Estimating Demand for Container Freight Service at the Port of Davisville

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Cover Letter:

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Dear Interfaces Editorial Board Members,

We are submitting our paper titled “Estimating Demand for Container Freight Service at the Port of Davisville” for possible review at Interfaces.

In this paper, we discuss a project in which we partnered with the Port of Davisville (located at Quonset Point, Rhode Island) to examine the viability of several proposals to expand the port’s operations to include the handling of containerized cargo. The findings of this study were included by the port’s managing organization (the Quonset Development Corporation) in their request for federal TIGER (Transportation Investment Generating Economic Recovery) grant funds that resulted in an award of $22.3 million to support the development of short-sea container freight shipping at the Port of Davisville.

We sincerely thank you for your kind consideration of our work. We are excited about our paper and hope we will be given an opportunity to address any comments the review team may have.

Sincerely,

James Kroes (Corresponding Author)
ABSTRACT

The Port of Davisville, located at Quonset Point, Rhode Island, is a former U.S. Navy facility that was turned over to the state for commercial development when the naval base was 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 such proposals: (i) a major expansion to become an international container megaport, (ii) a lesser investment to become a regional international port of entry for containers, and (iii) a minor expansion to become a short-sea shipping container port. This study's demand estimation was used successfully by QDC in their request for federal TIGER (Transportation Investment Generating Economic Recovery) grant funds that resulted in an award of $22.3 million to support the development of short-sea container freight shipping services at the Port of Davisville.

Keywords

Port usage demand, demand analysis, optimization, short-sea shipping
The Port of Davisville, located at Quonset Point, Rhode Island, is a former U.S. Navy facility that was turned over to the state for commercial development when the naval base was closed in 1974. The port has evolved into an import location for foreign automobiles; importing over 100,000 vehicles in 2010. However, the port still has excess capacity available to handle additional types of cargo. A number of plans to utilize this capacity and expand the port’s activities to include the handling of containerized cargo, dating as far back as 1973, have been proposed by a variety of state agencies. These proposals fall into three categories (i) a major expansion to become an international container megaport, (ii) a lesser investment to become a regional international port of entry for containers, and (iii) a minor expansion to become a short-sea shipping container port.

The Port of Davisville’s managing organization, the Quonset Development Corporation (QDC), has a mandate to develop the port facilities in a manner that maximizes the positive economic impact on the state of Rhode Island. In light of the wide range in the scope of the container freight proposals for the port, QDC partnered with this academic research team to objectively analyze the viability of the various port expansion proposals. To evaluate these expansion proposals, QDC first needed to understand the potential demand and the sensitivity of that demand to market pressures. QDC felt that a firm understanding of the demand for container freight services was the critical step in justifying any expansion plans.

In the next section, we discuss the motivation of the problem examined in this study. The third section details methodology, including the formulation of the specific models used to examine this problem and the results. We next present the managerial implications and outcome of this research project. The final section of the paper discusses the conclusions drawn from this project.
Motivation

The first major study that examined shipping containerized traffic through Davisville was conducted in 1973 (State of Rhode Island 1973); this study analyzed the demand for a container terminal and recommended the construction of an international container megaport at the Port of Davisville for a cost of $110 million (1973 dollars). Additional reports also suggest the development of a megaport at Davisville, with annual usage demand projections ranging from one million to 1.7 million containers (expressed in FEUs - Forty-Foot Equivalent Unit containers) requiring infrastructure and dredging investments ranging from $698 million to $974 million dollars (RIEDC 1998 and 1999, QDPCA 1999a and 1999b). 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 requiring investments ranging from $266 million to $354 million dollars (RIEDC 2000 and 2001).

More recent attention has focused on configuring Davisville as a short-sea shipping port in an East Coast Marine Highway system. In the U.S., 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, MA to Miami, FL), Interstate 10 (from Brownsville, Texas to Tampa, Florida), and the Pacific coast (from Seattle, WA to San Diego, CA) (Brooks, Hodgson, and Frost 2006, MARAD 2010, Texas Transportation Institute 2007, U.S. GAO 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 (interview with E. Matthews 2010). Additionally, during discussions with the port's management, we learned that a potential marine carrier would only consider developing short-sea shipping services to Davisville on shipping lanes where the expected container volume was
greater than 5,000 FEUs per year. At the initiation of this study, no studies into the viability of using the Port of Davisville as a short-sea shipping port had been conducted.

