Analysis of Containerized Freight Shipments into the U.S. -Port Choice and Inland Optimization

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THESIS

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SUMMARY

This dissertation focuses on the behavior analysis of international container freight into the U.S., and on the collection and manipulation of imported containerized shipment record data to help in the development of the model and for use in scenario analysis. The model designed as choice models estimated shipment's port choice behaviors between international trading partner countries and states in the U.S. under the intermodal freight framework. This is as opposed to or extended from the previous approach of aggregated optimization simulations or partial choice behavior analysis. The estimated port choice model allowed much deeper scope of freight demand management and facility enhancement policies to be evaluated, as compared to currently used approaches. Also optimization model is estimated to analyze overall freight flow into the U.S. in case of capacity expansions. This dissertation considered two capacity expansions on the Panama Canal and the port of Prince Rupert in Canada. Both models and its implications on freight flow into the U.S. demonstrated significant attributes for choosing ports and distributional changes in the U.S.

INTRODUCTION

The recent economic recession has seen a decrease in containerized shipments in the United States. According to data published by the U.S. Department of Transportation, the recorded metric ton shipments were 233 million in 2007, 228 million in 2008, and 206 million in 2009. After 2009, theses reduced container shipment volumes have somewhat recovered and reached 101 million metric tons during the first half of 2010 exceeding the record of 94 million metric tons during the same period in 2009 (U.S. DOT, January 2011). It is especially important to note that more than half of the imported container shipments originate in Asia and then are distributed throughout the U.S. mainly by rail or truck. Since the container shipments change transportation modes at the receiving port, various factors such as dwelling time on the ocean, shipping costs, congestion expectancy, rail or trucking costs, etc. are very important to determine the best route from several alternatives.

When the path of a containerized shipment to a location in the U.S. is considered, it almost always utilizes a connection between the port and a rail or highway system. Depending on the U.S. arrival port, alternate routes would be different. Currently, the most popular connection routes are between ports on the Pacific coast and the interstate rail and/or highway systems. The second most popular connection is between ports on the Gulf coast and rail and highway systems, while the third connection is between ports in Canada and rail systems into the U.S. Through these connection ports, international trade deals between trading partner countries and the U.S. are carried out.

According to a US DOT report (January 2011), the U.S.'s primary trade partner in terms of inbound container shipments is China, which accounted for 25% of the total containers imported by volume in 2000 and 48% in 2009. Furthermore, the top five partners for containerized import trading to the U.S. in 2009 were all in Asia: China, Japan, South Korea, Taiwan, Singapore, and Hong Kong. The report also says that weights of ocean freight from these six Asian countries made up 10% of total U.S. imports between 2007 and 2010. However, the values amount to 40% of the total ocean freight values coming into the U.S. from 169 countries.

When the maritime shipments are narrowed down by the mode of containerized cargos, weights and volumes of container shipments from the six Asian countries become a significant portion of the total weights and volumes of container cargos into the U.S. Chinese shipments make up almost 40% of the weight and 50% of the volume of the total imported container shipments into the U.S. and the volumes of shipments originating in Asian countries reaches over 50%, meaning that one in two containers imported into the U.S. is from one of the six Asian countries.

From the viewpoint of the U.S. ports, the top 10 busiest ports handled more than 85% of the containerized shipments from 2007 to 2010 (US DOT, 2011). Those include five ports on the West Coast (Los Angeles, CA, Long Beach, CA, Oakland, CA, Seattle, WA, and Tacoma, WA) and five ports on the East and Gulf Coasts (New York, NY, Savannah, GA, Norfolk, VA, Houston, TX, and Charleston, SC). The two ports of Los Angeles and Long Beach handled more than 40% of the total container freight volumes that came into the U.S. and the inbound containers are distributed to destinations throughout the U.S. by rail or truck. Among them, there are smaller shares that are locally distributed by trucks from the port, but relatively voluminous containers are loaded on rail and moved through the highly populated rail route between Los Angeles (LA)/Long Beach (LB), CA and Chicago, IL. (IHS Global Insight, Inc., 2009).

Once container cargos are imported into the U.S., the containers are distributed to their local destinations by rail or truck from the port. A report from the Federal Maritime Commission in 2012 analyzed distributions of containers imported via the U.S. and Canadian ports along the Pacific coast. Due to confidentiality issues, the analysis is based on regions, not on specific ports or cities. For the same reason, container distributions from the U.S. ports on the Gulf and East Coasts are not included in the report. Container flows from Vancouver and Prince Rupert in Canada are also included, but the flows to other states are not revealed because of the data confidentiality issues.

This data is very helpful in understanding container flows in the U.S. after being delivered to the ports. Among the containers imported to the U.S. between 2007 and 2010 almost 60% of all types–weight, value, and volume–were destined for the Midwest region. The Midwest region states include Illinois, Iowa, Indiana, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Tennessee, and Wisconsin. From 2007 to 2010, container volume distributions were compared by destination region, Midwest or all other states, subdivided by port of origin in the U.S. and Canada. Overall volumes of container shipments were found to have decreased from

2007 to 2009, but have somewhat rebounded after 2010. Since the global economic recession occurred during this period in U.S. trading history, the same trend can be observed. One remarkable point is that the distribution difference in the containers imported via Los Angeles and Long Beach is not much different than the destination regions. Instead, other ports on the Pacific Coast showed differences in container distribution to destination regions. Because container distributions from Canadian ports are only revealed for Midwest regions, it is hard to determine the difference. And container distributions from the U.S. ports on the Gulf and East coasts are not yet analyzed.

Thus, considering the current trade circumstances and international containerized freight movements, it is important to find the impact of the containerized shipment on its port choice behavior and on distributions that is believed to affect economic results in the U.S. In this thesis, the data availability and feasibility for port choice behaviors into the U.S. will be investigated. Then various attributes supporting data calibration processes will be established, and factors that affect the decision processes for containerized cargo will be reviewed. Finally, port choice estimates will be analyzed from the constructed datasets, and significant variables will be identified to understand port choice behavior for containerized shipments into the U.S. Also, based on these behavioral characteristics, it will be discussed that the distribution changes of imported container freights from the ports to states by maritime network capacity increases on the Panama Canal and the port of Prince Rupert.

LITERATURE REVIEW

Freight cargos are transported in various types of modes or in combinations of them. Since researchers and authors have defined these types of movements independently, there has been discordance in the definitions, but recently international commissions have moved to codify them (Reis et al., 2013). While they result in performance differences among multi-modal transportation, several key definitions are introduced by the European Commission and United Nations as follows.

In 1997, the European Commission provided a definition for “intermodality” for clarification, and the United Nations also provided definitions for “multimodal,” “intermodal,” and “combined” transports with the same purposes. Each definition is provided as quoted to deliver its exact meaning.

“Intermodality is a characteristic of a transport system that allows at least two different modes to be used in an integrated manner in a door-to-door transport chain. In addition, intermodal transportation is a quality factor of the level of integration between different transport modes. In that respect more intermodality means more integration and complementarity between modes, which provides scope for a more efficient use of the transport system” (European Commission, 1997).

“Multimodal Transport is the carriage of goods by two or more modes of transport” (United Nations, 2001, pp. 16).

“Intermodal Transport is the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes” (United Nations, 2001, pp. 17).

“Combined Transport is the intermodal transport where the major part of the European journey is by rail, inland waterways or sea, and any initial and/or final legs carried out by road are as short as possible” (United Nations, 2001, pp, 18).

Various types of freights transportation, intermodality, multimodal, intermodal, and combined transport, are listed and described above specifying the movement combinations. Even though there are subtle differences by types, the most common concept is that multiple modes are engaged in the freight transportation procedures from the origin place to the destination. That can be a combination of surface transportation modes or of a surface and a maritime and/or an air mode. As it is discussed in the previous chapter introducing global and domestic economic condition around the U.S., this thesis will focus on the containerized freights movements into the U.S. as an intermodal transport with a combination of a maritime and a surface transportation mode.

International Freight Analysis

Global trading activities in the U.S. engage with various types of transportation modes, maritime, air, rail, and truck. Recent research has shown this country’s transportation mode share and that maritime is a dominant transportation mode for international trade

(Nealer et al., 2011). In this research, international maritime transport covered 60% of all modes including international air (less than 1%), domestic rail, and truck (14% each).

In this context, active research on international maritime freight analysis has focused on imported containerized shipments (Fan et al., 2009, 2012; Leachman, 2005, 2009). Since there are expected capacity expansions for the Panama Canal due by 2015, and the Port of Prince Rupert in Canada by 2020 (Fan et al., 2009, 2012), and port expansions are ongoing around the San Pedro Bay area where the ports of Los Angeles and Long Beach are located (Leachman, 2005), the consequent effects of the completed expansions were analyzed from various perspectives.

For the impact analysis of the Panama Canal and Prince Rupert expansions, an optimization method was applied to model how the capacity expansion will shift the routes of containerized movements into the U.S. (Fan et al., 2009). Currently, the Panama Canal experiences significant congestion and the Port of Prince Rupert hosts a lower frequency of container vessels compared to ports on the West Coast of the U.S. To predict these facility expansions' effects, container flow volume was collected from the public use Waybill data, Journal of Commerce, and U.S. Maritime Administrations. Also, transit costs and time, port charges, and vessel transfer duration at ports were taken into consideration as constraints. From these data sources, it was concluded that more import containerized freight movements into the U.S. will be assigned through the Panama Canal and the Port of Prince Rupert after the expansions. In terms of the Panama Canal's expansions, the canal's competitiveness was also analyzed based on total cost, including maritime and inland (Ungo et al., 2012). They estimated the total cost combining maritime, inland, and other related costs for international vessel shipments, and concluded that the fuel prices will be a significant factor for the canal's competitiveness. That is, shippers will be less likely to choose the route through the canal compared to alternatives when fuel prices reach a certain point where the total cost exceeds shipper's or consignee's marginal costs.

