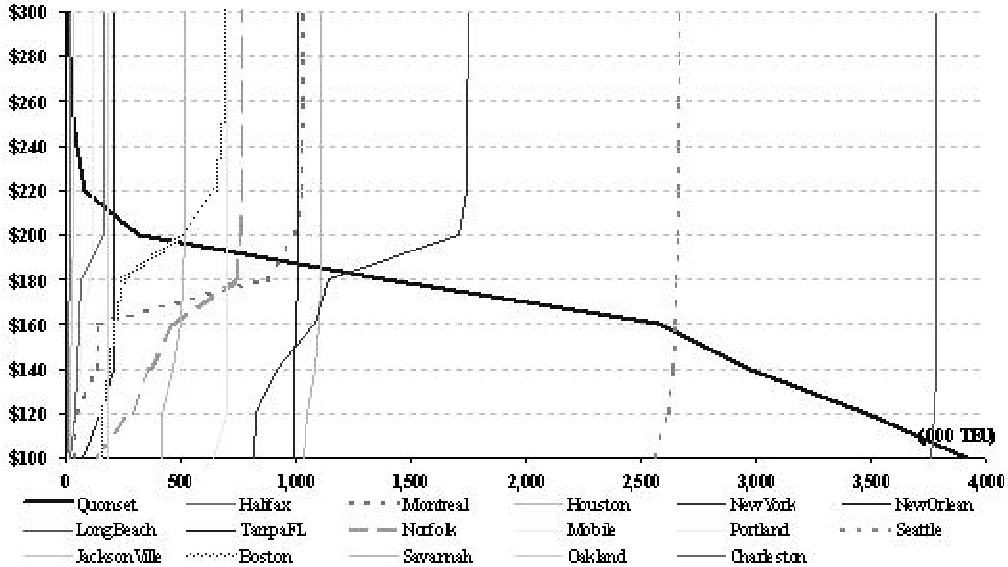


Figure 76 displays demand changes for all the ports, for the same range of price change at the hypothetical container port at Quonset. As stated above, for prices higher than $200, Quonset Point is a close substitute of Boston, so Figure 20 looks very similar to Figure 19. The impact of the new port on the demand of other ports is also very similar to Boston. However, the new port at Quonset is much closer to New York than Boston, so the substitution effect of Quonset is higher than that of Boston.

III. D. Summary

Demand estimation is critical for assessing the financial feasibility of a new port to investors and the net social benefits to the public at large. As the results of this chapter show, failure to consider substitute ports when estimating potential demand for a new port can lead to biased and potentially misleading results for the new port. Yet, taking substitute ports into account -- inter-port competition -- when assessing new ports is very difficult.

Figure 76 Demand Change for each Port when Cost per TEU Changes from $100 to $300 at Hypothetical New Port at Quonset Point, Rhode Island



This chapter examined the potentially important role of substitutes by applying a container port and related multi-modal transportation demand simulation model. The model was used to estimate the demand for a hypothetical, new container port at Quonset, Rhode Island. It started from the status quo, then added, in sequence, a hypothetical new port, improved rail connections, and the impacts of Atlantic Canadian ports on US containerized cargoes movements. The simulation results include demand for the new port and its impact on the other ports. For the new port, this model also provide the annual truck traffic and rail traffic. It also analyzes port competition and the resulting own price and cross-price demand curves.

The results illustrate clearly the critical role of multimodal transportation in the potential success of the proposed new port. Without access to a Class I rail system, initial demand for the new port (97 thousand TEU) is quite small. Adding access to the Class I rail network sharply increases initial demand for the port to 357,978 TEU. Much of this increase comes at the expense of the Port of Boston but interestingly, more distant ports (PNYNJ, Norfolk and Charleston) are also affected as the new port competes for some of the mid-West market.

Adding the Canadian ports of Halifax and Montreal to the shippers' choice set substantially lowers demand for the new port—as well as for the PNYNJ. Demand for the new port drops from 357,978 TEU to 315,712 TEU when the Canadian ports are included. This supports the view that Canadian ports compete with Northeast ports for the US Midwest market. Failure to consider these substitutes overstates estimates of the potential demand for the proposed new port at Quonset.

It is emphasized that when adopting the result from this model for development policy and economic analysis, the underlying assumptions of this simulation model must be taken together. For example, we have assumed in this chapter that all port charges are $200 per TEU. The demand should be understood as the potential containers a port can get, if the port does the same as all other ports. Future research on the supply side of container port production and incorporate it in the simulation model is necessary for the practical application of this model in the container port development policy analysis. Other refinements will also be made, such as changing the economic parameters used. Finally, we reemphasize that specific plans for a port at Quonset point are not yet available and the model still employs several oversimplifications. *As a result, the estimates must be regarded as illustrative and are used only to show the importance of considering substitution effects among container ports; the results but should not be viewed as conclusive.*

III. D. 1. Conclusions

- This research reveals that (1) the international trade pattern, (2) geographical location of a port, (3) availability of multimodal transportation networks, and (4) the associated general total cost are major factors influencing container transportation demand at ports.

- Competition among container ports is not limited to nearby ports. Instead, the service area of individual port and the cross-price demand curve shows that policies at a given port may have impacts even on distant ports.

- Demand for port services near population centers is high, since most of the container trade is imports and most of the imported cargoes are consumer cargoes.

- Simulation results show that Boston has higher potential demand than its throughput because Boston is a metropolitian area with a high population, and the model used population to allocate national import to the state and county level. The actual throughput is not as high, probably due to the constraints on rail and road access, terminal capacity, and the access channel.

- Application of the simulation model shows that a hypothetical container port at Quonset, Rhode Island, has a local service area which includes Rhode Island and Connecticut. Without improvement in rail access, the hypothetical port will operate at a modest scale.

- When rail access to the hypothetical port is improved, the market competitiveness of the hypothetical port increases significantly, with most of the cargo moving through the port carried on trains destined for distant markets (Figure 69).

- Competition from East Coast Canadian ports will affect the demand for a hypothetical new port. But the ports suffering the most from competition with Canadian ports are New York and Boston, not the hypothetical port. This is because East Coast Canadian ports compete with US ports mainly on multimodal cargoes, and the market share of the hypothetical port is not as big as PNYNJ and

Boston.

- Due to the current roadway connection problem at the hypothetical port, containerized cargo from the hypothetical port does not all move on Route I-95, but by some low speed local highways. This shows that there is some potential to increase local cargo by improving roadways access, particularly for southern access between route 4 and I-95.

III. D. 2. Limitations

As stated earlier, this chapter demonstrates the potential of using simulation method to estimate the demand for container port services, using basic economic factors. While the model provides considerable insights into the demand of container port services, it is still at the beginning of simulation stage, and the simulation results presented are only valid within the range of the basic assumptions. Therefore, before applying the simulation result from this research to decision making one must consider the following limitations. These include: (1) we use waterborne trade data as of 1999 and do not model international trade or project trade (see next chapter); (2) at this point we assume perfect competition on liner shipping; (3) data limitations need to be addressed to improve information on the movements of containerized cargoes in TEUs; and (4) better data is needed for the economic parameters used.

III. D. 3. Future Directions

To develop a full functional simulation model, further research is needed: (1) include port production analysis (i.e., the supply side) in the simulation model; (2) simulate strategic behavior in port competition, and its impact on port demand; (3) incorporate research on international trade, and improve the container trade OD flow estimation with better data and more disaggregated sources (e.g. major countries) and domestic markets (e.g., subdivide CA and other states; (4) simulate container transportation activities in a shorter time unit than the annual demand estimated in the current simulation model.

