Interfaces

Publication details, including instructions for authors and subscription information: http://pubsonline.informs.org

Estimating Demand for Container Freight Service at the Port of Davisville

James R. Kroes, Yuwen Chen, Paul Mangiameli,


Full terms and conditions of use: http://pubsonline.informs.org/page/terms-and-conditions

This article may be used only for the purposes of research, teaching, and/or private study. Commercial use or systematic downloading (by robots or other automatic processes) is prohibited without explicit Publisher approval, unless otherwise noted. For more information, contact permissions@informs.org.

The Publisher does not warrant or guarantee the article’s accuracy, completeness, merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications, or inclusion of an advertisement in this article, neither constitutes nor implies a guarantee, endorsement, or support of claims made of that product, publication, or service.

Copyright © 2013, INFORMS

Please scroll down for article—it is on subsequent pages

INFORMS is the largest professional society in the world for professionals in the fields of operations research, management science, and analytics.
For more information on INFORMS, its publications, membership, or meetings visit http://www.informs.org
Estimating Demand for Container Freight Service at the Port of Davisville

James R. Kroes  
College of Business and Economics, Boise State University, Boise, Idaho 83725,  
jimkroes@boisestate.edu

Yuwen Chen, Paul Mangiameli  
College of Business Administration, University of Rhode Island, Kingston, Rhode Island 02881  
{yuwen@mail.uri.edu, mangia@mail.uri.edu}

The Port of Davisville, located at Quonset Point, Rhode Island, is a former US Navy facility that was turned over to Rhode Island for commercial development when the naval base closed in 1974. Since then, a number of proposals have been put forth to expand the port’s operations to include the handling of containerized cargo. The Port of Davisville’s managing organization, the Quonset Development Corporation (QDC), partnered with this academic research team to objectively analyze the viability of three proposals: (1) a major expansion of the port to make it an international container megaport, (2) a lesser investment to make it a regional international port of entry for containers, and (3) a minor expansion to make it a short-sea shipping container port. We estimated the potential demand for each expansion option using transportation cost optimization models. QDC used our study’s demand estimation in its request for grant funds from the US Department of Transportation’s Transportation Investment Generating Economic Recovery program. As a result, QDC received $22.3 million to support the development of short-sea container freight shipping services at the Port of Davisville.

Key words: capacity expansion; facilities and equipment planning; decision analysis; linear programming; transportation; shipping.

History: This paper was refereed. Published online in Articles in Advance October 25, 2012.
Additional reports also suggest the development of a megaport at Davisville; annual usage demand projections range from 1 million to 1.7 million containers, expressed in 40-foot equivalent unit (FEU) containers, requiring infrastructure and dredging investments ranging from $698 million to $974 million (Normandeau Associates 1999a, b; QPD Intermodal, Inc. and Moffat & Nichol Engineers 1998; Quonset Point Partners, LLC 1999). Other reports have investigated developing Davisville as a smaller regional international port of entry with an estimated annual volume between 75,000 and 100,000 FEUs and required investments ranging from $266 million to $354 million (R. K. Johns and Associates, Inc. 2000, TransSystems Corporation 2001).

More recent attention has focused on configuring Davisville as a short-sea shipping port in an East Coast marine highway system. In the United States, short-sea shipping between ports has been proposed as an alternative to on-land highway traffic paralleling major inland routes, including Interstate 95 (from Boston, Massachusetts to Miami, Florida), Interstate 10 (from Brownsville, Texas to Tampa, Florida), and the Pacific Coast (from Seattle, Washington to San Diego, California) (Brooks et al. 2006, Knight 2010, Texas Transportation Institute 2007, US Government Accountability Office 2005). Upgrading the facilities at the Port of Davisville to support short-sea shipping will require an investment of approximately $12 million to purchase a mobile crane and to improve the existing piers (E. Matthews, pers. comm. 2009). At the initiation of this study, no studies into the viability of using the port as a short-sea shipping port had been conducted.

A common issue with previous studies that examine container service at Davisville, which is a driving factor in QDC’s pursuit of this research, is that none of the studies included demand estimations based on scientific methodologies. Study estimates were based on either unspecified estimation techniques, predictions that any added capacity to handle containerized goods would automatically be fully utilized,
or assumptions that all freight volume within the region would shift from competing ports and use the expanded port facilities without consideration of cost differences between the options. Further, none of these demand estimations included analyses of the demand’s sensitivity to market pressures, such as fuel price fluctuations and competitive responses by carriers using other transportation modes.

In the Scope of Study section, we discuss the scope and boundaries of our study. The Methodology and Results section details our methodology, including the formulation of the specific models used to examine this problem and the results. In Implications and Benefits, we present the implications and outcome of this research project. In the final section of the paper, Conclusions, we discuss the challenges of the effort and the conclusions we drew from the project.