Levine et al. in 2009 suggested conducting a general containerized import freight analysis with linear optimization routing methods. Containerized freights are assigned through the maritime networks into the U.S., and the gravity model was utilized to model attraction. Data was retrieved from a provider, the PIERS (the Port Import Export Reporting Service), and also from the Carload Waybill Sample for containerized freight movements for 2003.

Elasticity analysis has been applied for the San Pedro Bay area ports (Leachman, 2004). This was conducted to find the marginal cost for container fees at ports near the San Pedro Bay, which has been effective since 2005 (The Port of Los Angeles, 2013). Leachman concluded that container fees are a significant diversion factor shifting container traffic to other ports and port fees up to $200 per 40-foot container and reduced lead time will not change traffic routes to other ports. Data from the PIERS and the World Trade Atlas were retrieved and an optimization procedure was applied to them.

A shippers' mode choice behavior analysis for international maritime shipments has been conducted in Indonesia (Arunotavanun and Polak, 2011). Collected stated preference (SP) data was obtained from an interview survey in Java, Indonesia, and shippers' mode choice behavior was estimated using the multinomial logit (MNL) and mixed MNL (MMNL) models. It was concluded that the commodity is not the only attribute affecting shipper's mode choice decision processes, and additional significant factors were found including shipping time, service quality, and schedule flexibility. Since it has been known widely that the commodity type determines transportation mode, these additionally found attributes were recommended in modeling process.

For worldwide countries, a containerized shipment assignment model was developed by Tavasszy et al. (2011). Based on two different European statistics datasets, Comtrade and Eurostat, a super-network assignment model was proposed and scenario analyses were made in terms of shipping costs and transit time changes. Annual container flows at 437 worldwide container ports with 800 maritime container liner services were modeled in a network assignment model with six different scenarios: polar cap shortcut, landbridge China-Europe, increase in inland costs, reduction of Antwerp's cost, increase in transshipment costs, and slow steaming. The calibrated results presented the model's ability predicting the annual container flows quite well transporting all countries using major and minor container ports around the world. The model estimated in this research consider shipping cost obtained from the two datasets as a main constraints after normalizing the ocean and surface transportation cost. Even though it used the cost attributes only in the model, the results described well the current freight flow around the

European maritime networks and may be applied to the network distribution around the U.S.

Intermodal Freight Analysis

In the U.S., an international trade good should be transported from a port to a destination in the import case or from an origin to a port in the export case. In the import case, choice analysis of modes between rail and truck has been researched using binary logit and probit models (Samimi et al., 2011). Based on a survey for freight companies, they concluded that the rail mode is sensitive to shipping costs and the truck mode to haul time between a port and a destination.

For export shipments, representative freight choice analysis from an origin to a port in the U.S. was proposed using an elasticity method (Oum et al., 1992). Port selection was subjected to exporters' preferences, and measured port competitiveness among alternatives. Oum found that freight demand differed by market, and noted that each market had to be individually considered due to a port's unique conditions. In 2006, port choice models using a conditional logit approach were suggested by Blonigen et al. They included trade flow in addition to port choice analysis, and used a gravity model for the trade flow estimate. As a set of data source, the National Data Center (NDC) of the Army Corps of Engineers (ACE) and the World Development Indicators data of the World Bnak were used to obtain import volumes and to estimate market size respectively. Their analysis found that transport prices and distance were very significant, and were also very elastic by shipments. In 2004, there was another port choice research publisehd

(Malchow and Kanafani, 2004). They listed alternative ports and tried to measure port competitiveness among them based on volumes and distance datasets from the Journal of Commerce and MaritimeData.com. Malchow made an assumption that vessels are in the short-term and fixed schedule, and assigned export freight shipments with conditions of differnt combinations by geographic location, commodity types, characteristics of vessel schedules, and port characteristics. The most significant attribute of a port was found as the location. Additionally, commodity and carrier types were expected to be different for the predicted market shares.

In Greece, freight mode choice analysis using stated preference data from surveys has been recently introduced. Statistical significance comparisons among variables were analyzed (Moschovou and Giannopoulos, 2012), and the authors suggested ten criteria for analyzing the mode choice process: reliability and quality of transport services, cost, damage, customer service quality, packaging size, lifetime of cargo, value, frequency, tracking availability, and loading/unloading of equipment. As an expansion of this research, Moschovou (2012) analyzed attribute relations using linear regression, and mode choice behavior between truck and rail using a binary logit model. From this research, he found that chosen attributes for mode choice behavior were different for different firm types.

A macroscopic freight traffic model framework was introduced in Germany by Müller et al. in 2012. Based on various economic and transportation datasets including Gross Domestic Product (GDP), firm types, commodity types, truck types, etc., they proposed a framework which can be applied to the scale of freight analysis in Germany. The model was designed for a large scale freight flow calculation, and scenario techniques are also applicable to forecast the freight flows based on changes in given conditions. The model development was assumed to extend the understanding of the data in relation to the description of commercial traffic based on knowledge in the existing data usage. And it was an important step in a large scale freight traffic modeling.

Another macroscopic framework for freight movements was introduced in France (Combes et al., 2012). Combes empirically assessed national-scale freight shipments over heterogeneous populations using ECHO datasets of the French disaggregate commodity flow rate between shippers and receivers. The simple economic order quantity (EOQ) was applied in this analysis, and ordinary least squares was used to estimate the theoretical EOQ model. It concluded that shipment size and transportation mode choice were in an inter-dependent relationship occurring simultaneously when decisions are made.

In Sweden, a revealed preference (RP) dataset was applied to mode choice estimates (Rich et al., 2009). Based on the datasets from FEMEX/COMVIC and VFU, a logit model was introduced and tried on decoupling shipments and agents in the choice models. The results found that the value of time varies by commodity types.

Australian researchers also estimated mode choice behavior domestically based on their web-based survey results. Brooks et al. (2012) compared choice behavior between land-based transportation modes and coastal shipping. A multinomial logit (MNL) model was proposed to estimate the results, and found that respondents preferred surface transportation modes, and may change to short sea shipping mode when integrated service and/or carbon pricing exist. Also, using time, cost, and punctuality of freight service attributes in Australia, risk attitudes were estimated using a mixed multinomial logit (MMNL) model (Li and Hensher, 2012). In this research, they suggested a framework to estimate choice models under risks such as on-time delivery, congestion, and road accidents with rank dependent utility theory.

Comparison of cooperation among freight forwarders was analyzed vertically and horizontally in Norway, applying previous history data to results of a logit model (Saeed, 2013). Vertical coalition between large truck-operating companies and ship-operating companies was determined to work most efficiently. This cooperation would generate better payoffs in the form of profit. And the profit would be not only for the members in the coalition, but also for the companies out of the coalition. However, it was found that users do not significantly benefit from this kind of coalition.

Within export freight mode choice behavior, the relationships between increased containerization and inland terminal facilities for shipment clearance was highlighted in India (Ravibabu et al., 2013). Ravibabu structured and sent questionnaires to 124 export firms and supplemented the results with data from transportation firms and terminal operators in India, then estimated a nested logit model with rail container and road truck modes. Total cost and transit time were found as a significant attribute affecting the mode choices. The study, however, did not find effects of loss, reliability, or damage to be significant. Additionally, the model also predicted that non-transport attributes are important in the mode choice decisions: attributes including the percentage of letters of credit and the value of export benefits that materialized with inland waybills and the value of export benefits that materialize after export. Most recently, Steven and Corsi (2012) used individual shipment data, port characteristics, and actual freight charges to analyze port attractiveness for containerized shipments and concluded that factors affecting delivery speed than charges are more interests on larger shippers. But this model estimated general port attractiveness of the U.S. not specifying port choice behavior among alterative ports.

Finally, it can be summarized that various research has modeled and estimated freight flows not only in this country but also all around the world. Once freight activities and other research topics are considered, which are not discussed here, it can be assumed that tremendous exercises to understand freight movements have been undertaken. When a scope is narrowed down to the intermodal containerized shipments, two types of approaches are observed: an optimization model based on simulation and a discrete choice model. With the ease of data acquisition, an optimization model is much preferred for international trade analysis. However, the advantages of discrete choice models with potential to include many causal variables and policy measures support better understanding of freight movements, especially in a behavioral aspect. As discussed in this chapter, most of the modeling frameworks that were introduced in this chapter have not been studied in choice models from origin countries to the states in the U.S.

Therefore, many new challenges are expected in the way of developing a feasible data source and choice models. These challenges will be explained in the next section.