In summary, this chapter demonstrated the potential use of simulation in the container transportation demand estimation. This extends the collection of tools that can be used to address some complicated issues beyond the scope of regression analysis, for example. It not only contributes to the literature on container port transportation service demand estimation, but also expands the horizon of the general research on transportation demand. It reveals that, even through container transportation is a very complicated process, it still follows a fundamental economic behavior: cost minimization.

IV. FINANCIAL ANALYSIS FOR CONTAINER PORT DEVELOPMENT: CASE STUDY OF A HYPOTHETICAL PORT AT QUONSET, RI

IV. A. Introduction

This chapter presents the results of a re-estimation of the port investment appraisal and risk analysis carried out by the authors in our Year-One report (Grigalunas, Luo, and Chang, 2001, Chapter III; Grigalunas, Chang and Luo, 2002). To do this, we use data from three sources: (1) our earlier report, (2) the results from Chapter II and III of this report, and (3) new information from various sources collected during our Year Two research, described below.

First, we note that as of this date (November, 2002) Quonset container port development has not progressed far in terms of availability of specific plans since publication of our Year one report. Some $1.5 million of state money was appropriated for marketing and environmental impact studies, and the US Army Corps of Engineers suggested using $4.5 million for an environmental impact statement[9].

An interesting development is the initiative of Rhode Island Economic Development Corporation (RIEDC) to include Quonset as one part of the Port Inland Distribution Network (PIDN[10]) being advanced by the Port of New York and New Jersey (PNYNJ). This would involve a barge operation to carry containers between the PNYNJ and Quonset. Such an operation would not require major investment for superstructure or infrastructure, nor would expensive dredging be needed. The RIEDC states that the PIDN is independent of a possible container port at Quonset. An analysis of a PIDN is outside of the study scope of this project, but aspects of the PIDN proposal will be examined during the next phase of our research.

The logic of the overall approach adopted in this chapter is given in Figure 77. We begin with the results from the US container port demand simulation model from Chapters II and III. These provide an estimate of the *initial*, conditional demand for the hypothetical container port, for the base year of 1999. As noted, this estimation takes as given the existing pattern of US foreign trade, the location of existing ports and the hypothetical new port, and the highway, railway, and shipping lines. It is a *conditional* demand because the results rest upon the assumption that port costs are the same at all the ports.

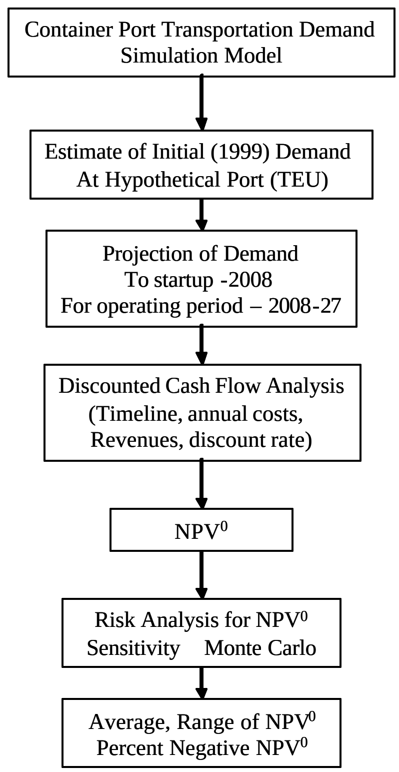
Although the port demand model provides an estimate of initial demand, container port development takes several years and operations occur over an extended period (here, 20 years). Hence, port development must be considered as a long-term project. Therefore, a long-term forecast of the growth rate of container traffic is necessary to assess a port investment project. For this purpose, as a second step, various published forecasts of

[9] Erin Emlock. "State hires three firms for impact study on Quonset", Providence Journal, 05/14/2002
[10] http://www.riedc.com/qpd/nynjqpd/PIDN%20%20Report%20Web.pdf, accessed 05/21/2002

container traffic have been reviewed, and a preliminary econometric analysis of this issue was undertaken as part of this project

(Jung, 2001). This information is used to project TEU movements through the hypothetical port. We then use information on (1) port development investment and operating costs and (2) the timing of development activities and projected port operations in order to assess the operator's net present value, NPV^o .

Figure 77. Logic of Approach Used in Financial Feasibility Analysis



The remainder of this chapter is organized as follows. First, we summarize the concepts, methods, data, and assumptions for the port investment feasibility analysis done during our year-one study. This summary is important as it reviews some critical issues for port investment appraisal and risk analysis. Then, forecasts of growth of container traffic are presented. Next, simulation results given in chapters II and III and the annual growth forecasts for container movements are used in the investment appraisal and risk analysis. Lastly, a comparison of this appraisal with year one report is provided at the end of this chapter.

Although this research is a big step forward from the port investment appraisal and risk analysis in year one, we stress again that it is still illustrative and preliminary in nature. No formal port proposal as yet exists for Quonset, and the container port demand simulation model needs further refinement, as described in the preceding chapters. Ongoing research will refine and extend the components of our comprehensive framework.

IV. B. Background

This section summarizes the key concepts, methodologies and data presented in our year one report in order to provide background information for the work presented later in the chapter. Readers interested in more detailed information should refer to our year one report (Grigalunas, Luo and Chang, 2001; Grigalunas, Chang, and Luo, 2002).

IV. B. 1. Important Concepts

Central to any investment feasibility analysis is the concept of Net Present Value (NPV). NPV is the standard criterion used to assess the financial feasibility of an investment. In our analysis, it is the present value of the *net incremental cash flows* paid for or received by the terminal operator (NPV^o) over a 20-year operating period. In the context of port development, the general formula for calculating the NPV^o used in this report is:

$$NPV^o = \sum_{t=t_0}^{T} \frac{(R_t^o - F_t^o - C_t^o - I_t^o - M_t^o - MIT_t^o)}{(1+r)^{t-t_o}}$$

Where:

NPV^o = Net present value to container terminal operator at time 0 (here, 2002)

I_t^o = the operator's investment outlay in year t

R_t^o = the revenue received in year t

F_t^o = fees paid by the operator in time t

C_t^o = operating costs in year t

M_t^o = maintenance costs in time t

MIT_t^o = Mitigation cost in time t

r = the discount rate (weighted average cost of financing)

t_0,T = respectively, the first and last periods considered in the analysis

A positive NPV^o indicates that the investment on port development is worthwhile: it earns a rate of return greater than r, the firm's overall cost of debt and equity financing. A negative NPV^o reveals that the port project is a bad investment, earning a rate of return less than r. Note that in the above formula, taxes are not included. Taxes are omitted due to (1) the specialized issues raised by taxes, (2) the lack of information at the present time surrounding development plans for Quonset, and (3) lack of information on private sector and possible private-public sector financial arrangements that might be made for a proposed port.

IV. B. 2. Risk and Uncertainty

Container port development requires a major financial commitment for infrastructure and superstructure, and recovery of this investment will take many years. Also, port developers also must accommodate environmental concerns and potential delays. Hence, risk and uncertainty are unavoidable and are part of any *ex ante* investment analysis (Harambides, 1991; Grigalunas, Chang and Luo, 2002).