Scope of Study

An important consideration in our attempt to estimate the potential demand for container freight services at the Port of Davisville was how to evaluate the port’s ability to compete with existing port locations. To do this, we chose to assess which customer locations would be optimally served by each port, based on the lowest hinterland transportation costs (from the port to the customer), and then determined the demand level for each customer using historical shipping data. This approach was driven by several factors. In conversations with shippers in the region, the lowest total shipping cost was cited as the most important factor driving carrier and routing decisions. We also learned that steamship carrier rates are not based explicitly on distance and volume; the rates are determined through private negotiations held between each carrier and each shipper. The rates charged for shipping containers, even on the same ship between the same port pair, can vary depending on the volume of containers that a shipper moves and the strength of the relationship between the shipper and carrier. In our conversations with a marine carrier, we were informed that differences in the oceanic transportation costs between different ports of entry are not substantial sources of variation in the total transportation costs when compared to the variation caused by differences in the inland transportation costs. Prior research, which has found that the hinterland costs are typically between 5 and 30 times greater per pound per mile than the oceanic maritime costs (Notteboom 2008), supports this opinion. We also learned that although other costs (e.g., port fees and drayage charges) vary between ports, these costs are typically small in comparison to the inland transportation costs. These factors led us to focus on optimizing the hinterland transportation costs in our models, while treating the oceanic portion of the container’s journey and port fees as fixed costs.

When evaluating the three options for Davisville, we chose to examine only the potential demand for international import marine containers that would pass through the port. Two concerns led us to make this decision. First, the focus on only containerized freight is driven by the current business conditions at the port. As we mentioned before, the port currently annually imports over 100,000 new vehicles, which are typically stored outdoors on the port’s piers. An agreement with the automobile processor precludes the port from handling any uncontained bulk cargo (e.g., coal, salt, ore, scrap metal) that may damage the vehicles. Second, the decision to consider only imports was driven by comments made by a potential marine carrier, in which we learned that (1) the export container volume is significantly less than the import volume, and (2) the primary containerized export products from the region are waste paper and other disposed goods, which are shipped to Asia for recycling and reclamation. The low value of the exports and the low volumes, compared to imports, have forced the carrier to set export rates essentially equal to operating costs to reduce the number of empty containers returned to Asia. Explicitly, the carrier stated that all of his firm’s profit is generated by imports and that the export operations are, at best, a breakeven proposition. Therefore, we decided to focus on imports.

We also considered whether we could base the demand estimates on a single period of data or should consider potential future changes to the import market. To gain insight into the future of the import market, we used the US Department of Transportation’s freight analysis framework (FAF) commodity flow survey, which tracks and predicts commodity flows within the United States. The FAF data predict that oceanic imports into the United States are expected...
to increase by only 17.5 percent between 2007 and 2020 (US Department of Transportation 2009). The expected stability and lack of significant traffic growth led us to not consider future growth and to use only import data from 2008 for our demand estimations, because 2008 represented the most recent year of complete data at the time that we initiated this research.

Methodology and Results

When evaluating potential methodologies for our demand estimations, we were faced with determining an approach that could best analyze a multimodal import transportation network involving thousands of nodes and links. Complicating this decision was the knowledge that humans make most individual transportation shipment decisions, which are therefore somewhat subjective in nature. Despite this subjectivity, shippers made clear in conversations that low cost was the dominant factor in shipping. The shippers’ consistent focus on cost led us to conclude that a cost-optimization approach, although not perfect, would allow us to generate demand estimates that were sufficiently accurate to assist QDC with its policy decisions. We conducted a review of the operations research (OR) literature to identify existing studies that use transportation cost-optimization network models to estimate traffic flows. Karabakal et al. (2000), Leachman (2008), Rahimi et al. (2008), and Sery et al. (2001) use cost-optimization network models incorporating multiple transportation modes to determine the optimal inland transportation paths for goods. Our method combines approaches used in these studies to create a network model, which we then tailor to model each possible expansion option at Davisville.

Network Model Design

We created a general transportation cost-optimization network model that we tailored to evaluate each of the various options for containerized service at the Port of Davisville (Appendix A details the model formulation). The model includes sea, rail, and highway nodes, and links within the continental United States that are relevant to our study; this allows us to examine the cost-optimized hinterland transportation solutions for various options investigated in this study. The model structure incorporates nodes representing ports of entry, transshipment points (intermodal rail yards, short-sea shipping ports, and truck transfer points), and customers with links between these locations (where present). Two versions of the model are used to examine the three proposed expansion options at the port.