RESEARCH GAPS AND OBJECTIVES

Research Gaps

Currently freight analysis models represent movements in scale of states, regions, or cities, and these domestic freight movements are analyzed by attributes of time, cost, distance, commodity types, shipment sizes, number of stops, time of loading or unloading, and facility conditions. However, the manufacturing volume in the U.S. is not sufficient to meet domestic demand, rather, more manufactured goods must come into the U.S. from external sources (IMF, 2014). Imported manufactured goods are transported in appropriate sizes by modes and commodity types, and this is one of the reasons why size and volume are significantly considered in freight movement research (Pourabdollahi, et al., 2012; Nealer et al., 2011; Train and Wilson, 2006; Leachman, 2005; Oum et al., 1992). Since not all goods are manufactured in the U.S., shortfalls have to be imported from outside of the U.S. and these imported goods will be directed to states, which are considered to be shipping origins in domestic freight research.

Previous research highlighted international shipments into the U.S. at an aggregate level (Fan et al., 2012; Blonigen and Wilson, 2006; Leachman 2005). That is, imported freight at major or targeted ports was collected in total volume periodically, usually annually, and this total volume was simulated with an optimization process, with a network analysis, or with an elasticity analysis considering various constraints at origin/arriving ports, maritime networks, rail/highway networks, etc.

These analytic approaches to imported freight movement are reasonable since lack of information on the disaggregate level is the primary obstacle to greater active research on the behavior of U.S. trading partners (Jong et al., 2004; Cullinane and Toy, 2000). However, these aggregate level approaches have disadvantages including data requirements, little causality-insight, or non-transferrable issues (Jong et al., 2004). While even the disaggregate model has the disadvantage of difficulty in data acquisition, that is outweighed by the advantages of theoretical support, potential causal variable inclusion, and policy measurement.

Discrete choice modeling is one of the most theoretically supported methods to analyze choice behavior, and recent choice analysis has been highlighted in the previous section in terms of port and mode choice behavior, noting an outstanding increase of freight volume and value internationally and domestically (Reis at al., 2013; Ravibabu et al., 2013; Brooks et al., 2012; Ungo and Sabonge, 2012; Moschovou and Giannopoulos, 2012; Samimi et al., 2011; Levine et al., 2009; Rich et al., 2009; Malchow and Kanafani, 2004; Moschovow and Giannopoulos, 2012; Oum et al., 1992). However, these efforts dominantly focused on freight mode choices analysis. Samimi et al. (2011) analyzed imported freight mode choice behaviors from the U.S. ports to the states, and Moschovow and Giannopoulos (2012) found relationship between firm types and mode choice behavior in Greece. Rich et al. (2009), Brooks et al. (2012), and Saeed (2012) adopted discrete choice models for domestic freight mode choice behaviors. For the port selection behavior analysis, there are several efforts found. Oum et al. (1992) and Moschovow and Giannopoulos (2012) analyzed port selection behavior finding significant attributes of distance, price, location, and commodity types for exporting shipments from the U.S., and Arunotavanun and Polak (2011) found commodity types, shipping time, service quality, and schedule flexibility as significant attributes of port choice behavior for the export shipments.

As it is introduced and discussed in the chapter of introduction, it is found that economic condition changes container flows into the U.S. by ports. Also, while recovering from the recent economic recession, major port authorities and state governments within the same municipal try to attract and receive more vessel calls. Additionally, maritime network capacity increases are almost certain in the near future at the Panama Canal and the Port of Prince Rupert, and this may change or affect the containerized freight flows into the U.S. Finally, policy provision with long term plan for each port authority and state will be valued.

Since there was little research identifying the behaviors of port choice into the U.S., a framework to analyze port choice behaviors into the U.S. and the distribution of imported containerized cargos will be suggested in this thesis.

Research Objectives

The purpose of this thesis is to address all of the aforementioned issues found in current research for imported containerized shipments from origin country to the final destination states in the U.S., and to propose an approach to estimate a port choice model for international shipments and to analyze behaviors of the shipments. The practices of discrete choice modeling will be combined with a data manipulation procedure to estimate a port choice model. In addition to this port choice model, an optimization model will be implemented to analyze overall distributional changes with increasing maritime network capacity.

DATA SETS

Several data sets from various sources have been reviewed and selected in this research for the analytical purposes of port choice behavior and distributional optimization. The proposed two analyses require different types of data sets. The port choice behavior analysis needs a disaggregate-level data structure that describes each shipment's characteristics including choice attributes for port selections. The optimization analysis needs an aggregate level data source that describes overall volume movements. That is, a data source for port choice behavior needs information for chosen ports, alternative port lists, attributes of networks, ports, freight, and additional attributes that can be supplemental to the data set. And a data source for optimization can be prepared with attributes of overall amounts of container volumes by ports, destinations, commodities, and other relative conditions.

From various data sources about freight transportation, the Carload Waybill Sample data and the WISERTrade database were selected for port choice and optimization analyses, respectively. In addition to the two sources, a distance matrix from Oak Ridge National Laboratory, Port World, and a survey of the port authorities were considered to add credence to the data preparation, since several attributes in the Carload Waybill Sample data sets are not released due to confidentiality issues on shipping cost, transit distance, additional cost, etc.

Due to data source availability, five major trading partner countries were selected: China, Japan, South Korea, Taiwan, and Hong Kong, and 12 major U.S. ports were selected:

New York, Norfolk, Charleston, Savannah, Miami, Mobile, Houston, Los Angeles/Long Beach, Oakland, Tacoma, Seattle, and Prince Rupert. The criteria of trading partner countries and the U.S. major ports are based on the volume of traded containerized shipments. The five Asian trading partner countries export a containerized freight volume that covers 60% of the total imports of the U.S., and the 12 major U.S. ports handle more than 80% of the imported containerized freight annually. Therefore, the data sets are refined as to the origin countries and the arrival ports as these are considered country and port lists.

The Public Use Waybill Sample data

The Public Use Waybill Sample (PUWS) is a non-proprietary version of the Surface Transportation Board (STB) Carload Waybill Sample (Surface Transportation Board, 2014). These data samples collection have been continued almost a century. Since 1946, a sample of all carload traffic has been taken continuously on an annual basis. Beginning in 1981, sampling methodology of the Waybill was modified for improvement in the sample's quality by means of the regulatory purposes where it is collected. Contributing to this trend, currently, under the requirements, an annual sample of waybill is submitted by all U.S. railroads more than 4,500 revenue carloads to the STB. And the STB collects and distributes this data to use when some qualifications are met. And some samples over represent the total population, and some does not.

Since the full Carload Waybill Sample data includes information that needs more credential attentions such as origin, junction, and termination stations, and rail carrier and cost, public release is not appropriate. Alternatively, the Public Use Waybill Sample is retrieved from the full source by eliminating credential information from each data record. For the locations of origin, transfer, and termination stations are replaced by Business Economic Area (BEA), state, or province. The recorded rail freight movements are commodities handled at least three freight stations in the U.S. Commodity types are indicated by STCC at the five-digit level excluding munitions items. Commodity of munitions is recorded at the two-digit level due to its sensitive nature, and locational information is nullified. In the PUWS, the Business Economic Areas (BEAs) code is followed by the "three-FSAC rule." Since the PUWS still contains sensitive data, the rule is anticipated to avoid any disclosure of competitive information. Even though records do not meet the "three-FSAC rule", they are still included in the PUWS. But location information will be removed.

In 1997, a publication discussing the PUWS addressed guidelines for the use and interpretation of the Carload Waybill Sample highlighting shipping rates and freight revenues since those rates and revenues are not revealed to the public due to legal restrictions or data collection procedures (Wolfe and Linde, 1997). The restrictions of data acquisition have led to complaints by many researchers, and in 2005, Leachman concluded the data acquisition for containerized shipments into the U.S. was a tremendous challenge. Even though the shipping rates and other revenue sources should be carefully handled for productivity analysis, several variables still can be used for choice modeling attributes including OD regions, car types and sizes, weights, interchange states, distances, type of moves, commodities, and commodity values.

Table 1 Criteria for PUWS data

File No.	Description	Value
8	Intermodal Service Code	O, P, Q, R (Intermodal Shipments)
11	Trailer/Container Type	Container
20	Type of Move	Imported Commodity
21	All Rail/Intermodal Code	Intermodal

This research collected the PUWS data from 2007 to 2012, and chose records of only imported intermodal shipments. The STB provides a downloadable PUWS data source on its webpage with data element descriptions. Based on the given descriptions, the criteria of record selection was determined as illustrated in Table 1. From the attributes of “Intermodal Service Code,” “Type of Move,” and “All Rail/Intermodal Code,” appropriately selected records were assumed to be intermodal shipments and were prepared for port choice behavior analysis. The total numbers of records by year from 2007 to 2012 are shown in Table 2. Since this PUWS is based on the total number of waybill records, the reason why the total amount decreased since 2008 and began to increase after 2009 can be explained through actual international economic conditions. To make this portion of chosen number of records represent total number of records, the PUWS provides theoretical expansion factor that can be multiplied by the number of carloads, tonnages, freight revenue, and container counts. The factor is used in this thesis and, analysis of the PUWS hereafter is based on the multiplied numbers.

Table 2 Numbers of Total PUWS Records and Intermodal PUWS Records 2007-2012

Year	Total Number of Records	Chosen Number of Records
2007	666,686	58,851
2008	622,318	54,763
2009	518,343	46,650
2010	580,717	51,103
2011	599,284	49,745
2012	622,884	54,813
Total	3,610,232	315,925

WISERTrade database

The World Institute for Strategic Economic Research Trade (WISERTrade) database affords extensive international trade data including the amounts of U.S. imports and exports by individual port (WISERTrade.org, 2013). This source is based on census data; it provides periodical containerized cargos by origin countries, ports and states in the U.S., volumes, weights, and commodities. The most recent aggregate freight data for trading partner countries during 2007 to 2012 was retrieved from this database. And dataset retrieved from this source was applied to the preceding optimization research.