Major sources of risk include (1) business and financial risks and (2) risks to environmental and natural resource assets. Business risks stem from the inherent nature of the specific business and the overall economic conditions in which a business operates. They come from many sources that are hard to predict with certainty, and may be beyond the control of the operator, such as labor problems, cost increases, inter-port competition and strategic behavior, economic recessions, and exchange rate changes.

Environmental risks involve potential costs which the operator might face for studies and mitigation of threats (perceived or real) to area natural resources and amenities. For example, development will require dredging and disposal and possibly filling in of a section of the Bay and some wetlands. The operator may be called upon to fund studies of these and other issues. Further, mitigation, changes in design, or delays—or all three—may be required, perhaps substantially increasing the costs of development. However, specific costs cannot be precisely anticipated, especially at this early stage.

IV. B. 3. Methodology

To address the many risk and uncertainties faced, two methods are used: Sensitivity analysis and Monte Carlo Simulation. Both methods were used in our year one research. *Sensitivity analysis* involves the use of "what if" comparisons and examines the responsiveness of the NPV^o when important and uncertain variables (e.g., the startup volume or growth rate) are given alternative values. *Monte Carlo* analysis is an extension of sensitivity analysis. Important and uncertain variables are assigned a probability distribution, based on the researcher's judgment in the particular case being studied. For each variable included, a value is drawn at random by the computer, and then the NPV^o is calculated. This is repeated many thousands of times – 100,000 times in our case. The results are a distribution of NPV^o, which reveals the expected value and standard deviation of estimated NPV^o. The variability – variance -- of NPV^o is a standard measure of risk; another important measure of risk given in the Monte Carlo analysis is the probability of a negative NPV^o -- that is, the risk of failure.

IV. C. Data

Financial feasibility analyses for container port construction and operation require considerable data. At the present time, no authoritative data are available for a hypothetical port at Quonset Point. As a result, the analysis which follows draws upon readily available data from many different sources and must be understood to be somewhat generalized. For many issues, we use the same data as in our Year One analysis, including crane productivity, number of jobs, wages, revenue per move, and investment cost (see, Grigalunas, Luo, and Chang, 2001, Chapter III). Of course, as better data eventually become available an updated and improved analysis can be provided.

However, also incorporated in the analysis below are three new factors. One is the adjustment of the timeline for assessing NPV^o to incorporate the additional two years required for the EIS study. The second is adoption of the container port demand simulation result for the estimate of initial demand described in Chapter II and III. Third, we adopt estimates in the literature and in an econometric analysis done as part of our work in order to project container transportation demand over the assumed 20-year operating life of the investment[11].

IV. C. 1. Forecasts for US Container Traffic Annual Growth Rate

Port investment decisions involve a long-term time horizon. Hence, a long-term prediction for growth of container traffic through US ports is needed for any container port development project. Such predictions necessarily involve inherent uncertainty. As part of this project, forecasts from several different sources are used. This allows us to consider a range of forecasts by industry experts, enabling us to analyze the project feasibility for several different scenarios.

We are mindful that an individual terminal operator or port may have private information of hold different views about the prospects for their specific facility than the aggregate estimates of projected growth which we of necessity employ in this chapter. Given such estimates, the results presented later in this chapter can be redone. Lacking such facility-specific information at the present time, sensitivity analyses and Monte Carlo analysis are used to show the effects of the range of possible start up volumes of TEUs and future growth rates, as we explain below.

As stated, we use the same project timeline as in the year one report, but allow for a two-year lead time for an EIS study, before the four-year construction period begins. Therefore, operations are delayed and begin in “2008” (that is, year 7 after an EIS). We continue to use a 20-year operating time horizon, with the ending year of forecasting period 2027 (Figure 78). *Note that all estimates of NPV^o are as of the year 2002.*

[11] Twenty years is a standard time horizon for investment analysis. Once developed, a port may well extend beyond 20 years. However, major investments would be required and changes made, making assessments beyond 20 years especially tenuous.

Figure 78. Timeline of Major Activities at Quonset Point

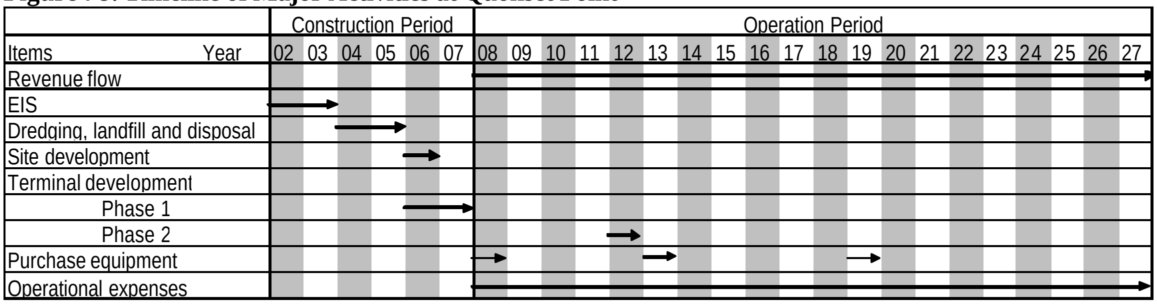


Figure 79 summarizes (1) the actual national container throughput growth rate from 1990 to 2000, and (2) three forecasts for this growth rate. Figure 80 displays the *actual* throughput of all US container ports before 2000, and *projected* container throughput from 2000 to the end of 2027. In the past decade, the container traffic at US container ports experienced dramatic growth, about 7.1% per year from 15 million TEUs at 1990 to 30 million at 2000 (AAPA[12]). If this trend continues, then the US national container traffic would reach 195 million TEUs in 2027 (Figure 80). McGraw-Hill has forecasted that US containerized trade will grow at 7% for imports and 5% for exports from 1999 to 2004[13], with an overall growth rate of about 6.2%. If it continues to grow at this rate, then the national container trade would be 151 million TEUs at year 2027.

The Port Authority of New York and New Jersey (PNYNJ) and its consultants forecasted the annual growth rate from 2000 to 2040 at about 4.2%, with a lower range at 3.7% and high range at 4.6%[14]. Using this range, the corresponding national container traffic estimations are 77 million TEU for 3.7%, 89 million TEUs for 4.2% and 99 million TEUs for 4.6% at year 2027.

[12] http://www.aapa-ports.org/pdf/US_Canada_Containers.PDF, accessed May 21, 2002
[13] http://www.marad.dot.gov/publications/PDF/McGraw-Hill's%20U.S%20industry%20&%20Trade%20outlook%202000.pdf, accessed May 21, 2002
[14] PNYNJ (2001). "Building a 21st Century Port", page 7.