A common issue with all of these studies, which is a driving factor in QDC’s pursuit for this research, is that none of them included demand estimations based on scientific forecasting methodologies. Their estimates were either based on unspecified estimation techniques, predictions that any added capacity to handle containerized goods will automatically be fully utilized, or assumptions that all freight volume within the region would shift from competing ports and utilize the expanded port facilities without consideration of cost differences between the modes. 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 utilizing other transportation modes.

**Methodology and Results**

We utilize a flexible network optimization model to evaluate various options for containerized service at the Port of Davisville. Our method combines approaches used in previous academic studies in which a general network optimization model is created and then tailored to model specific scenarios of interest (Karabakal, Günal, and Ritchie 2000, Leachman 2008, Sery, Presti, and Shorbys 2001, Fan, Wilson, and Tolliver 2010). Our model is populated with actual freight volume and cost data and then solved to determine the optimal modes, costs, and volumes of freight flows through ports. Two versions of the model are utilized to examine the three proposed expansions at the port. We first utilize an “International Port of Entry” version of the model in which Davisville is configured as an international port of entry to examine the port’s viability as a container megaport and as a regional international port of entry for containers. Next we examine a “Short-Sea Shipping” version of the model in which Davisville is configured as a
potential short-sea shipping destination for international containerized freight that enters the United States at a major east coast port of entry before being shipped to Davisville. After screening the three proposed options, we then examine the sensitivity to market fluctuations of options deemed potentially viable. In all of the analyses, we assume that customers importing freight in marine containers choose the optimal (lowest cost) transportation solution from the port of entry to the final destination. Further, we consider only the domestic transportation costs incurred after a container arrives at the port of entry and do not consider potential cost differences in the international transportation costs. Under these assumptions, we estimate the total demand potential of the proposed investment options by cost optimizing a network model representing the port expansion option of interest.

When conducting this study, we focus only on the demand of imported international marine containers. This decision was driven by comments made by potential marine carriers; one carrier’s representative stated that due to the significant trade imbalance in the New England region, his organization would only consider establishing service to the Port of Davisville if the level of international imports alone was sufficient to justify the service. The carrier felt that imported containers represent a more reliable revenue source compared to exported goods. To reflect this approach, all of the rates used in the analysis reflect the costs of transporting a single full import FEU container to its destination.

Network Model Design
To conduct our study, we constructed a network model representing the possible multimodal transportation options available to move containerized freight from the port of entry to the final destination. The model includes sea, rail, and highway nodes and links within the continental United States relevant to our area of study which allow us to examine the cost optimized
intermodal transportation solutions for various options investigated in this study (a detailed mathematical description of the model is included in the Appendix.) The model was created using Insight, Inc.’s SAILS v.4.5 strategic supply chain modeling software program.

The model includes nodes for the top 22 largest ports (ranked by 2008 total loaded goods in FEUs) for international import containerized traffic into the continental United States. During 2008, 97.3% of all containerized imports into the U.S. passed through these 22 ports (U.S. Army Corp of Engineers 2008). The model also includes nodes for 22 additional domestic ports (the next 21 largest U.S. ports and the Port of Davisville) that may potentially be utilized in a short-sea shipping network. Nodes representing rail intermodal yards were added to the model (where present in actuality) to facilitate the modeling of container transportation via rail. To identify the rail nodes, we examined the published locations of all intermodal rail yards operated by the five Class 1 U.S. railroads, which resulted in 135 intermodal yard nodes in the model (rail yards located within the same five digit zip code were combined into a single node.) Nodes representing water or rail to truck transfer points were incorporated at all port and rail yard locations.

Links between the nodes were created in the model to represent the actual linkages present in the United States. Highway links were established between all ports, intermodal yards, and customers automatically by the software program’s inherent highway system database, which also 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.
To reduce the complexity and improve the tractability of the model, we assumed that all shipments in our model would be made using standard forty-foot international shipping containers (FEUs), 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 forty-foot shipping container.