Oak Ridge Data

The PUWS contains distance attributes between origin and destination BEAs, but more than half of the selected data sources do not hold appropriate values or are left empty on purpose because of confidentiality issues. Since the distance attribute is critical for both port choice behavior and optimization analysis, distance information for all the selected records from the PUWS were replaced with the estimated distance from the county-to-county distance matrix prepared by the Oak Ridge National Laboratory (ORNL). In the matrix from the ORNL, unit distance is in rail mileage and region code is in a five-digit Federal Information Processing Standard (FIPS) code identifying counties and county equivalents in the United States. Since region coded BEAs in the PUWS are different from the distance matrix from the ORNL, a conversion process was undertaken to match the FIPS and BEAs based on a matrix matching these two code tables distributed by the Federal Communications Commission (FCC).

Portworld

In addition to the surface transportation network distance matrix from ORNL, distances between the ports of trading partner countries and the ports of the U.S. ports were obtained from the Portworld website as Table 3. The distance calculator from this website is prepared by Petromedia Ltd. and provides distances in nautical mileages among major maritime ports all around the world. As the distance attribute is critical in port choice and optimization analysis, this nautical distance attribute is also important for both analyses. The ports of the major trading partner countries were selected as a representative port for each country: Shanghai in China, Tokyo in Japan, Busan in Korea, Kaohsiung in Taiwan, Hong Kong in Hong Kong, and Singapore in Singapore.

Table 3 Nautical Distances between Asian Trading Partner Countries' and the U.S. Ports*

Descriptions	NY/NJ, NJ	Norfolk, VA	Charleston, SC	Savannah, GA	Miami, FL	Mobile, AL	Houston, TX	LA/LB, CA	Oakland, CA	Tacoma, WA	Seattle, WA	Prince Rupert, BC
Shanghai, China	10,553	10,348	10,138	10,123	9,741	9,946	10,089	5,693	5,378	5,042	5,042	5,032
Tohyo, Japan	9,983	9,778	9,568	9,553	9,171	9,376	9,519	5,140	4,833	4,544	4,544	4,535
Busan, Korea	10,108	9,903	9,693	9,678	9,296	9,501	9,644	5,249	4,933	4,597	4,597	4,588
Kaohsiung, Taiwan	10,857	10,652	10,442	10,427	10,045	10,250	10,393	6,014	5,707	5,383	5,383	5,374
Hong Kong, Hong Kong	11,219	11,014	10,804	10,789	10,407	10,612	10,755	6,370	6,054	5,277	5,277	5,713
Singapore, Singapore	12,025	11,987	11,724	11,688	11,249	11,429	11,643	7,150	6,842	6,171	6,171	6,521

* In Nautical Mileages

Port Authority Surveys

To find values and opinions as attributes in addition to the previous four data sources, a short survey containing four questions was sent to the authorities of the 12 major ports listed above. The list includes ports of NY/NJ, Norfolk, Charleston, Savannah, Miami, Mobile, Houston, LA/LB, Oakland, Tacoma, Seattle, and Prince Rupert. The survey was designed with purpose of obtaining information about: 1. additional fees at ports, 2. congestion experiences, 3. labor disputes, and 4. readiness for Ultra Large Container Vessels (ULCV).

Questionnaires were sent to the 12 major port authorities, but only six of them responded: Mobile, Houston, LA/LB, Tacoma, Seattle, and Prince Rupert. Three authorities did not respond, and the last three refused to provide information due to confidentiality issues. The first question asked if there is an additional fee at ports. Pierpass and Clean Truck fees for the purposes of congestion mitigation and environmental policy in the state of

California can be examples. However, there have not been any fees outside of California. The second question was about congestion experiences. In detail, information about severe congestion seasons or dates, and/or congestion hours were requested, but authorities refused to respond. All six respondents insisted that they have not experienced congestion in the last decade. The third question was about union disputes that could stop port operations, and dates were requested if the ports experienced such disputes. As in the second question, only port authorities on the West Coast reported union dispute experiences for the last decade. With effort of reviews about the port union dispute, it was not difficult to find about union's dispute and strike news from multiple sources. For example, in the beginning of 2000, there were several labor disputes in the West coast port facilities and the dispute behavior such as strikes, lockouts, work stoppages, and "go-slow" disrupted port services seriously. In 2002, the International Longshoremen and Warehouse Union (ILWU) went on strike and more than a dozen of the West coast ports were closed for 10 days. As a result of this strike, a lot of importers, retailers, and costumers experienced hard times and the estimated U.S. economic loss was over $16 billion (Johnson, 2008). In 2004, 2007 and 2008, there were additional union disputes and resulted closures from a number of ports. When the survey results and the announced news about the union dispute are considered, there were union disputes in the recent decade. To find its actual affect on freight business field, different sources from container liner and logistics companies were asked to find actual influences during the proposed dispute dates. A container liner of Hanjin shipping and five logistics companies operated more than 10 years in Chicago area were contacted to search their database or resource to trace hints of union disputes on the U.S. ports. With deep search on the records from these six sources, several notices from the ports were found, but actual delays and additional cost/fees due to disputes were not found. Almost all the containerized cargos were trans-loaded on rail or picked up at the port by trucks. So, the issue on union disputes will not be considered as a variable for a port choice model and optimization approach. The last question was about the port's readiness for ULCV, Post Panamax, or New Panamax size vessels that can pass through the new Panama Canal lock system. Since the current Panama Canal lock system is smaller than the Post Panamax vessels and larger vessels have begun to be built, the East and the Gulf Coast ports have not received such large vessels from Asian trading partner countries. However, once the new lock system initiates its service at the Panama Canal, more opportunities for receiving vessels at the ports along the coasts increases, and enough channel depth should be prepared at the ports. Among the respondents, the ports on the West Coast, Long Beach, Prince Rupert, Seattle, and Tacoma, were ready for the ULCV with a channel depth of 50 feet or deeper. But the ports of Houston and Mobile responded that they are equipped with a 45 foot depth for the channels and that is sufficient for the Post Panamax with an 80% of maximum load.

Summary of the survey is prepared in Table 4. The four questions about additional fee, congestion, union disputes, and channel depth/ULCV readiness were asked to supplement in the data sources for port choice and optimization models. Since the congestion and union disputes were not provided with meaningful data, additional fees at ports and channel depth as a representative for ULCV readiness will be added for the models. A copy of the survey letter is attached in Appendix I.

Table 4 Survey Question Items and Answers from Six Port Authorities

No.	Question	Mobile	Houston	LA/LB	Tacoma	Seattle	Prince Rupert
1	Additional Fee	No	No	Yes	No	No	No
2	Congestion	No	No	No Data	No	No	No
3	Union Disputes (Year)	No	1970s	- Office Clerical Union strike : 27 November 2012 – 4 December 2012 - ILWU* strike: 1 May 2008 - ILWU* lockout : 27 September 2002 – 9 October 2002	2002	2002	No
4	Channel Depth (Feet)	45	45	55	51	50	51

* ILWU: International Longshore and Warehouse Union. This is a labor union primarily represents dock workers on the West Coast of the U.S.

DATA DESCRIPTION AND CONVERSION

In this chapter, a descriptive analysis of the two main data sources is reviewed. Both the WISERTrade database and the Public Use Waybill Sample data are considered from 2007 to 2012. The WISERTrade database provides total weights in kilograms of containerized freight shipments from the six Asian trading partner countries to the proposed 12 ports and to the 48 U.S. states, excluding Hawaii and Alaska. And the Public Use Waybill Sample data provides samples of each carload shipment record. Each record contains origin port information in the U.S. and the destination information of the U.S. state. Commonly comparable indexes between the two sources are weight in kilograms, weight proportions by ports, by commodities, by destinations, and by years.

WISERTrade database (WISERTrade data)

Since this database provides annual containerized freight shipments into the U.S. by weight, overall container freight flows into the U.S. can be analyzed. In Table 5, annual containerized freight shipment records by port from 2007 to 2012 are provided. As discussed in previous chapters, a notable decrease began to be observed in 2008. The flow touched the bottom of the decreasing flow into the U.S., and started to increase in 2009. Even though the recovery was slow, all ports received more freight by 2012. The ports of Los Angeles and Long Beach receive more than 40% of the total containerized shipments into the U.S. from the six Asian trading partner countries. And it is noted that the ports on the West Coast receives more than the ones on the East and Gulf Coasts. Also, it is interesting that the Port of Prince Rupert in Canada receives more than 12% than previous years around 2007 and 2008, and New York/New Jersey receives more than 10% of the total container shipments in the U.S. as well. The increased amounts of containerized freights into the U.S. are believed due to the recovery from the economic recession.