Figure 79. US Container Traffic Growth Rate: Observations and Forecasts

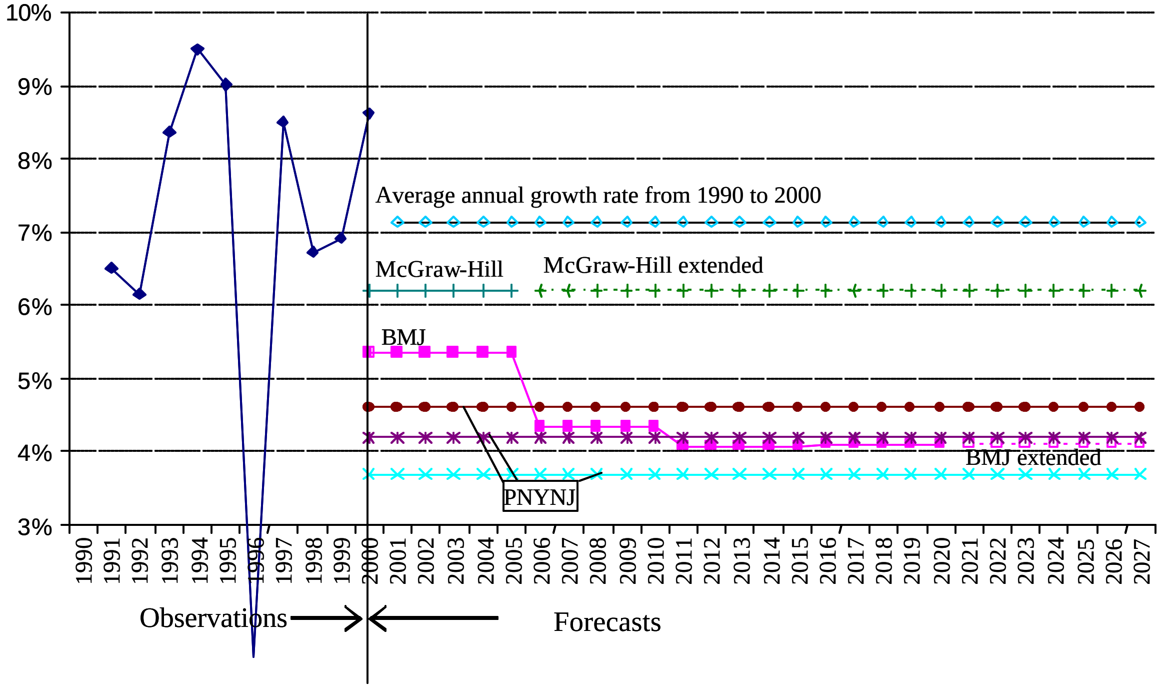
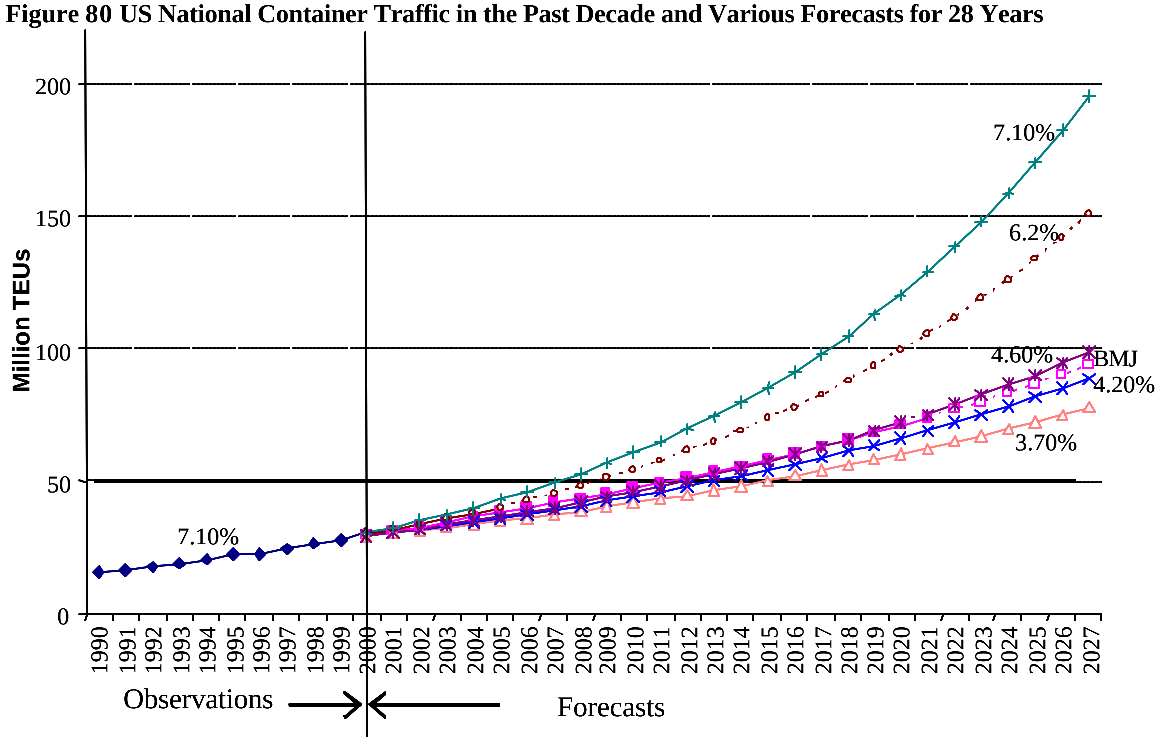


Figure 80 US National Container Traffic in the Past Decade and Various Forecasts for 28 Years



Dr. Bong Min Jung (BMJ) of the URI Korea-American Joint Marine Policy Research program used an econometric model to forecast US annual container traffic growth rates from 2000 to 2020 (Jung, 2001). Five different statistical models were estimated and used to predict the annual container traffic for US container ports from 2000 to 2020. The average annual growth rates of these models are 5.36% from 1999 to 2005, 4.35% from 2006 to 2010, 4.09% from 2011 to 2015, and 4.10% from 2016 to 2020 (Figure 80). From this set of growth rates, US container traffic would be 94 million TEUs at year 2027.

In sum, this survey of existing forecasts of growth in US container moves reveals widely different perceptions about the future development of container transportation. The projected annual growth rate varies from 3.7% to 6.2%. These estimates can be compared with the average annual growth rate of TEU moves in the past decade of about 7.1%. This range of estimates in growth rates could lead to a difference of 118 million TEUs at year 2027. Again, we acknowledge that an individual terminal operator may have projections different from those above; given this information, the discounted cash flow model and other analyses in this chapter can be redone with much more certainty. Meanwhile, sensitivity analyses are used to reflect the broad range of projected growth rates given in the literature.

IV. D. Application

Now we are ready to turn to the major task of this chapter: Integrating the new results from our year two research (Chapters II and III), and new estimates of projected growth from various sources, described above, to reassess the feasibility and risks for a hypothetical container port at Quonset Point. To help understand the nature of the new data, a brief description is given.

IV. D. 1. Description of the New Data

The container port demand simulation model estimates the conditional demand of the proposed port, based one the underlying assumption given in Chapters II and III (again, for details, see Luo, 2002; Grigalunas, Luo, and Chang, 2001). The estimated result is based on the container flow OD matrix converted from 1999 waterborne trade data (www.marad.dot.gov). This OD matrix is detailed to state import and export, to or from different continents, for cargoes detailed to SIC 2-digit level.

The forecasted annual increasing rates of US container traffic from previous section are national growth rates, with all foreign countries, for all cargo. Hence, in effect we assume that the international trade *pattern* of US with other countries will not change in the project period, and that the pattern – not the volume -- will be the same as our base year, 1999. We also are implicitly assuming no major relative population shifts within the US which might affect relative demand between ports. Hence, TEUs at the proposed, new port will grow at the same rate as the national growth rate. Again, if more disaggregated forecasts become available, these can be used to improve the estimated growth for the new port.

In sum, the calculation of conditional demand for the new port at the initial year of operation is the conditional demand at base year 1999. This demand is projected to grow, based on estimates of growth at the national level, and we use a range of growth rates to reflect uncertainty in this area.