Model 1 (the international port-of-entry version of the model) in Appendix A applies to cases that explore the Port of Davisville as a container megaport or a regional international port of entry for container traffic entering the United States at a major East Coast port of entry; hence, we examine 23 ports. In the optimization model, we allow the total container traffic volume to be optimized (i.e., each container can be assigned to any of these 23 ports). Rail is the only mode used to ship containers between two transshipment nodes and truck is the only mode used from the transshipment nodes to the customers. We also allow truck-to-ship mode directly from a port to a customer. The objective function minimizes the total hinterland transportation costs from the port of entry through possible transshipment points to the customers. In the first constraint, we allow all ports to compete with one another for the total container traffic volume imported into the United States in 2008 (note that the Port of Davisville had no direct import container volume in 2008). The next two constraints include the inflow and outflow balance at all ports of entry and transshipment points, respectively. The fourth constraint in the model ensures that customer demand is satisfied exactly. The last two constraints are the non-negativity constraints of the decision variables. The optimized model’s results estimate the demand for import container service at Davisville if it were configured as an international port of entry competing against the existing major international ports of entry currently operating in the United States.

Model 2 (the short-sea shipping version of the model) in Appendix A configures Davisville as a potential short-sea shipping port for import container traffic entering the United States at a major East Coast port of entry before being shipped to Davisville. Short-sea shipping is now available at the port to compete with rail for transshipment from other ports of entry to the customers. Davisville is not considered an international port in this version. The meanings of the objective function and other constraints
are the same as in Model 1, except that the container traffic volumes through 22 ports of entry are no longer assigned to the optimal international port of entry; the volume at each port is set equal to the actual volume that passed through each port in 2008 (US Department of Homeland Security: Customs and Border Protection 2009). The short-sea shipping container traffic estimates generated by the model are then used to evaluate Davisville’s potential as a short-sea shipping port.

The models are populated with actual freight volume and cost data and then solved to determine the optimal modes, costs, and volumes of freight flows through ports. After screening the three proposed options, we examine the sensitivity to market fluctuations of any options deemed potentially viable. All models were created and solved using Insight, Inc.’s SAILS v. 4.5 strategic supply chain modeling and optimization software program.

Network Model Nodes and Links
The models include nodes for the 22 largest ports, ranked by 2008 total loaded goods in FEUs, for international import containerized traffic into the continental United States, and a node for the Port of Davisville (see Figure 2).

During 2008, 97.3 percent of all containerized imports into the United States passed through the 22 ports included in our model (US Army Corps of Engineers 2008). We added transshipment nodes representing rail intermodal yards to facilitate the modeling of container transportation via rail. To identify the rail node locations, we examined the published locations of all intermodal rail yards operated by the five Class 1 US railroads, which resulted in 135 intermodal yard nodes in the model (we combined rail yards located within the same five-digit zip code into a single node). Nodes representing water- or rail-to-truck transfer points were incorporated at all port and rail yard locations.

We created links between the nodes in the model to represent the actual linkages present in the United States. The software program’s inherent highway system database automatically established highway links between all ports, intermodal yards, and customers, and determined road distances between nodes based on the shortest path between two nodes. Rail linkages were manually added between intermodal points under the assumption that the combined Class 1 railroads operate as a single integrated rail network. Potential short-sea shipping linkages were created between all ports with access to the Gulf of Mexico and the Atlantic Ocean. The mathematical models permit containers to travel only along legitimate links between the various nodes.

Data Collection
We collected international import container data to capture the demand levels for containerized goods at the customer locations in the model; we also
collected container import data for the year 2008 using the Manifest Journals database. This database captures and summarizes data from the US Customs and Border Patrol’s automated manifest system (http://www.manifestjournals.com), which tracks the waybill and manifest information for every good imported into the United States. For the 22 international ports of entry in the model, we collected 410,306 individual records tracking full container shipments to estimate the customer demand in the model. Each individual record details the port of entry, the consignee's five-digit zip code, and the shipment’s total volume in FEUs. The freight volume of 5,460,870 FEUs included in the model represents 67 percent of the total imports for 2008 into these 22 major ports of entry. The remaining 33 percent of shipments are less than full-container load shipments; we do not include these shipments in the data because they are typically removed from their import containers near the port of entry. To reduce the complexity and improve the tractability of the model, we assumed that all shipments in our model would be made using standard FEU international shipping containers, which are currently the predominant container size for international imports (World Shipping Council 2010). Based on this assumption, all transportation rates included in the model represent the costs to convey a standard FEU shipping container.