Table 5 Annual Containerized Freight Shipments from the Asian Countries by Ports (kgs)

Year / Port	2007	2008	2009	2010	2011	2012
NY/NJ	6,350,024,241	6,564,782,396	5,771,925,735	6,889,428,196	7,004,919,801	7,140,167,022
Norfolk	1,772,840,854	1,720,170,903	1,391,459,285	1,613,924,210	1,649,636,707	1,755,971,097
Charleston	1,385,312,315	1,371,276,724	949,650,538	1,189,411,697	1,256,867,511	1,347,950,979
Savannah	3,821,572,807	3,897,122,679	3,177,935,727	3,942,140,238	3,960,638,962	4,051,091,963
Miami	652,580,688	754,746,776	607,064,437	681,232,003	762,941,647	822,420,404
Mobile	133,408,191	185,272,542	171,604,707	191,361,720	307,919,086	362,653,072
Houston	1,724,987,521	1,456,083,773	1,005,356,033	1,155,286,920	1,294,221,173	1,582,508,845
LA/LB	35,913,165,319	32,637,468,205	26,141,269,491	30,641,726,209	31,584,575,835	31,987,743,928
Oakland	3,160,448,675	2,779,941,611	2,293,567,932	2,730,663,317	2,701,293,283	2,824,688,545
Tacoma	3,554,918,432	3,427,518,432	2,348,200,591	2,540,710,359	2,541,417,245	3,333,147,503
Seattle	3,858,148,320	3,269,449,756	2,964,349,292	4,732,965,780	4,152,999,339	4,266,128,957
PR	9,400,491,394	9,978,799,769	7,662,154,092	7,533,932,885	8,050,258,402	9,053,545,550
Total	71,727,898,757	68,042,633,566	54,484,537,860	63,842,783,534	65,267,688,991	68,528,017,865

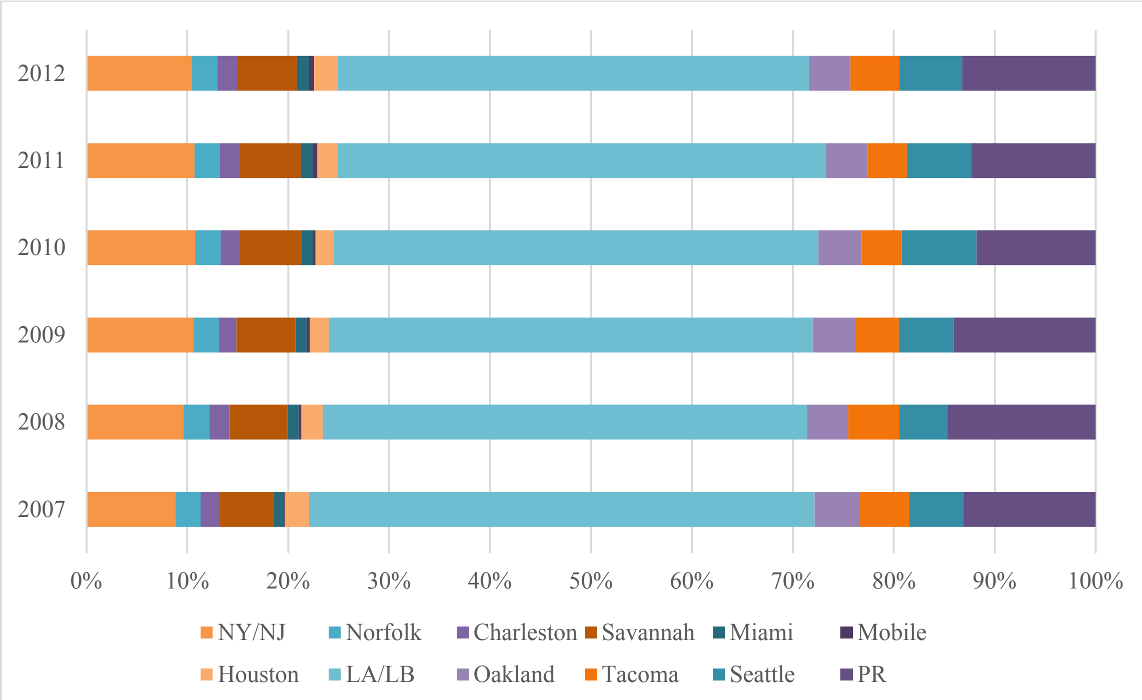


Figure 1 Annual Containerized Freight Shipments into the U.S. by Port from the Asian Trading Partner Countries - WISERTrade Data

In addition to the overall flow at the U.S. ports by years, distributions between the six origin countries and 48 U.S. states are prepared in Appendices II. The distributions showed almost similar proportions within a 5% change compared to the previous years, and no significant change was observed. When the amount is compared by countries, container freight from China accounted for more than 70% of the total, and the other five countries shared the other 30%. And for each distributed amount to the states, shipments from China were the most among the countries. When compared by state, California received the most containerized freight shipments, over 30% of the total imported from the six Asian countries followed by Texas, New York, New Jersey, Georgia, and Illinois.

The annual flow amounts by commodity types are reviewed in Table 6. Since the commodity types from the WISERTrade database are recorded by the Harmonized Commodity Description and Coding Systems, usually called as the Harmonized System Code (HS Code) with 99 types of categories, the types are re-grouped by similar types into six categories for ease of analysis, as seen in Table 7. From

Table 6, Figure 2 is plotted representing annual trends by commodity types that the containerized freight shipments differ in weight by commodity types. Commodity types 4 and 5 are the most popular commodity for containerized shipments, followed by types 3 and 6 and types 1 and 2 are the least popular commodities for containerized shipments into the U.S. This can be explained that the majority of imported freights are materials for manufacturing and assembling items, then textures and heavy machines were followed. Relatively, raw materials were assumed to be less imported through containerized mode.

Table 6 Commodity Flow by Years

Year / Commodity	2007	2008	2009	2010	2011	2012
Commodity 1	3,140,712,826	3,352,263,346	2,983,261,010	3,075,983,379	3,137,701,725	3,265,671,567
Commodity 2	3,965,562,081	3,852,066,999	3,129,073,579	3,972,419,947	4,464,070,985	4,414,283,280
Commodity 3	11,798,013,778	10,911,609,093	9,225,670,482	10,653,644,102	10,565,277,893	11,131,733,556
Commodity 4	20,287,454,538	19,127,696,961	15,022,531,585	18,167,158,396	18,734,010,936	19,574,014,165
Commodity 5	19,867,924,792	19,495,787,825	15,034,048,781	16,909,859,012	18,106,512,940	19,709,650,011
Commodity 6	12,668,230,742	11,303,209,342	9,089,952,423	10,986,234,258	10,260,114,512	10,432,665,286
Total	71,727,898,757	68,042,633,566	54,484,537,860	63,765,299,094	65,267,688,991	68,528,017,865

*Commodity Types are categorized in Table 7.

Table 7 Commodity Category Grouping

HS Code Number	HS Item Description	Re-Group Category
01-05	Animal & Animal Products	1
06-15	Vegetable Products	
16-24	Foodstuffs	
25-27	Mineral Products	2
28-38	Chemicals & Allied Industries	
39-40	Plastics / Rubbers	3
41-43	Raw Hides, Skins, Leather, & Furs	
44-49	Wood & Wood Products	
50-63	Textiles	4
64-67	Footwear / Headgear	
68-71	Stone / Glass	5
72-83	Metals	
84-85	Machinery / Electrical	6
86-89	Transportation	
90-97	Miscellaneous	
98-99	Service	

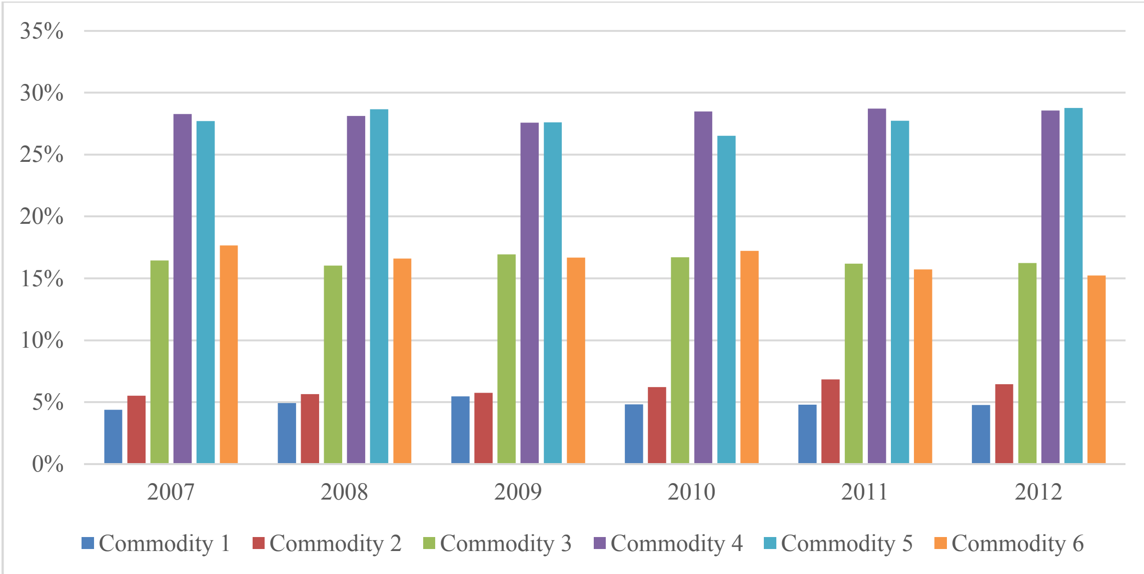


Figure 2 Freight Weight Proportions by Commodity Types – WISERTrade data

Port distributions by commodity types are reviewed in Table 8. Similar to the previous distributional characteristics, the ports on the West Coast received more than the ports on the East and Gulf Coasts showing 62% of commodity type 1, 63% of type 2, 73% of type 3, 76% of type 4, 85% of type 5, and 73% of type 6. Among the West Coast ports, the ports of Los Angeles and Long Beach handled more than 50% from Asian trading partner countries.