The initial conditional demand estimate from the simulation model is about 316,000 TEUs in *1999*, our base case year (Table 12). Assuming demand would grow at 5.4% (see discussion in following paragraph), the initial demand for port services would be 507,000 TEU in 2008 (Figure 41). These figures are the conditional demand for the hypothetical port, with access to class I rail, and taking into account the impact of East Coast Canadian ports (based on the assumption that the real cost for all other ports is the same).

Our estimate for the base case growth rate (5.4%) for this port is the mean value of the lowest forecast (3.7%) and the highest (7.1%). The starting year of the hypothetical port project evaluation is 2002. Hence all benefits and costs are measured as of this date – 2002. Under the assumption stated before, we estimate NPV^o in 2002 using the number of TEUs each year starting from 2008, when the hypothetical port begins operation, for a 20 year operational period, assuming 2-year's EIS and 4-year's construction period. We also converted from number of TEU to number of lifts or moves (Figure 81), using a conversion rate of 1:1.68 (the average TEU/lift ratio for PNYNJ in the past 10 years).

Figure 81. Number of TEUs, Lifts and Annual Growth Rate for Planning Period (thousand)

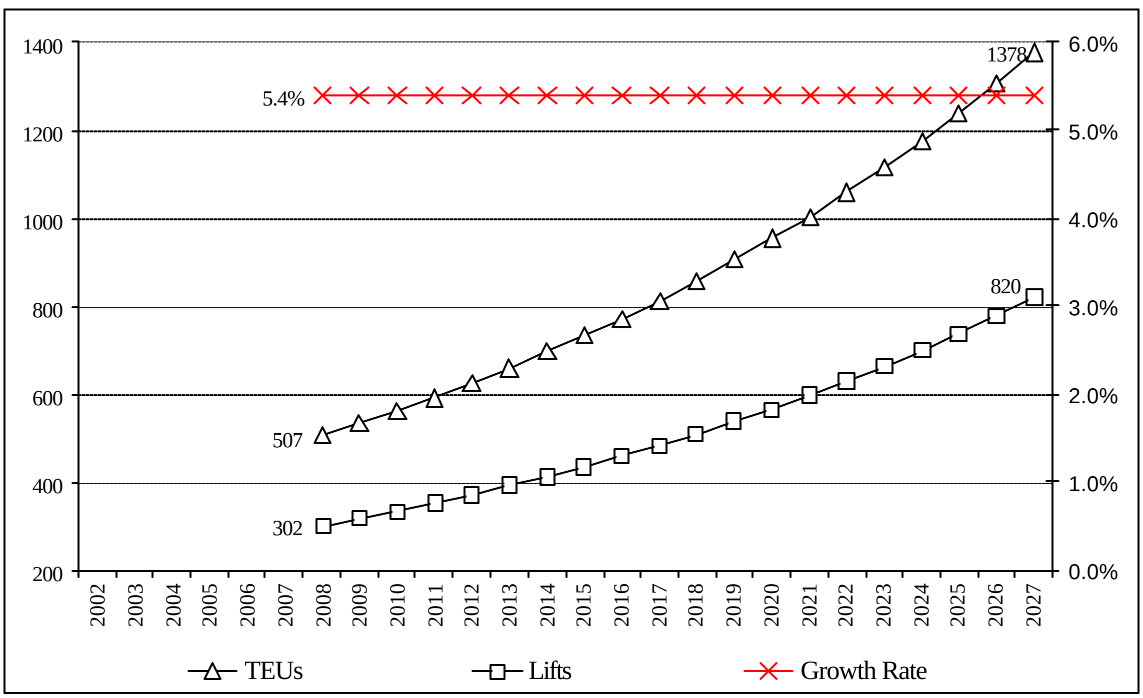


Figure 81 also shows the initial lifts at the first year of operation is about 302 thousand, and it will be 820 thousand lifts (or 1.378 million TEU) at the 20th year of operation.

IV. D. 2. Sensitivity Analysis

Consistent with the year-one report, our sensitivity analyses examines how NPV^o is affected by (1) changes in the number of moves, (2) the growth rate in moves, and (3) gantry crane efficiency[15]. From the simulation results given in Chapter III, the estimate of base case demand for TEU moves through Quonset in *1999* is 316,000 TEUs according to the simulation model results in Chapter III. This compares with 336 thousand TEUs in our earlier report, based on the information available at that time (Grigalunas, Luo, Chang, 2001; Grigalunas, Chang abd Luo, 2002). For the sensitivity analyses, alternative initial (1999) moves are set from 252.8 thousand to 379.2 thousand TEUs, or 20% lower or 20% higher than the base case, respectively.

In the model, short-run costs -- labor costs – vary with annual moves. For this purpose, we use the engineering-cost relationships set out in a prototype port design for Quonset by RK Johns&Assoc. (1999).

An interesting issue, and one important for our sensitivity analysis, concerns how costs vary with changes crane productivity. Generally, the production function for output (container moves, in our case) depends on technology, labor, capital, and other inputs. However, our sensitivity analyses assumes TEU moves in a given year are not directly related to technology (crane moves/hour) changes with the cases considered (e.g., 40 moves per hour versus 50).

To examine the consequences for NPV^o of different sustained productivity standards, we use alternative productivity estimates ranging from 30 – 50 moves per hour, and the number of yard workers used is a function of the productivity of the gantry cranes (Grigalunas, Luo and Chang, 2001). Hence, if actual productivity is less than the planned 50 moves/hour, additional labor must be hired to move the number of containers assumed to pass through the port in a given year, all else equal. This labor requires use of available gantry cranes for a longer period but the marginal cost of crane time as such is treated as zero[16].

Specifically, we calculate the additional "demand" for labor (number of yard workers), N, as:

$$N=\frac{L}{C \cdot H} n \cdot 1.5$$

Where:

N: Number of yard workers
L: Annual total lifts
C: Crane efficiency (lifts/hour)
H: Annual working hours (use 2288 hours)

[15] Terminal efficiency depends upon a host of factors in combination, not just gantry crane efficiency. Our analysis assumes that other factors such as movement and storage of boxes supports the range of crane efficiencies considered.
[16] At the present time we do not have variable costs for crane operations apart fom labor but plan to refine this aspect of the discounted cash flow model in late research.

n: number of workers per gang (20)
1.5: Constant reflecting shift breaks, lunch, and overtime

We assume workers are fully employed (work 2288 hours a year), and their hourly wage (w) is $48. Therefore, the total labor cost for yard workers is: N*H*w, where these terms are defined above.

For the annual growth rate of move, the middle value (5.4%) is used as the base case; a range of from 3.7% to 7.1% is used for growth, as stated in previous section. The third sensitivity analysis is for gantry crane efficiency where we use the same sensitivity range as in our year one report (30, 40, 50 moves per hour).

Error! Reference source not found. summarized the sensitivity analysis of NPV^o with parameter changes including crane efficiency, simulated number of TEUs at 1999 for the hypothetical port, and the forecasted growth rate from the presumd start up date, 2008, to 2027.