We created individual domestic demand nodes for containers (henceforth referred to as customers) within zip code areas across the United States by aggregating the volumes of all container shipments to the consignees located in a specific zip code from each international port of entry. We then consolidated the customer demand by three-digit zip codes, except in the area surrounding the Port of Davisville; in this region, we created individual customer locations within each five-digit zip code area to provide greater granularity around this study’s point of interest. The final model includes 1,360 customer locations throughout the continental United States.

We collected the transportation rate data used in the model from various sources, including published rate tables and interviews with shippers and carriers. The rail and truck rates both include a fixed base charge per container (FEU) component and a variable-per-mile, per-FEU-rate component. The rail transportation rates were established using the intermodal rate tables published by Class 1 railroads operating in the United States. The fixed base charge for each FEU and the variable-per-mile, per-FEU rate were estimated using a regression analysis of the published Class 1 intermodal rail rates. We validated the accuracy of the rail rates in an interview with a manager at a Class 1 rail carrier. The truck transportation per-FEU fixed base charge and variable-per-mile, per-FEU rates were determined by a series of interviews with shippers and carriers. Again, data from multiple interviews were analyzed using regression to determine a fixed base charge and variable-per-mile trucking rate. These rates were then verified in an interview with an operations manager at a trucking carrier. The rates for the proposed short-sea shipping services were determined in interviews with a potential marine carrier; the short-sea rates include the port fees and lift charges at both ends of the service.

Rail, sea, and trucking carriers each adjust their rates by multiplying the rate by a fuel surcharge percentage, which is determined by the current spot price of diesel fuel. To examine the impact of diesel fuel price fluctuations on the demand, we reviewed the diesel fuel spot prices in the United States for the five years prior to the initiation of the analysis to determine which price levels to test in our study. We found that the diesel fuel spot price at the initiation of the study was $2.86 per gallon (which closely corresponded to the five-year average spot price of $2.88 per gallon), the five-year low was $2.02 per gallon, and the five-year high was $4.76 per gallon (US Department of Energy, Energy Information Administration 2010). This led us to choose three sets of rates—low, medium, and high—for each transportation mode, equivalent to the transportation rates determined through our research and interviews, which we multiplied by the respective fuel surcharge charged by the rail, truck, and sea carriers at diesel spot prices of $2.02 per gallon, $2.86 per gallon, and $4.76 per gallon.

Model Analyses and Results
We solved all the models using SAILS v4.5’s Optima modeling system v10.07.19 optimization engine running on a Windows XP laptop operating a 2.4 GHz Intel Core 2 Duo processor. The solution generation time averaged 3.5 minutes.
Figure 3: The results of the Model 1 (international port of entry) analysis show that the Port of Davisville’s potential optimal service area as a port of entry (and associated demand for container freight service) is limited because of the port’s geographic positioning between the Port of New York/New Jersey and the Port of Boston.

Our analysis using Model 1 (see Appendix A), in which Davisville serves as an international port of entry, estimates that between 32,597 FEUs (at the low rates) and 32,674 FEUs (at the high rates) of containerized imports would pass through the Port of Davisville annually. The geographic area served by Davisville in all three scenarios, depicted in Figure 3 for the medium rates, would extend from the middle of Connecticut, through Rhode Island, to southeastern Massachusetts.

This analysis indicates that the Port of Davisville’s service area is bounded by areas optimally served by the Port of New York/New Jersey (NY/NJ) and the Port of Boston. A comparison of the results of this analysis with the various port development scenarios discussed previously in the paper leads to the conclusion that the estimated container volume does not justify the infrastructure investments required to upgrade the Port of Davisville to an international megaport (i.e., 1 to 1.7 million FEUs) or a regional international port of entry (i.e., 75,000 to 100,000 FEUs).

We use Model 2 (see Appendix A) to estimate the potential demand for short-sea container service between the international ports of entry and the Port of Davisville. Specifically, we estimate the demand on each potential short-sea shipping lane between the 22 international ports of entry and Davisville (routes from West Coast ports require transit of the Panama Canal). The results of the initial short-sea shipping analysis estimate that 7,720 FEUs (at the low rates), 8,716 FEUs (at the medium rates), and 8,646 FEUs (at the high rates) optimally use short-sea shipping between the 22 international ports of entry and the Port of Davisville to reach their destinations. These containers originate from 10 of the international ports of entry (zero volume is predicted from 12 of the ports); however, the majority of these containers originate at the Port of NY/NJ—6,308 FEUs (78 percent) at the low rates, 7,034 FEUs (81 percent) at the medium rates, and 6,964 FEUs (81 percent) at the high rates. In all three scenarios, the next-highest volume of 577 FEUs per year was found on the Port of Charleston to Davisville lane. From these results, we observe that the only viable short-sea shipping link (i.e., the annual volume is greater than 5,000 FEUs) for import containers into the Port of Davisville originates at the Port of NY/NJ.