**Data Collection**

To conduct this study, we first needed to identify the demand sources for international import container shipments and the rates associated with transporting those container shipments. We collected international import container data to capture the demand levels for containerized goods at the customer locations in the model. We chose to conduct the study utilizing year 2008 data, as 2008 represented the most recent year of complete data at the time that this research was initiated.

Container import data for the year 2008 was collected using the *Manifest Journals* database system. This database captures and summarizes data from the U.S. Customs and Border Patrol’s Automated Manifest System (AMS) which tracks the waybill and manifest information for every good imported into the United States (U.S. CBP 2010). For the 22 international ports of entry in the model, 410,306 individual records tracking full container shipments were collected to estimate the customer demand in the model. Each individual record details the port of entry, the consignee’s five digit zip code, and total volume of the shipment in FEUs. The freight volume of 5,460,870 FEUs included in the model represents 67% of the total imports for 2008 into the United States’ 22 major ports of entry. The remaining 33% of shipments are less than full container load shipments that are not included in the data as these shipments are typically removed from their import containers near the port of entry. Individual domestic demand points
for containers (henceforth referred to as “customers”) were created within zip code areas across the U.S. by aggregating the volumes of all container shipments to the consignees located in a specific zip code from each international port of entry. The customer demand was consolidated by three-digit zip codes, except in the area surrounding the Port of Davisville; in this region, individual customer locations were created 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.

The transportation rate data used in the model was collected from various sources, including published rate tables and interviews with shippers and carriers. The base rail transportation rates were based on the intermodal rate tables published by Class 1 railroads operating in the U.S. A fixed base charge and variable per mile per FEU rate was estimated using a regression analysis of the published Class 1 intermodal rail rates. The accuracy of the base rail rates was validated through an interview with a manager at a Class 1 rail carrier. The truck transportation base 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 through an interview with an operations manager at a trucking carrier. The base rates for the proposed short-sea shipping services were determined through interviews with a potential marine carrier; the short-sea rates include the port fees and lift charges at both ends of the service.

The total rate for each transportation mode is calculated as the sum of the mode’s base rate (dependent on the point to point distance) plus an additional fuel surcharge tied to the current average diesel fuel spot price in the United States. We examined the diesel fuel spot prices in the United States for the five-year period prior to the initiation of the analysis to
determine which price levels would be tested in our study. We found that the diesel fuel spot price at the initiation of the study was $2.86/gallon, which closely corresponded to the five year average spot price of $2.88/gallon (U.S. EIA 2010). This led us to choose three sets of rates, LOW, MEDIUM, and HIGH, equivalent to the base rates plus the appropriate fuel surcharge for the transportation mode, charged by the rail, truck, and sea carriers at diesel spot prices of $2.86/gallon, $2.02/gallon (the five year low), and $4.76/gallon (the five year high) respectively.

**Model Analyses and Results**

We first investigated the options of expanding Davisville to serve as a megaport or a regional international port by analyzing a port selection model that estimates the theoretical maximum annual international import container volume that would optimally flow through the Port of Davisville. The base model is structured so that container imports are assigned to the port of entry listed in the waybill, but in order to determine the theoretical maximum volume we remove this assignment constraint and allow each of the 5,460,870 containers (FEUs) to be reassigned to the port of entry that results in the lowest inland transportation costs. Three scenarios, representing the three sets of carrier rates discussed in previous paragraph, were tested. All models were solved using SAILS’ Optima Modeling System v10.07.19 running on a Windows XP laptop operating a 2.4 GHz Intel Core 2 Duo processor. The solution generation time averaged 3.5 minutes.

The results find 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 if it were used as an international port of entry. The geographic area served by Davisville in all three scenarios, depicted in Figure 1 for the MEDIUM rates would extend from the middle of Connecticut, through Rhode Island, to southeastern Massachusetts. This analysis indicates that
Figure 1: The results of the “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 due to the port’s geographic positioning between the Port of New York / New Jersey and the Port of Boston.