Table 13. Sensitivity Analysis - NPV^o (million)

		TEU 99 (000)	Growth Rate		
			3.7%	5.4%	7.1%
Crane Efficiency (lifts/hour)	30	252.8	($441.7)	($273.0)	($41.1)
		316.0	($323.6)	($112.8)	$176.8
		379.2	($205.5)	$47.2	$394.6
	40	252.8	($404.1)	($222.0)	$28.2
		316.0	($276.6)	($49.2)	$263.4
		379.2	($149.1)	$123.6	$498.5
	50	252.8	($381.5)	($191.4)	$69.9
		316.0	($248.4)	($11.0)	$315.4
		379.2	($115.3)	$169.4	$560.9

The result in **Error! Reference source not found.** can be summarized as follows:

- The worst case is negative NPV^o of $441.7 million; the best case shows a positive NPV^o of almost $561 million.

- The start-up volume (the simulation result for the hypothetical port) and annual growth rate are very important. If container traffic at the new port grows at the average national rate for the past decade (7.1%), most of the time the NPV^o will be positive. If the increasing rate is at 3.7%, the low range in available forecasts, NPV^o will always be negative.

IV. D. 3. Monte Carlo Simulation

Monte Carlo analysis simulates the possible range of outcomes by specifying random distributions for key, uncertain parameters. Sensitivity analyses only consider selected changes in key variables -- with no likelihood assigned to their occurrence. Hence, Monte Carlo simulation has the desirable feature of requiring the researcher to specify their beliefs about the probability of occurrences for each of the uncertain variable included, which then are used to analyze the possible range of results NPV^o. Therefore, Monte Carlo analysis incorporates much more information for assessing investment feasibility and risks than sensitivity analyses.

Four variables are considered in the Monte Carlo simulation, as in the year-one report. These are: gantry crane efficiency, the growth rate for container traffic, the cost of equipment and maintenance, and container movements. Table 7 summarizes the four parameters we use and their input distribution parameters.

Table 15 list the assumptions used for each variable in graphical form.

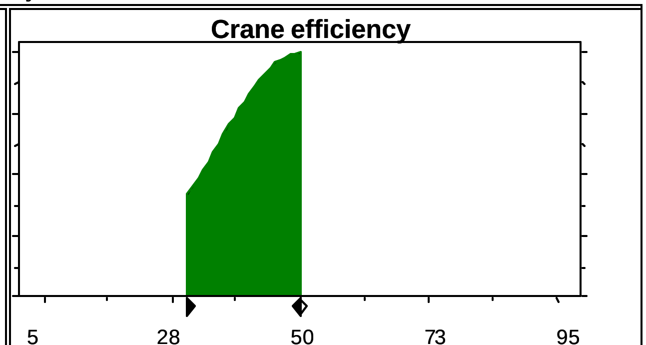
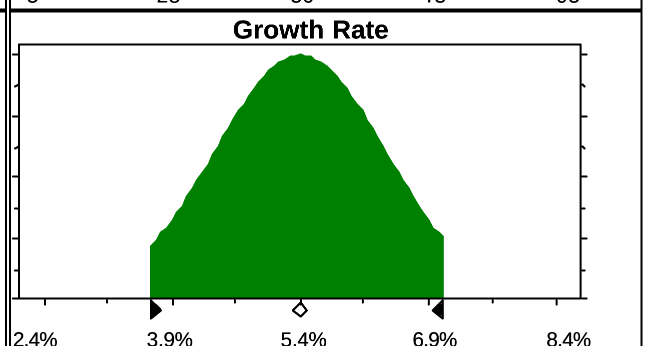
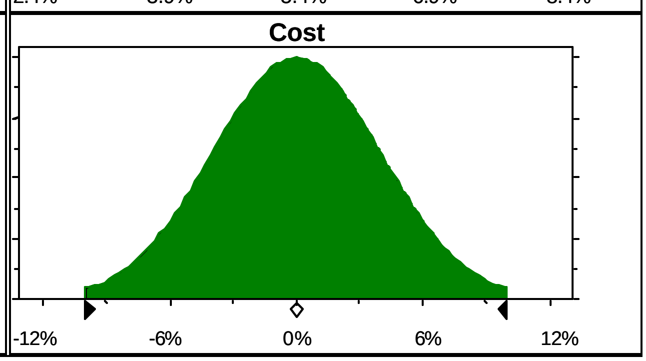
Table 14. Parameters of Input Distributions (Normal Distribution) for the Monte Carlo Simulation Model

Parameters	Range	Mean	Standard Deviation
Crane Efficiency **(lifts per hour per crane)**	30 - 50	40	15
Growth Rate	3.7% - 7.1%	5.4%	1%
Cost	-10% - +10%	0%	4%
TEU in Base Year (1999)	200 – 916	316	200

As in year one, we also conducted one simulation for each of the four uncertain variables, with all other factors held constant at their mean value. Then, we carried out one simulation where variations in all these variables were considered. Each case was simulated for 100,000 trials. Table 16 summaries the results from these simulations.

We stress that the NPV^0 given here is an estimate of the financial worth for the *operator*. It is *not* an estimate of net benefits and costs to a host state or to the nation as a whole, which requires an assessment of transportation cost savings, offsite costs external to the port itself, costs of administration, and potential environmental costs and mitigation, and perhaps other items and is beyond the scope of this report (see Grigalunas, Luo, and Chang (2001) for a discussion of the concepts and issues).

Table 15 Assumptions Used in Monte Carlo Analysis

Assumption: Crane efficiency Normal distribution with parameters: Mean 50 Standard Dev. 15 Selected range is from 30 to 50 Mean value in simulation was 41	
Assumption: Growth Rate Normal distribution with parameters: Mean 5.4% Standard Dev. 1% Selected range is from 3.7% to 7.1% Mean value in simulation was 5.4%	
Assumption: Cost Normal distribution with parameters: Mean 0% Standard Dev. 4% Selected range is from -10% to 10% Mean value in simulation was 0%	

Assumption: TEU99
Normal distribution with parameters:
Mean 316
Standard Dev. 200
Selected range is from 200 to 916
Mean value in simulation was 409.64

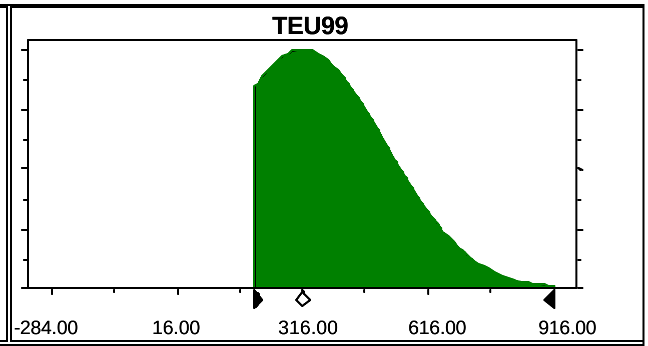


Table 16. Monte Carlo Analysis: Summary Results

Variable	Range Used	Expected Value ($million)	Standard Deviation ($million)	Probability of $NPV^0<0$
Efficiency (lifts/hour/crane)	30 – 50	-$46	$27	100%
Growth Rate	3.7% - 7.1%	-$42	$126	50%
Cost	-10% - +10%	-$49	$14	100%
Initial TEU (1999)	200 – 916	$208	$391	29%
Combination	NA	$220	$433	34%

The simulation result shows that changing either crane efficiency or cost does not change the nature of the project: the NPV^o on average is negative for the range of value considered for both variables (with all other variables fixed at their mean value). There is a 50% chance that the NPV^o will be negative for the growth rates considered. The most important variable in terms of risk of loss is the startup container traffic in the base year (1999). The result shows only a 29% chances that the project will lose money due to variations in the intial demand. Stated another way, most likely (71%), the project will earn a positive NPV^o if this is the initial demand (over the range considered) is the only source of variation.