As Figure 4 shows, the geographic area served by the Port of Davisville as a short-sea shipping port includes central and northern Rhode Island and southeastern Massachusetts.

Based on the Model 1 analysis, we eliminate the two options in which Davisville acts as an international...
port of entry. In evaluating Model 2, we identify only one potentially viable lane; therefore, we perform an in-depth analysis of the short-sea shipping lane from the Port of NY/NJ to Davisville to determine the sensitivity of the demand estimations to fluctuations in transportation rates charged by carriers at each of the three diesel fuel spot prices. To conduct the sensitivity analysis, we examine the impact on demand of three pricing levels for the truck, rail, and short-sea service. We construct the model with the short-sea service as the dependent variable and independent binary indicator variables representing the low and high conditions for each of the three transportation mode rates and the diesel fuel spot price. Appendix B details the regression model formulation.

The regression results (see Table 1) show that the resulting model is significant ($F = 18.9$, $p < 1%$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6708.8***</td>
</tr>
<tr>
<td>(445.1)</td>
<td></td>
</tr>
<tr>
<td>Short-sea rates reduced 10%</td>
<td>948.7**</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Short-sea rates increased 10%</td>
<td>-2,075.3***</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Truck rates reduced 10%</td>
<td>-1,632.8***</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Truck rates increased 10%</td>
<td>674.2+</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Rail rates reduced 10%</td>
<td>-495.2</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Rail rates increased 10%</td>
<td>156</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Diesel fuel spot rate = $2.02/gal</td>
<td>-1,166.6***</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Diesel fuel spot rate = $4.76/gal</td>
<td>896.8+</td>
</tr>
<tr>
<td>(363.4)</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.64</td>
</tr>
<tr>
<td>$F$</td>
<td>18.9***</td>
</tr>
<tr>
<td>Observations</td>
<td>81</td>
</tr>
</tbody>
</table>

Table 1: A regression analysis of the results of the 81 optimization models tested shows that the demand for short-sea shipping at Davisville is significantly impacted by pricing changes in the short-sea shipping rates and truck rates and fluctuations in the diesel spot price.

Note. Standard errors in parentheses. *Significant at 10%, **significant at 5%, ***significant at 1%.

An examination of the coefficients of the independent binary indicator variables in the model provides insight into the sensitivity of the demand for short-sea service between NY/NJ and Davisville to rate and fuel cost variations. We find that a 10 percent decrease in the short-sea rate, a 10 percent increase in trucking rate, and an increase in the diesel fuel spot price to $4.76 per gallon are each significantly associated with higher demand for the short-sea shipping service from NY/NJ to Davisville. Similarly, we find that a 10 percent increase in the short-sea rate, a 10 percent decrease in trucking rate, and a decrease in the diesel fuel spot price to $2.02 per gallon are each significantly associated with lower demand for the short-sea service. We also find that changes in the rail rates of +10 percent and −10 percent are not significantly associated with changes in the short-sea service demand level at the Port of Davisville.

**Implications and Benefits**

At the request of QDC, we developed demand estimates for three options for handling containerized...
freight at the Port of Davisville. The first two options involved expanding the port to serve as an international port of entry. Our estimation of the theoretical maximum container volume that would optimally use Davisville as an international port of entry led us to conclude that the demand level did not justify the investment required to facilitate either option.

Next, we examined whether using the port for short-sea shipping was a viable strategy and found one potentially feasible service lane (short-sea shipping between NY/NJ and Davisville). The sensitivity analysis of the NY/NJ short-sea shipping service showed that the demand exceeded the desired minimum volume of 5,000 FEUs per year in 66 of the 81 scenarios, with an average volume of 5,811 FEUs and a standard deviation of 2,229 FEUs; assuming normality, this equates to a 64 percent probability ($z = -0.36$) that the container volume will be greater than the desired minimum volume of 5,000 FEUs. These results led us to report to QDC that we believe that the establishment of short-sea shipping service between the Port of NY/NJ and the Port of Davisville is a viable option purely from a demand standpoint.