Table 8 Distribution of Containerized Freight into the U.S. Ports by Commodity Types (Kgs)

Total	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	4,948,016,643	2,843,644,393	8,076,950,286	11,345,509,207	5,609,871,354	6,885,872,419
Norfolk	463,088,574	495,060,343	2,166,324,924	2,233,260,196	1,841,854,365	2,691,161,847
Charleston	220,382,162	816,838,905	1,327,453,861	2,434,681,539	1,614,072,312	1,082,955,202
Savannah	517,346,167	1,313,044,680	4,085,824,295	6,960,480,036	4,812,864,257	5,151,164,283
Miami	676,730,326	125,072,502	768,991,404	1,277,492,733	868,127,693	563,881,806
Mobile	2,654,338	50,480,196	121,482,692	329,343,753	771,897,066	76,238,249
Houston	284,068,626	3,079,710,442	721,088,413	2,510,240,394	738,226,527	888,688,713
LA/LB	6,798,254,743	8,954,253,097	33,045,252,439	53,618,620,698	54,750,998,072	31,708,690,943
Oakland	1,797,982,049	686,845,172	3,071,921,292	4,722,370,042	3,272,078,916	2,931,558,430
Tacoma	349,162,266	647,466,347	2,909,439,609	5,212,909,045	5,329,816,790	3,298,251,511
Seattle	782,801,220	2,341,986,117	3,804,013,487	6,519,417,285	5,837,363,647	3,949,065,325
PR	2,117,784,020	2,400,537,620	4,181,120,385	13,749,777,229	23,668,527,546	5,514,980,512
Total	18,958,271,134	23,754,939,814	64,279,863,087	110,914,102,157	109,115,698,545	64,742,509,240

*Commodity Types are categorized in Table 7.

The Public Use Waybill Sample data (PUWS data)

The Public Use Waybill Sample (PUWS) data were collected and refined to represent intermodal shipments into the U.S. between 2007 and 2012. In Table 9, annual containerized freight shipments from the six Asian trading partner countries to the twelve U.S. major ports are provided. Similar to the distribution of the WISERTrade database, as also shown in Figure 3, the West Coast ports received more than the East and Gulf Coast ports with 56% of the total shipments in weight. Among the West Coast ports, the ports of Los Angeles and Long Beach were dominant, and the ports of New York and New Jersey were prominent on the East and Gulf Coasts.

Table 9 Annual Containerized Freight Shipments from the Asian Countries by Ports – PUWS data (Tons)

Year Ports	2007	2008	2009	2010	2011	2012
NY/NJ	481,931	120,431	94,170	268,316	287,049	262,985
Norfolk	32,996	30,854	13,780	22,249	23,426	26,190
Charleston	10,948	8,638	6,689	2,480	8,193	9,045
Savannah	11,131	12,195	2,001	5,145	1,882	6,757
Miami	3,361	1,791	1,699	4,779	4,102	1,188
Mobile	11,689	3,353	3,045	4,384	20,276	25,632
Houston	250,662	188,853	198,807	198,627	178,231	208,737
LA/LB	728,657	725,073	383,495	387,096	392,147	474,317
Oakland	63,175	60,394	66,958	69,221	61,851	59,749
Tacoma	96,560	72,041	49,851	45,623	46,178	45,487
Seattle	113,484	101,446	63,184	109,586	102,824	117,061
PR	325,240	130,588	92,360	183,656	84,101	126,114
Total	2,129,834	1,455,657	976,039	1,301,162	1,210,260	1,363,262

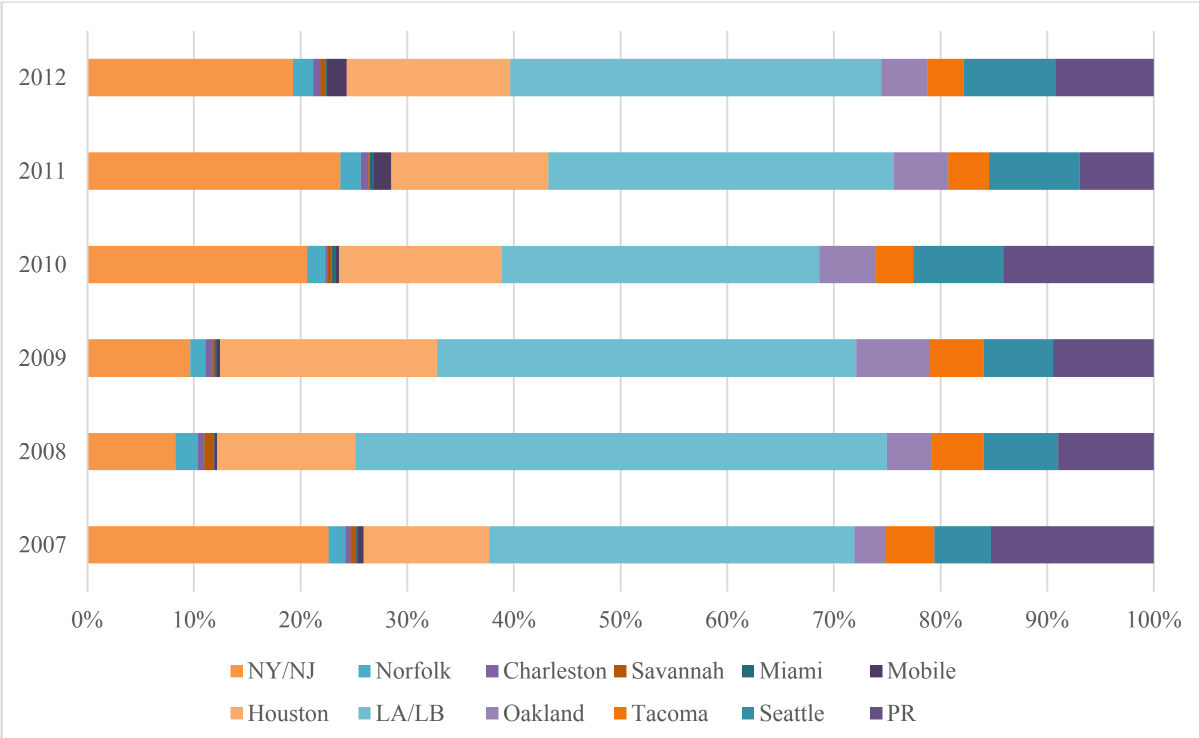


Figure 3 Annual Containerized Freight Shipments into the U.S. by Port from the Asian Trading Partner Countries - STB Data

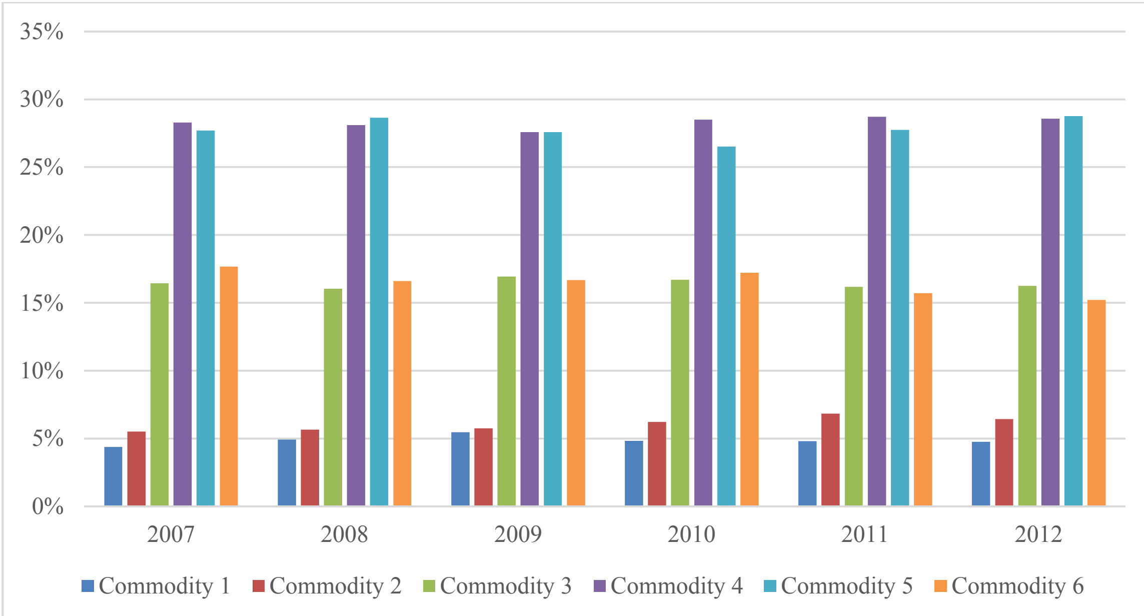
However, shipment records at PUWS data present somewhat irregular distributions by ports between 2007 and 2012 as seen in Figure 3, and this also can be recognized from the annual commodity distributions at ports. The annual commodity types were reviewed in Table 10, and the commodity distributions from PUWS data were also recognized its difference with the WISERTrade database in Figure 4. These two distributional differences in total amount and commodity types are believed to occur due to the data sizes. The WISERTrade data is sourced from the Census data that is based on the complete enumeration survey retrieving all the intermodal freights in containerized mode into the U.S. However, the PUWS data is sample data about less than 10% of the total waybill records. As discussed the difficulties of finding disaggregate level freight data source, utilizing the PUWS data is expected to be the best suggestion for estimating a port choice model.