When all of the uncertain variables are considered together (the "combination case"), the project will have a positive NPV^o 66 % of the time. This is because the combined effect of probability distribution of TEU99 and crane efficiency.

Table 17 and Figure 82 show the Monte Carlo results when uncertainty associated with all of the four variables is considered.. For this ‘combination case’, the simulation results can be described in several ways.

- First, the results show a picture of a ‘skewed’ (not a normal or “bell shaped”) probability distribution.

- Second, the *average* outcome over 100,000 trials is +$200 million, while the *median* is lower at +$144 million (half the outcomes fall below and half above this value).

- Third, the mode or most likely outcome is NPV^o = - $86.5 million, with a probability of 2.3%.

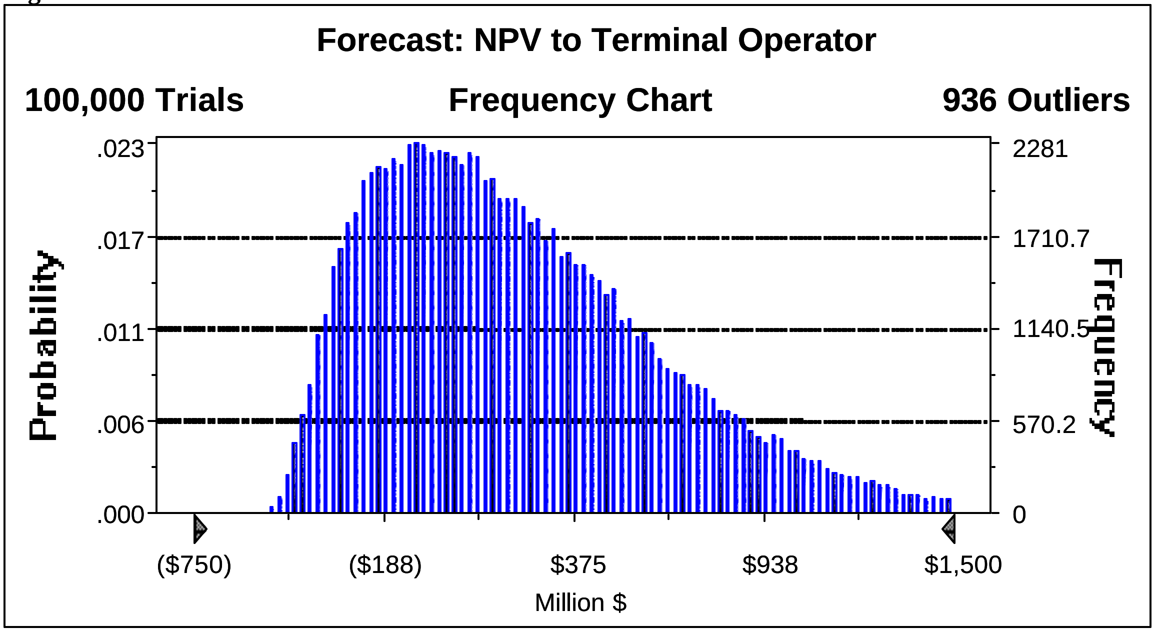
- About 92% of the time, the NPV^o is between -$435 million to $915 million, 81% between -$390 million to $623 million, and 39% between -$255 million to $150 million.

Table 17. Monte Carlo Results for Combination Case of the Variables

Statistics	***Value***
Trials	100,000
Mean	$220 million
Median	$144 million
Standard Deviation	$433 million

We note that the NPV^o model itself remains somewhat simplified in it does not consider tax issues and their effect of operator profitability. The use of better information for a planned port, when it becomes available, will make estimation of the NPV^o more precise than is possible now, given the dearth of specific information.

Figure 82. Monte Carlo Results: Combination of All Variables



IV. E. Summary, Qualifications, and Future Directions

The assessment of NPV^o for a terminal operator provides critical information about the feasibility of a hypothetical new project and is a key building block for assessing benefits and costs and their distribution. Our assessment of NPV^o in this chapter draws upon standard investment valuation methods—discounted cash flow (DCF) analysis. To implement the analysis, the initial demand for a hypothetical port at Quonset Point was estimated using the results of a container port transportation and related multimodal demand simulation model. The initial 1999 demand then was projected to be 507,000 TEUs (316,000 box moves) for the hypothetical start up year, 2008, using an assumed growth rate of 5.4%, an average from national forecast results in the literature.

Our estimate of 319,000 TEUs for the initial year assumes *ready rail access with double stack capability* and port fees of $200/TEU at all ports. Other assumptions are described in the text. Growth at the port was projected at 3.7% - 7.15% using estimates available in the literature, including a preliminary set of estimates generated as part of this project. For costs, we used available general information for prior proposals for a container port at Quonset. The DCF was carried out over a 26-year time period, allowing for environmental studies (2 years), construction (4 years), and operation (20 years).

The bottom line is that, of the factors considered, the financial success of the hypothetical port depends critically on the start up volume and the growth rate. Productivity and costs are important but were not as important startup volume and growth rate over the range we considered.

We close by reemphasizing a point made throughout this report. We have made much progress in implementing the "comprehensive framework" Set our in our Year One Report (Grigalunas, Luo, and Chang, 2001) Nevertheless, our results remain *illustrative* of the potential usefulness of the comprehensive framework under development and *must not be taken as conclusive*. Our container port demand simulation model needs to be refined and more realistic economic parameters are needed for truck, rail costs, and port fees. The OD matrix needs to be improved by disaggregating further by geographic areas and commodities. The port appraisal model still is based on generalized data, as no specific plan has been advanced as yet. Also, tax issues should be included in the DCF analysis, when specific information about any formal port proposal becomes known.

As noted, the container port and multimodal demand simulation model described in this report will be extended and refined (see Chapter II). We also are substantial refining and extending our environmental analyses in an ongoing project to link environmental issues with projected development. Further, we are extending the transportation demand simulation model to consider in greater detail emerging, container transportation-related issues in the Northeast. The results of these and other, related analyses will be presented in future research reports.

V. BIBLIOGRAPHY

1. AAPA (2002). U.S./Canada Container Traffic in TEUs (1990-2000). *American Association of Port Authority*. http://www.aapa-ports.org/pdf/US_Canada_Containers.PDF, Accessed June 11, 2002
2. Bank, James H.. *Introduction to Transportation Engineering*. New York: McGraw Hill, 1998
3. Benacchio, Marco, Claudio Ferrari, Hercules E. Haralambides, Enrico Musso. On the Economic Impact of Ports: Local vs. National Costs and Benefits. *Forum of Shipping and Logistics, Special Interest Group on Maritime Transport and Ports International Workshop*. Genoa – June 8 – 10, 2000
4. Bertsekas, Dimitri P. (1995). *Dynamic programming and optimal control*. Belmont, Mass.: Athena Scientific, c1995
5. Beuthe, Michel, Bart Jourquin, Jean-Francois Geerts, Christian Koul a Ndjang' Ha. Freight transportation demand elasticities: a geographic multimodal transportation network analysis. *Transportation Research Part* E 37 (2001) 253-266
6. Bobrovitch, Dov. Decentralised planning and Competition in A National Multi-port System. *Journal of Transport Economics and Policy*, 16 (1982): 31-42
7. Bolduc, Denis. A Practical Technique to Estimate Multinomial Probit Models in Transportation. *Transportation Research Part* B 33(1999): 63-79
8. Bomba, Michael S., Robert Harrison and C. Michael Walton. Planning for Mega-containerships: A Statewide Transportation Planning Approach. Washington, D.C.:*Transportation Research Board 80th Annual Meeting* July 7-11, 2001
9. BTS (Bureau of Transportation Statistics), US DOT. *National Transportation Statistics 1999*.