One area that our analysis did not consider is the financial justification of investments to expand the port, such as the desired level of return on the substantial investment ($12 million) that is required to facilitate short-sea shipping at the port. QDC concluded that the potential financial payback at the estimated demand levels made internal financing of the short-sea shipping infrastructure improvements through loans or the issuance of bonds difficult to justify. However, QDC agreed that short-sea shipping would be a viable operation if the infrastructure investment costs could be mitigated. To alleviate the financial burden of the needed infrastructure improvements, QDC submitted a request for grant funds from the Federal Transportation Investment Generating Economic Recovery (TIGER) program in the fall of 2009. The demand estimations and findings of this research study, which QDC included in its proposal, were a major factor in justifying the grant request. QDC’s application was favorably reviewed; in the spring of 2010, it was awarded a $22.3 million grant, $12 million of which will be used to purchase a mobile harbor crane and to strengthen the piers to support the crane’s operations (the additional $10.3 million dollars will be used to fund a variety of infrastructure improvements to ensure the long-term viability of the port). Although over 1,400 organizations submitted TIGER fund requests, QDC was one of only 50 organizations that were awarded grants (Columbia Coastal Transport, LLC 2010). As of May 2012, the port has ordered a multiuse crane that it expects to have operating by the end of summer 2012. The crane will have the capacity to handle approximately 41,600 containers annually when operating eight hours per day, five days per week. A short-sea shipping marine carrier has already begun marketing the new service to potential shippers and is planning to launch the service between Davisville and the Port of NY/NJ when the crane becomes operational.

Conclusions

This study can serve as a successful example of collaboration between academia and the public sector. As previously discussed, numerous studies conducted over the previous 30 years failed to objectively assess the demand for new services at the Port of Davisville. To address this issue, QDC approached this academic team to conduct an unbiased, scientific analysis of the potential demand for container services at the port. The results helped to justify QDC’s successful TIGER grant application.

Although our optimization approach does not consider every intricacy of the import shipping industry, we feel that the demand estimations are robust enough to confidently support short-sea shipping as the only potentially viable expansion option. Further boosting our confidence is that the capacity of the proposed crane will be capable of handling the demand for short-sea shipping services, even if export levels approach the level of imports and the actual demand triples beyond our estimates.

This study was not without its challenges. Collecting the transportation rate and volume data needed to construct the model was a painstaking process. Many shippers and carriers consider their rate data to be proprietary; therefore, we had to survey a number of firms to collect and verify the data used in the model. Additionally, the use of an optimization approach required significant explanation when communicating our findings to individuals who do not
have a substantial mathematical background. Finally, discussions to expand the Port of Davisville into a major seaport have been a political hot button for almost 40 years; some entities in Rhode Island tout the port as a potential source of significant revenue and job creation. Our findings, which do not support the massive expansion, were not well received by some of these entities. Several studies (Martin Associates 2011, Reeve and Associates 2010), which were conducted after our research, predict much higher volumes than our study; however, none of these counterstudies uses an OR approach to justify its predictions.

Appendix A. Cost Optimization Network Models

The transportation cost (TC) optimization network models are solved to determine the lowest cost hinterland transportation path to the customer from a port of entry for each container.

Model 1: International Port of Entry Model

Indices

- \( i \) parameter used for a port of entry, \( i \in I \).
- \( j, \alpha, \beta \) parameters used for transshipment points, \( j, \alpha, \beta \in J \).
- \( k \) parameter used for a customer, \( k \in K \).

Parameters

- \( c_{ijT} \) transportation cost by truck (T) from port of entry \( i \) to transshipment point \( j \).
- \( c_{a\beta m} \) transshipment cost from transshipment point \( \alpha \) to transshipment point \( \beta \) (\( \alpha \neq \beta \)) via mode \( m \) (\( m \in \{R\} \)), \( R \) = rail.
- \( c_{jkT} \) transportation cost by truck (T) from transshipment point \( j \) to customer \( k \).
- \( S \) total FEUs of the container traffic volume in 2008 Manifest Journals database from the 22 largest ports of entry in the United States.
- \( d_k \) total number of FEUs to customer \( k \).

Decision Variables

- \( x_{ijT} \) FEUs shipped by truck (T) from port of entry \( i \) to transshipment point \( j \).
- \( y_{jkT} \) FEUs shipped by truck (T) from transshipment point \( j \) to transshipment point \( k \).
- \( t_{a\beta m} \) transshipped FEUs between two transshipment points \( \alpha \) and \( \beta \) (\( \alpha \neq \beta \)) via mode \( m \) (\( m \in \{R\} \)), \( R \) = rail.
- \( s_i \) total number of FEUs at port of entry \( i \).

In this model, we estimate the potential import container volume that would pass through the Port of Davisville if it were a direct international port of entry. We include the 22 largest container ports of entry in the United States and the Port of Davisville as ports of entry; hence, \(|I| = 23\). The model also contains 158 transshipment nodes, \(|J| = 158\), which include 135 intermodal rail yards and 23 dummy nodes used as transshipment points at each port of entry. These dummy nodes allow for the container to be shipped directly via truck from the port of entry to customers without rail transshipment at a cost \( c_{ijT} = 0 \) when \( i \) and \( j \) are the same location.