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 predicted container volume does not justify the infrastructure investments required to upgrade the Port of Davisville into an international megaport (1 to 1.7 million FEUs) or a regional international port of entry (75,000 to 100,000 FEUs).

Next, we investigated the potential demand for short-sea container service between the international ports of entry and the Port of Davisville. To model this scenario, we reconfigure Davisville to act only as a short-sea shipping port. The model was again solved to optimize the
total costs from the ports of entry to the customer location for each of the three the sets of transportation rates.

The results of the initial short-sea shipping analysis predict 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 through the Port of Davisville to reach their destinations. These containers originate from ten of the international ports of entry; however the majority of these containers originate at the Port of NY/NJ (6,308 FEUs [78%] at the LOW rates, 7,034 FEUs [81%] at the MEDIUM rates, and 6,964 FEUs [81%] at the HIGH rates). In all three scenarios, next highest volume of 577 FEUs 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 FEU) for import containers into the Port of Davisville originates at the Port of NY/NJ. As shown in Figure 2, the geographic area served by the Port of Davisville as a short-sea shipping port includes central and northern Rhode Island and southeastern Massachusetts.

We then 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 prediction to fluctuations in transportation rates at 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 transportation rates (-10%, 0%, and +10%) at the LOW, MEDIUM, and HIGH transportation rates. These sensitivity choices result in 81 unique scenarios (i.e. all combinations of the 3 pricing levels for each of the three modes at each of the three diesel spot prices [3^3 x 3]), including the three scenarios already tested, that are solved to evaluate the robustness of our results. We include only the 855,957 containers (FEUs) entering the United States through the Port of NY/NJ in these 81 model runs. The results of the sensitivity analyses predict a mean and median annual container volume of 5,811 FEUs and 6,738 FEUs respectively for NY/NJ to Davisville short-sea service. The maximum annual container volume is predicted to be 7,748 FEUs. The sensitivity analysis also found that the demand exceeded the desired minimum volume of 5,000 FEUs / year in 66 of the 81 scenarios. The short-sea service was not utilized (i.e. the annual volume = 0 FEU) in six of the 81 scenarios. In each of these six scenarios, at least one of the competing modes’ rates (rail or truck) was discounted relative to the short-sea shipping mode’s rate.

We utilized the results of the 81 scenarios to build a post-hoc regression model. The regression model allows us to further examine the sensitivity of the demand for port services to
changes in the various rates. The model was constructed with the short-sea service volume 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. 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 / gallon. The regression model
formulation is detailed below:

\[ y = b_0 + b_1BL + b_2BH + b_3TL + b_4TH + b_5RL + b_6RH + b_7FL + b_8FH \]

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% from the base rate
- \( BH \) = indicator equal to 1 when short-sea rates are increased by 10% from the base rate
- \( TL \) = indicator equal to 1 when truck rates are reduced by 10% from the base rate
- \( TH \) = indicator equal to 1 when truck rates are increased by 10% from the base rate
- \( RL \) = indicator equal to 1 when rail rates are reduced by 10% from the base rate
- \( RH \) = indicator equal to 1 when rail rates are increased by 10% from the base rate
- \( FL \) = indicator equal to 1 when the diesel fuel spot price is $2.02 / gal
- \( FH \) = indicator equal to 1 when the diesel fuel spot price is $4.76 / gal

The regression results, detailed in Table 1, show that the resulting model significantly
predicts the expected demand for the short-sea service (\( F = 18.9, p < 1\% \)). An examination of the
coefficients of the independent 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% decrease in the short-sea rate, a 10% increase in trucking rate, and an increase in
the diesel fuel spot price to $4.76 / 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%
increase in the short-sea rate, a 10% decrease in trucking rate, and a decrease in the diesel fuel
spot price to $2.02 / gallon are each significantly associated with lower demand for the short-sea
Table 1: A regression analysis of the results of the 81 models tested in our sensitivity analysis finds that the demand for short-sea shipping at Davisville is significantly impacted by pricing changes in the short-sea and truck rates and fluctuations in the diesel spot price.

service. We also found that changes in the rail rates of +10% and -10% 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 both 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 investment required to facilitate either option was not justified by the demand level.