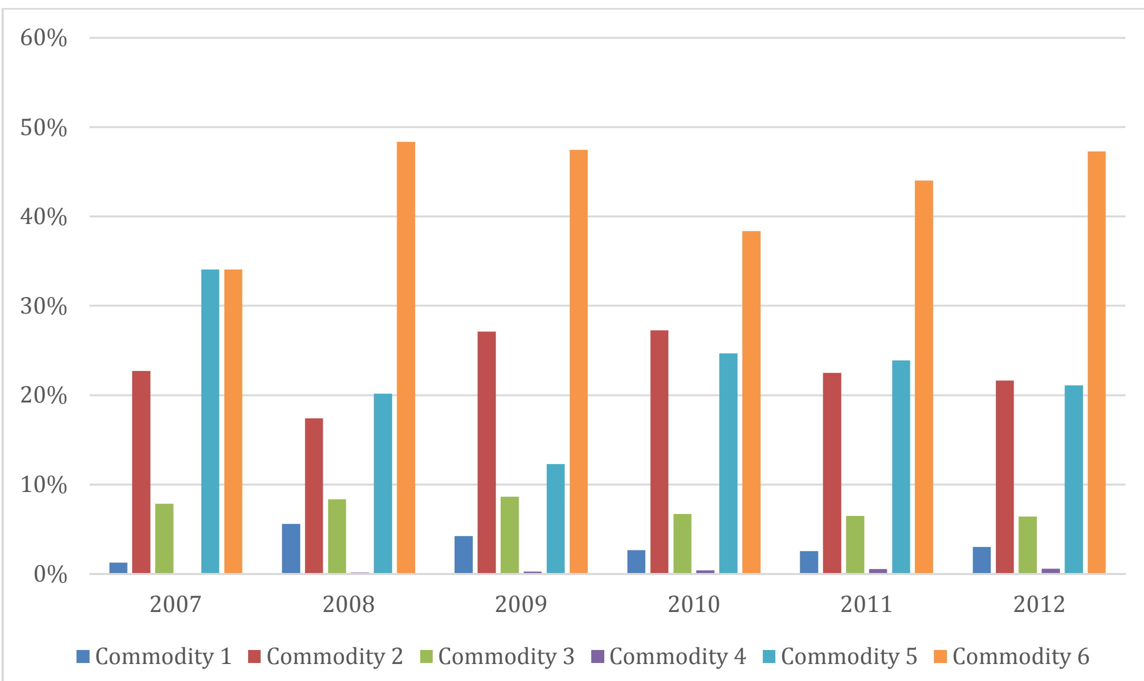
Before using the PUWS data in port choice model, comparisons of the distributions by port and commodity type are reviewed, and differences were found significant. To minimize distributional gap between the PUWS and WISERTrade data sources, an iterative proportional fitting (IPF) procedure to adjust tables of data columns and rows in the PUWS was adopted. As explained in the previous paragraph, the WISERTrade data is based on the Census, it is more than rational to modify the PUWS data. As the IPF procedure, first, each row of cells was proportionally adjusted to equal the pre-determined totals of commodity types. Then each column of cells was proportionally adjusted to equal the pre-determined totals of ports. Finally, each slice of cells was proportionally adjusted to equal the pre-determined totals of years. These three steps were repeated until desired level of convergence was met.

Table 10 Commodity Flow by Years (Tons)

Year / Commodity	2007	2008	2009	2010	2011	2012
Commodity 1	27,035	81,335	41,409	34,537	30,648	40,949
Commodity 2	483,434	253,664	264,789	354,442	272,408	294,790
Commodity 3	166,963	121,310	84,383	87,032	78,503	87,357
Commodity 4	1,966	1,985	2,389	5,348	6,540	8,019
Commodity 5	725,263	293,745	119,906	320,892	289,324	287,527
Commodity 6	725,173	703,618	463,163	498,911	532,837	644,620
Total	2,129,834	1,455,657	976,039	1,301,162	1,210,260	1,363,262

*Commodity Types are categorized in Table 7.





*Upper is plotted with WISERTrade, and lower is plotted with PUWS data

Figure 4 Freight Weight Proportions by Commodity Types – WISERTrade and PUWS

Once the distribution was proportionally matched, an inland distribution matrix between ports and states was reviewed. Unfortunately, ten states as destinations were deleted from the data set: Connecticut, Delaware, Indiana, Maryland, Montana, New Hampshire, New Jersey, New Mexico, Rhode Island, and Vermont. It is believed that there was not enough information in the data records indicating these states as final destinations in the original PUWS data source and they were removed from the procedure for finding intermodal shipments. In Table 11, the distribution between the 12 major U.S. ports and the U.S. states, 39 states and District of Columbia, is shown, and the missing values are also removed from the procedure. Except for these missing destination lists and values, overall distributions between ports and states are similar to the WISERTrade database. As an example, fitted plots of Commodity Types are shown in Figure 5. With comparison with Figure 4, commodity types of 3 and 4 that are less presented in the original plot are highlighted in the fitted plot. Even though the IPF procedure was taken to match the distribution shape, the commodity type 6 is trill protruding in the fitted plot. This can be assumed with the item descriptions of commodity type 6 including "Miscellaneous" that may vary by items. Since this type is possibly preceded in combined form of multiple commodities, much frequent sampling probabilities among others can occur.

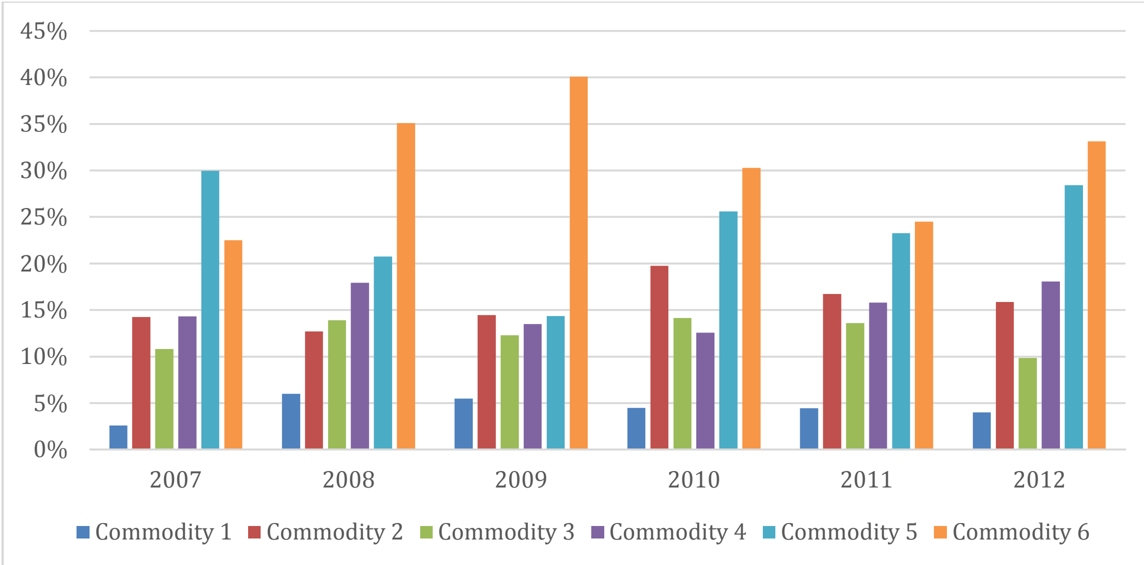


Figure 5 Freight Weight Proportions by Commodity Types by Weight (Ton) - Fitted

Table 11 Containerized Freight Shipments Distribution between Ports and States (Tons)

State Port	AL	AR	AZ	CA	CO	DC	FL	GA	IA	ID	IL	KS	KY	LA	MA	ME	MI	MN	MO	MS
NY/NJ	354	63	-	7,538	20	34,864	4,111	8,198	223	-	78,470	-	79	449	2,412	-	4,527	1,161	8,991	6,211
Norfolk	306	-	-	1,629	127	-	-	597	121	-	44,372	-	-	1,256	68	-	11,094	1,989	9,318	2,507
Charleston	456	-	-	450	-	-	890	3,880	-	-	160	-	-	-	-	-	-	-	18	774
Savannah	80	-	-	558	-	249	6,043	128	-	-	1,432	-	-	26	149	-	219	441	314	5,664
Miami	1,771	-	-	333	-	-	-	4,740	-	-	2,596	-	-	-	-	-	-	84	310	1,770
Mobile	-	577	183	2,376	188	377	912	2,590	2,701	-	4,541	-	-	2,391	72	-	1,922	1,456	1,659	2,727
Houston	2,783	33,935	13,843	308,685	15,168	839	2,665	19,834	45,052	4,687	91,059	3,650	1,548	62,422	4,512	-	9,819	38,160	37,937	46,747
LA/LB	1,444	299	226,952	2,168	9,637	840	9,193	51,579	38,010	168	665,344	2,043	329	2,137	300	-	4,231	5,763	197,262	209,303
Oakland	355	65	1,184	1,761	558	402	2,830	2,744	32	1,213	78,502	19	-	575	652	-	273	186	14,327	6,258
Tacoma	101	101	13,564	181,896	12,064	3,201	128	348	210	3,494	18,049	-	-	1,752	66	-	962	2,921	7,454	2,492
Seattle	215	265	1,783	16,624	4,925	-	24	428	195	89	356,651	-	-	-	1,029	-	2,034	26,629	25,180	6,803
PR	5,373	1,537	18,399	26,865	4,048	3,359	3,032	7,559	3,967	1,023	385,960	1,405	446	330	14,963	8,489	44,757	38,394	17,231	37,861