Objective Function

Minimize \[
TC = \sum_{i} \sum_{j} c_{ijT} x_{ijT} + \sum_{\alpha} \sum_{\beta} c_{a\beta m} t_{a\beta m} + \sum_{j} \sum_{k} c_{jkT} y_{jkT}
\]
\[
\text{s.t. } S = \sum_{i=1}^{23} s_i, \quad (A1)
\]
\[
s_i = \sum_{j} x_{ijT}, \quad \forall i \in I, \quad (A2)
\]
\[
\sum_{j} x_{ijT} = \sum_{k} y_{jkT} - \sum_{\alpha} \sum_{\beta} t_{a\beta m}, \quad m \in \{R\}, \quad \forall j \in J, \alpha, \beta \in J, \text{ and } \alpha \neq \beta, \beta \neq j, \quad (A3)
\]
\[
d_k = \sum_{j} \sum_{k} y_{jkT}, \quad \forall k \in K, \quad (A4)
\]
\[
x_{ijT}, y_{jkT} \geq 0, \quad \forall i \in I, \forall j \in J, \quad (A5)
\]
\[
t_{a\beta m} \geq 0, \quad \alpha, \beta \in J, \text{ and } \alpha \neq \beta, \beta \neq j, \quad (A6)
\]

The model minimizes the total costs of shipping by truck and rail from the international ports of entry (including Davisville) through the various transshipment points and ultimately to the customer. Constraint (1) describes that \( \sum_{i} s_i \) must equal \( S \) where \( S \) is the total FEUs of the container traffic volume from the largest 22 ports of entry in the 2008 Manifest Journals database. Constraint (2) represents the inflow and outflow balance in the ports of entry. Constraint (3) represents the inflow and outflow balance for each transshipment point \( j \). It is modeled such that the shipment from \( j \) to all \( k \) customers is equal to the sum of all shipment received by \( j \) from all ports \( i \) and all transshipment points \( (\alpha) \) less flows from \( j \) to other transshipment points \( (\beta) \). Note that \( \alpha \) represents all transshipment points sending containers to \( j \) and \( \beta \) represents transshipment points receiving containers from \( j \). Constraint (4) states that the total of all inflows to customer \( k \) has to equal its actual demand \( d_k \). The last two constraints are nonnegativity constraints for the decision variables.

Model 2: Short-Sea Shipping Model

The short-sea shipping model retains all the nodes from Model 1. This model differs from Model 1 in the following ways.

1. The Port of Davisville is a short-sea shipping port, not an international port of entry; thus, \(|I| = 22\).
2. Rail (R) and water (W) may both be used for trans-shipment between the ports of entry and Davisville; hence, \( m \in \{R, W\} \).

3. \( s_i \) is no longer a decision variable. We set each \( s_i \) to the actual import FEU volume at port of entry \( i \) from the 2008 Manifest Journals database.

### Objective Function

Minimize

\[
TC = \sum_i \sum_j c_{ij} x_{ijT} + \sum_a \sum \beta c_{abm} t_{abm} + \sum_j \sum_k c_{jkt} y_{jkt}
\]

s.t. \( s_i = \sum_j x_{ijT}, \quad \forall i \in I \) \hfill (A7)

\[
\sum_i x_{ijT} = \sum_k y_{jkt} - \sum_a l_{ajm} + \sum_a l_{bjm}, \quad m \in \{R, W\}, \quad \forall j \in J, \quad \alpha, \beta \in J, \quad \alpha \neq j, \quad \beta \neq j
\]

\[
d_k = \sum_j y_{jkt}, \quad \forall k \in K \] \hfill (A8)

\[
x_{ijT}, y_{jkt} \geq 0, \quad \forall i \in I, \quad \forall j \in J
\]

\[
l_{ajm}, l_{bjm} \geq 0, \quad \alpha, \beta, j \in J, \quad \alpha \neq \beta, \quad \beta \neq j
\]

### Appendix B. Sensitivity Analysis Regression Model

The regression model examines the impact of transportation rate and fuel price changes on the demand for short-sea shipping services between the Port of NY/NJ and the Port of Davisville. The model formulation is detailed below:

\[
y = b_1 + b_2 BL + b_3 BH + b_4 TL + b_5 TH + b_6 RL + b_7 RH + b_8 FL + b_9 FH,
\]

where

\( y \) = annual volume of NY/NJ to Davisville short-sea service;

\( BL \) = indicator equal to 1 when short-sea rates are reduced by 10 percent from the base rate;

\( BH \) = indicator equal to 1 when short-sea rates are increased by 10 percent from the base rate;

\( TL \) = indicator equal to 1 when truck rates are reduced by 10 percent from the base rate;

\( TH \) = indicator equal to 1 when truck rates are increased by 10 percent from the base rate;

\( RL \) = indicator equal to 1 when rail rates are reduced by 10 percent from the base rate;

\( RH \) = indicator equal to 1 when rail rates are increased by 10 percent from the base rate;

\( FL \) = indicator equal to 1 when the diesel fuel spot price is $2.02 per gallon;

\( FH \) = indicator equal to 1 when the diesel fuel spot price is $4.76 per gallon.