Next, we examined if utilizing the port for short-sea shipping was a viable strategy and found one service lane potentially feasible in our case (short-sea shipping between NY/NJ and Davisville). The sensitivity analysis of the NY/NJ short-sea shipping service found that the demand exceeded the desired minimum volume of 5,000 FEUs / year in 66 of the 81 scenarios with an average volume of 5,811 FEUs and a standard deviation of 2,229 FEUs (which assuming normality, equates to a 64% probability, $z$ score $= -0.36$, that the container volume will be greater than the desired minimum volume of 5,000 FEUs). These results lead 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.

Our analysis does not consider financial factors, 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 predicted demand levels made internal financing of the short-sea shipping infrastructure improvements through loans or the issuance of bonds difficult to justify. However, QDC did agree that short-sea shipping would be a viable operation if the infrastructure investment costs could be mitigated. In an attempt to alleviate the financial burden of the needed infrastructure improvements, QDC submitted a request for Federal TIGER (Transportation Investment Generating Economic Recovery) grant funds in the Fall of 2009. The demand estimations and findings of this research study were included in their proposal and were a major factor in the justification for the grant request. QDC’s application
was favorably reviewed and in the Spring of 2010 they were awarded a $22.3 million grant to support infrastructure improvements at the Port of Davisville. While over 1,400 organizations submitted TIGER fund requests, QDC was one of only 50 organizations that were awarded grants (Columbia Coastal Transport, LLC 2010). The TIGER funds relieved QDC of the burden of internally financing the expected $12 million expenditure. They are currently using a portion of the funds to purchase a multiuse crane and upgrade the port’s infrastructure to facilitate short-sea shipping. As of the Summer of 2011, discussions are currently underway with carriers to begin short-sea container service between the Port of NY/NJ and the Port of Davisville upon completion of the infrastructure improvements.

**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, the QDC approached this academic team to conduct an unbiased, scientific analysis of the potential demand for container services at the port, the results of which helped justify QDC’s successful TIGER grant application.

The flexible methodology utilized in this study, adapted from previous research efforts, can easily be used to estimate the demand levels at other port locations and for other freight types. Further, the optimization analysis could also be adapted to examine other objectives such as delivery time.
References


Appendix

Two versions of the model are utilized to examine the three proposed expansions at the port. The transportation cost (TC) optimization model incorporates three modes of container transportation from the international ports of entry to the customer locations (via truck, rail, and short-sea shipping). The model structure incorporates nodes representing ports of entry, transship points (intermodal rail yards, short-sea shipping ports and truck transfer points), and customers and links between these nodes where present in reality. The model is solved to determine the lowest transportation cost path from the port of entry to the customer for each container; the lowest cost path may be an intermodal solution using a combination of the modes.

International Port of Entry Version:

In this version, the Port of Davisville is a competing port of entry for international import containers and short-sea shipping is not available for transshipment.

minimize $TC = \sum_i \sum_j c_{gt} x_{gi} + \sum_\alpha \sum_\beta c_{\alpha\beta} t_{\alpha\beta} + \sum_j \sum_k c_{jk} y_{jk}$

s.t. $s_i = \sum_j x_{gi}, \forall i \in I$

$\sum_i x_{gi} = \sum_k y_{jk} - \sum_\alpha t_{\alpha j}, \forall j \in J, \alpha, \beta \in J$, and $\alpha \neq j, \beta \neq j$

$d_k = \sum_j y_{jk}, \forall k \in K$

$x_{gi}, y_{jk}, t_{\alpha j} \geq 0, \forall i \in I, \forall j \in J$

$t_{\alpha j} \geq 0, \alpha, \beta \in J$, and $\alpha \neq \beta$
**Short-Sea Shipping Version:**

In this version, the Port of Davisville operates as a short-sea shipping port for transshipped international import containers.