BTS99-04, Washington, DC:1999
10. BTS, US DOT. *National Transportation Statistics 2000*. BTS01-01, Washington, DC:2001
11. Cullinane, Kevin and Mahim Khanna. Economies of Scale in Large Containerships: optimal size and geographical implication. *Journal of Transport Geography*. 8 (2000): 181-195
12. Cullinane, Kevin and Mahim Khanna. Economies of Scale in Large Containerships. *Journal of Transport Economics and Policy*. Vol. 33, Part 2 (1999): 185-208
13. Emerson, William and James Anderson. A Spatial Allocation Model for the New England Fisheries, *Marine Resource Economics*. 6 (1989): 123-144
14. Ertl, Gerhard. Shortest path calculation in large road networks. *OR Spektrum* 20 (1998): 15-20
15. Fagerholt, Kjetil (2000). Evaluating the trade-off between the Level of Customer Service and Transportation Costs in a Ship Scheduling Problem. *Maritime Policy and Management*. 27 (2000): 145-153
16. Fowler, Chris. Application of the Least-Cost Transportation Model in Estimating the Impacts of Major Transportation System Changes – A case study of Dam Breaching on the Snake River. *Transportation Research Board, Washington, D.C.:80th Annual Meeting*, July 7-11, 2001
17. Garrido, Rodrigo A., Hani S. Mahmassani. Forecasting Freight Transportation Demand with the Space-time Multinomial Probit Model. *Transportation Research Part* B 34 (2000): 403-418
18. Gilman, S. and G. F. Willians (1976). The economics of multi-port Itineraries for Large Container Ships. *Journal of Transport Economics and Policy*. 10 (1996): 136-149
19. Grigalunas, Thomas A., M. Luo and YT. Chang (2001). *Comprehensive Framework for Sustainable Container Port Development for the United States East Coast Year One Final Report, URI – TC Project No. Grant 536106*, October 11.
20. Grigalunas, T. and J. Opaluch, 2002. Propoposed Delaware River Channel Deepening Project: review and Critique of Economic Analyses. State of Delaware Dept. of Natural Resources and Environmental Control, Wetlands and Subaqueous Land Section (Apr.)
21. Hancock, Kathleen L., A. Sreekanth (2001). Conversion of Weight of Freight to Number of Railcars. *Transportation Research Board 2001*. Paper No. 01-2056.
22. Harambides, H. (1991) Monte Carlo Simulation in Risk analysis, Financial Management Summer: 15-16. Maritime Economics, Edited by K. M. Gwilliam, Kluwer Academic Publishers.
23. Harambides, H. (1993) Sensitivity Analysis of Risk in Shipping Finance: from Current Issues in, pp. 168-177
24. HDR Engineering, Inc. (2001) and John Martin & Associates. *Port of Portland Marine Economic Impact Study: Container Transportation Cost-Benefit Analysis*. http://www.portofportlandor.com/htmlpop/a%5F20011119115cntrcostbenefitrls.htm, accessed 12 June 2002
25. Hensher, David A. and Kenneth J. Button (ed) (2000). *Handbook of Transport Modelling*. Pergamon.:Elsevier Science Ltd: UK.
26. Hillier, Frederick s., Gerald J. Lieberman. *Operations Research*. 2nd ed. San Francisco:Holden-Day, Inc., 1974.
27. Hoffmann, Jan. Concentration in liner shipping: its causes and impacts for ports and shipping services in developing regions. Unidad de Transporte: Santiago: ECLAC, 1998. 97 p.
28. Jones, James R. and Lu Qu. A spatial equilibrium port cargo projection model. *Maritime Policy and Management*, vol. 22. no. 1 (1995): 63-80,
29. Kesic, B., P. Komadina, D. Cisic (2000). Towards the Unified Theory of the Port Gravitational Areas – Introducing Information Centrality. *Transportation Research Board,80th Annual Meeting*, January 7-11, 2001
30. Klein, Christopher C. and Reuben Kyle. Technological Change and the Production of Ocean Shipping Services. *Review of Industrial Organization*. 12 (1997):733-750
31. Kronsjö, Lydia and Dean Shumsheruddin. Ed. *Advances in Parallel Algorithms*. New York, Toronto:Halsted Press-John Wiley & Sons, Inc, 1992
32. Kurose, James F. and Keith W. Ross (2000). *Computer Networking: A Top-Down Approach Featuring the Internet*, Addison-Wesley, 1st Edition,
33. Luo, Meifeng (2002). *Container Transportation Service Demand Simulation Model for U.S. Coastal Container Port*. Ph.D. Diss. Uni. Of Rhode Island, USA, 2002
34. Malchow, Matthew Brain. *An analysis of port selection*. Diss. Uni. Of California, Berkeley, 2001

35. McFadden, Daniel. The measurement of Urban Travel Demand. *Journal of Public Economics*. 3 (1974): 303-328
36. MISER (2000). *Foreign Trade Database. Massachusetts Institute for Social and Economic Research*. http://www.umass.edu/miser/axes/oldstuff/. Accessed June 11, 2002.
37. Murphy, Paul R., James M. Daley and Douglas R. Dalenbery (1992). Port Selection Criteria: An Application of a Transportation Research Framework, *The logistics & Transportation Review*, Vol. 28, No 3, September 1992
38. Opaluch, James, Thomas Grigalunas, Meifeng Luo, Huiting Zhang, Suk-Jae Kwon, Bong-Min Jung and Young-Tae Chang. Improving Marine Policy Through Use of Visualization Tools in a Policy Simulation Lab, *Korea Observer*, Vol. 33. No. 2 Summer 2002: 219-238.
39. PNYNJ Press Release (2001). Port Authority Seeks Financial Support from Congress for more than $100 Million in Vital Dredging Projects – Channel Deepening Work is Key to Continuing Economic Growth in Ny-NJ Region. http://www.panynj.gov/hrd/hrdframe.HTM, accessed 12 June 2002
40. Preston, John. Integrating Transport with Socio-economic Activity – a Research Agenda for the New Millennium. *Journal of Transport Geography*. 9 (2001): 13-24
41. Southworth, Frank and Bruce E. Peterson. Intermodal and International Freight Network Modeling. *Transportation Research Part* C. 8 (2000): 147-166
42. Stepford, Martin. *Maritime Economics*, Routledge: July 1997
43. Tsamboulas, Dimitrios A. and Seraphim Kapros. Decision-Making Process in Intermodal Transportation. *Transportation Research Record* 1707, Paper No. 00-1304, 2000
44. US DOT. *The Impacts of Changes in Ship Design on Transportation Infrastructure and Operation*. Office of Intermodelism, US DOT, Feb. 1998.
45. US Geneal Accounting Office, 2002. Delaware Rivee Deepening Project: Comprhensive Reanlysis Needed. GAO-02-604 (June).
46. Winston, Clifford. A Multinomial Probit Prediction of the Demand for Domestic Ocean Container Service. *Journal of Transportation Economics and Policy*, 15 (1981): 243-52.