Note that indicator variable values of zero represent the initial transportation rates (i.e., the rates are not discounted or increased) and a base diesel fuel spot price of $2.86 per gallon.

### Acknowledgments

We thank the editorial staff and reviewers for their comments and suggestions, which have substantially improved this paper. We also thank the University of Rhode Island Transportation Center for its support of our research effort and Evan Matthews, the director of the Port of Davisville, for his invitation that led us to collaborate with the Quonset Development Corporation on this project.

### References


Columbia Coastal Transport, LLC (2010) Increasing the use of the marine highway Rhode Island–NY–NJ. Presentation, Rhode Island State Port Commission, February 24, Providence, RI.


Quonset Point Partners, LLC (1999) World class intermodal transportation facility: Quonset Point, Davisville, Rhode Island, Report, Quonset Point Partners, LLC, Davisville, RI.


Verification Letter

Evan H. Matthews, port director, Quonset Development Corporation, North Kingstown, RI, writes:

“I am writing on behalf of the Quonset Development Corporation (QDC) to verify our involvement in the demand estimation study performed by Dr. Kroes, Dr. Chen, and Dr. Mangiameli. QDC manages the Port of Davisville, which offers 6,800 linear feet of berthing space, consisting of two piers (each 1,200 feet in length), a bulkhead, 35-ft. channel draft, on-dock rail, and a 70-acre laydown area.

“QDC sought an academic partner in an attempt to accurately estimate the potential demand for containerized freight services at the Port of Davisville. This partnership was driven by our suspicion that previous studies concerning expansions at the Port of Davisville lacked rigor and objectivity.

“QDC is extremely pleased with the outcome of this study. For the first time, we believe that we have an accurate understanding of the potential market demand for containerized freight services at the port. Further, the findings of this study were an integral part of our successful request for federal TIGER (Transportation Investment Generating Economic Return) grant funds that resulted in an award of $22.3 million for the Port of Davisville. QDC is currently using a portion of these funds to develop the Port of Davisville’s infrastructure to allow the port to handle containerized cargo and engage in short-sea shipping. We expect scheduled container freight services to commence in 2012.

“Please contact me at (401) 295-0044 extension 237 with any additional questions about the project.”

James R. Kroes is an assistant professor in the Department of Information Technology and Supply Chain Management at Boise State University’s College of Business and Economics. Prior to coming to Boise State, Dr. Kroes was assistant professor in supply chain management at the University of Rhode Island. He earned his PhD and master’s at Georgia Institute of Technology and his undergraduate degree at Rensselaer Polytechnic Institute. His research interests include sustainable operations management, manufacturing and service outsourcing, and transportation optimization. Dr. Kroes has authored a number of papers and is a member of a number of professional organizations, including Decision Sciences Institute and the Production and Operations Management Society.

Yuwen Chen currently is an assistant professor of supply chain management at the University of Rhode Island. His interest and curiosity is inspired by observing changes in life then contemplating the solutions to react the changes. He teaches operations and supply chain management and transportation at the university. He brings live business examples to the classroom and connects to the theory that it applies. He encourages students to understand the complexity and interconnectivity of the business world. His research papers are shown in the areas of new product development, operations and supply chain management, logistics and transportation, and business mindfulness. Yuwen is also interested in technology’s impact to business, mobile technology, sustainability, and business responsibilities. His publications are shown in the journals of Production and Operations Management, Decision Sciences, Journal of Business Research, and European Journal of Operations Research.

Paul Mangiameli is a professor of operations and supply chain management in the College of Business Administration of the University of Rhode Island where he has taught for the past 36 years. Dr. Mangiameli received his Bachelor of Science (1972) and Master of Business Administration (1974) degrees from New York University and his Doctor of Philosophy (1979) from the Ohio State University. Dr. Mangiameli’s teaching interests are in the areas of operations management and supply chain management. He teaches at the undergraduate, master, and doctoral levels. He has published in journals such as Decision Sciences, European Journal of Operational Research, Decision Support Systems, Omega, Interfaces, Computers and Operations Research, International Journal of Production Research, Journal of Operations Management, Journal of Business Research, and International Journal of Quality and Reliability Management.