\[
\text{minimize } \text{TC} = \sum_i \sum_j c_{ijT} x_{ijT} + \sum_\alpha \sum_\beta \sum_m c_{\alpha \beta m} t_{\alpha \beta m} + \sum_j \sum_k c_{jkT} y_{jkT}
\]

s.t. \[
\sum_j x_{ijT} = \sum_k y_{jkT} - \sum_\alpha \sum_\beta \sum_m t_{\alpha \beta m}, \ m \in \{R,W\}, \ \forall j \in J, \ \alpha, \beta \in J, \ \text{and } \alpha \neq j, \beta \neq j
\]

\[
d_k = \sum_j y_{jkT}, \ \forall k \in K
\]

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

\[
t_{\alpha \beta m} \geq 0, \ m \in \{R,W\}, \ \alpha, \beta \in J, \ \text{and } \alpha \neq \beta
\]

**Decision Variables**

- \(x_{ijT}\) is FEUs shipped by truck (T) from port of entry \(i (i \in I)\) to transshipment point \(j (j \in J)\)
- \(y_{jkT}\) is FEUs shipped by truck (T) from transshipment point \(j (j \in J)\) to a customer \(k (k \in K)\)
- \(t_{\alpha \beta m}\) is the transshipped FEUs between two transshipment points \(\alpha\) and \(\beta (\alpha \neq \beta)\) via mode \(m (m \in \{R,W\})\), R=Rail, W=Water
- \(t_{\alpha \beta R}\) is the transshipped FEUs between two transshipment points \(\alpha\) and \(\beta (\alpha \neq \beta)\) via Rail (R)

**Parameters**

- \(c_{ijT}\) is the transportation cost by truck from port of entry \(i (i \in I)\) to transshipment point \(j (j \in J)\)
- \(c_{\alpha \beta m}\) is the transshipment cost from transshipment point \(\alpha\) to transshipment \(\beta (\alpha \neq \beta)\) via mode \(m (m \in \{R,W\})\), R=Rail, W=Water
- \(c_{\alpha \beta R}\) is the transshipment cost from transshipment point \(\alpha\) to transshipment \(\beta (\alpha \neq \beta)\) via Rail (R)
- \(c_{jkT}\) is the transportation cost from transshipment point \(j (j \in J)\) to customer \(k (k \in K)\)
- \(s_i\) is the total number of FEUs from port of entry \(i (i \in I)\)
- \(d_k\) is the total number of FEUs to customer \(k (k \in K)\)
Founded in 1892, the University of Rhode Island is one of eight land, urban, and sea grant universities in the United States. The 1,200-acre rural campus is less than ten miles from Narragansett Bay and highlights its traditions of natural resource, marine and urban related research. There are over 14,000 undergraduate and graduate students enrolled in seven degree-granting colleges representing 48 states and the District of Columbia. More than 500 international students represent 59 different countries. Eighteen percent of the freshman class graduated in the top ten percent of their high school classes. The teaching and research faculty numbers over 600 and the University offers 101 undergraduate programs and 86 advanced degree programs. URI students have received Rhodes, Fulbright, Truman, Goldwater, and Udall scholarships. There are over 80,000 active alumnae.

The University of Rhode Island started to offer undergraduate business administration courses in 1923. In 1962, the MBA program was introduced and the PhD program began in the mid 1980s. The College of Business Administration is accredited by The AACSB International - The Association to Advance Collegiate Schools of Business in 1969. The College of Business enrolls over 1400 undergraduate students and more than 300 graduate students.

**Mission**

Our responsibility is to provide strong academic programs that instill excellence, confidence and strong leadership skills in our graduates. Our aim is to (1) promote critical and independent thinking, (2) foster personal responsibility and (3) develop students whose performance and commitment mark them as leaders contributing to the business community and society. The College will serve as a center for business scholarship, creative research and outreach activities to the citizens and institutions of the State of Rhode Island as well as the regional, national and international communities.

The creation of this working paper series has been funded by an endowment established by William A. Orme, URI College of Business Administration, Class of 1949 and former head of the General Electric Foundation. This working paper series is intended to permit faculty members to obtain feedback on research activities before the research is submitted to academic and professional journals and professional associations for presentations.

An award is presented annually for the most outstanding paper submitted.