State Port	NC	ND	NE	NV	NY	OH	OK	OR	PA	SC	SD	TN	TX	UT	VA	WA	WI	WV	WY	Grand Total
NY/NJ	4,218	-	20	-	251,520	265,100	121	270	16,417	-	-	1,592	5,318	4,525	603,668	354	1,032	1,393	-	1,313,219
Norfolk	585	-	1,150	-	682	17,892	5,092	281	1,781	115	-	78	17,111	809	-	97	-	-	-	119,057
Charleston	33,202	-	-	-	273	-	-	8	-	-	-	-	571	-	1,895	75	-	-	-	42,652
Savannah	2,934	-	-	-	5,549	647	-	-	2,009	80	-	526	885	-	3,189	41	927	-	-	32,093
Miami	-	-	-	-	128	-	-	90	527	-	-	1,040	-	-	-	30	-	-	-	13,418
Mobile	953	-	2,422	-	1,752	3,867	903	110	4,682	193	-	2,701	6,948	-	-	-	5,763	-	-	54,968
Houston	19,861	547	10,256	24,448	29,900	13,387	11,390	6,776	27,018	-	-	13,711	15,198	12,837	5,112	9,951	23,207	1,040	15,970	983,952
LA/LB	101	14,619	1,471	209,697	11,609	1,337	267	45,027	3,023	-	-	-	869,092	30,553	388	21,308	256	-	7,286	2,643,035
Oakland	7	-	462	8,481	25,822	3,735	-	10,720	2,965	-	181	-	52,937	80,026	375	8,175	840	-	390	307,052
Tacoma	85	-	542	5,064	1,137	670	4,301	1,309	2,499	-	-	-	26,111	15,597	-	3,946	1,300	-	260	311,624
Seattle	-	-	883	307	583	-	3,672	69,781	780	-	152	-	19,931	4,908	-	105	761	-	33	544,771
PR	9,255	-	5,225	2,149	24,249	5,835	2,889	18,664	7,524	790	708	2,009	50,471	4,084	2,389	195	42,989	-	-	804,423

Descriptive information of the Public Use Waybill Sample data from 2007 to 2012 is shown in Table 12. Proportions of port choice, commodity type, container size, and channel depth are reviewed. Proportional distributions of port choice and commodity types are similarly matched with WISERTrade database, and Twenty-foot Equivalent Unit (TEU) size containers were over 70% of total containerized freight shipments. And about 80% of records used ports with depth of 50 foot or more. In addition to these, attributes of nautical distances, rail distances, port usage per month, value of commodity, and additional fees are contained in the data set for port choice behavior analysis. In Table 13, nautical distances are listed by the 12 major U.S. ports, and it is estimated from the six Asian trading partner countries. In general, the East Coast ports have longer maritime network distances than the West Coast ports, and the Miami, FL showed shorter distance than the Gulf Coast ports of Mobile, AL and Houston, TX. In Table 14, rail distance from the U.S. ports to the states are presented. The intermodal shipments on the East Coast ports showed shorter rail shipment distances than on the West Coast ports. Also, the minimum rail shipment distance was shorter from the East Coast ports than the West Coast. And for the monthly port usage, it is provided by each port authority and compared in the Twenty-foot Equivalent Unit (TEU) unit in

Table **15**. By ports, it is observed that almost all ports are utilized more than their capacity in terms of monthly usage, except the port of NY/NJ. The port of NY/NJ is assumed to receive less vessel calls than others during its off-season, and it does not seem so long with its median and mean usage amount. Finally, the value of commodity by shipments is described in U.S. dollar and it varied by items and sizes.

Table 12 Descriptive Table of the Public Use Waybill Sample Data 2007-2012 (Intermodal Shipments from the Six Asian Trading Partner Countries)

Variable	Value
Port Choice	
NY/NJ	7.68%
Norfolk	2.97%
Charleston	2.99%
Savannah	4.86%
Miami	3.04%
Mobile	2.11%
Houston	7.34%
LA/LB	48.43%
Oakland	3.35%
Tacoma	1.38%
Seattle	10.78%
PR	5.06%
Commodity Types	
Type 1	3.95%
Type 2	17.41%
Type 3	9.44%
Type 4	21.23%
Type 5	16.13%
Type 6	31.85%
Container Size	
Twenty-feet Equivalent Unit (TEU)	74.88%
Forty-feet Equivalent Unit (FEU)	25.12%
Channel Depth	
Deeper than 50 Feet	79.63%
Less than 50 Feet	20.37%

*Commodity Types are categorized in Table 7.

Table 13 Descriptive Analysis of Nautical Distances to U.S. Ports

Unit: Nautical Mileage	Min	Max	Median	Mean
NY/NJ, NJ	9,983.00	12,025.00	10,705.00	10,790.83
Norfolk, VA	9,778.00	11,987.00	10,500.00	10,613.67
Charleston, SC	9,568.00	11,724.00	10,290.00	10,394.83
Savannah, GA	9,553.00	11,688.00	10,275.00	10,376.33
Miami, FL	9,171.00	11,249.00	9,893.00	9,984.83
Mobile, AL	9,376.00	11,429.00	10,098.00	10,185.67
Houston, TX	9,519.00	11,643.00	10,241.00	10,340.50
LA/LB, CA	5,140.00	7,150.00	5,853.50	5,936.00
Oakland, CA	4,833.00	6,842.00	5,542.50	5,624.50
Tacoma, WA	4,544.00	6,171.00	5,159.50	5,169.00
Seattle, WA	4,544.00	6,171.00	5,159.50	5,169.00
Prince Rupert, BC	4,535.00	6,521.00	5,203.00	5,293.83

Table 14 Descriptive Analysis of Rail Distances from U.S. Ports to States

Unit: Rail Mileage	Min	Max	Median	Mean
NY/NJ, NJ	3.00	3,153.20	1,115.20	1,261.19
Norfolk, VA	5.10	3,278.20	1,044.00	1,296.04
Charleston, SC	19.00	3,227.00	1,061.70	1,308.72
Savannah, GA	108.40	3,210.00	1,123.00	1,298.76
Miami, FL	25.40	3,667.20	1,580.20	1,736.60
Mobile, AL	20.90	2,921.40	1,202.30	1,258.90
Houston, TX	257.90	2,615.70	1,301.50	1,339.39
LA/LB, CA	35.50	3,365.40	2,192.10	2,168.56
Oakland, CA	455.20	3,408.40	2,413.30	2,295.15
Tacoma, WA	36.40	3,688.10	2,578.00	2,354.39
Seattle, WA	24.70	3,668.50	2,529.80	2,346.02
Prince Rupert, BC	1,088.00	6,000.00	3,070.00	2,968.86

Table 15 Descriptive Analysis of the U.S. Port Monthly Usage in Tons (Capacity is in Thousand TEU)

	Min	Max	Median	Mean	Capacity
NY/NJ, NJ	19,975.37	251,211.95	218,789.58	213,017.41	8,772.00
Norfolk, VA	51,215.78	79,664.77	65,753.84	65,601.81	2,715.00
Charleston, SC	42,821.81	60,266.29	51,481.09	51,384.23	1,384.00
Savannah, GA	60,607.51	126,505.01	94,558.46	95,860.30	2,952.00
Miami, FL	28,606.61	33,899.11	33,799.59	33,112.02	1,292.00
Mobile, AL	28,863.62	34,301.87	34,100.69	33,440.55	898.00
Houston, TX	32,264.39	55,685.62	44,500.34	43,931.22	3,127.00
LA/LB, CA	355,298.45	735,190.96	608,903.29	603,870.09	16,342.00
Oakland, CA	35,725.22	76,543.93	61,074.79	61,428.51	3,369.00
Tacoma, WA	36,729.00	59,393.25	49,754.25	48,258.00	2,250.00
Seattle, WA	48,977.06	79,185.08	66,342.02	64,339.17	2,950.00
Prince Rupert, BC	9,542.62	23,543.32	13,564.07	15,019.51	452.00

Table 16 Descriptive Analysis of Value of Commodity (In U.S. Dollar)

Min	Max	Median	Mean
2900.00	697,300.00	12,107.00	20,117.00

PORT CHOICE BEHAVIOR MODEL

International freight shipments are directly affected by global economic conditions. The most recent economic recession has affected the fluctuation of international freight flow since 2008 falling export, rising unemployment, and falling incomes. (U.S. DOT., 2011) From then, with recovering economic conditions, overall freight flow in international trading activity increased and the U.S. import flow has also increased since 2009. In the process of fast recovery in trade varying from 9% to 20% (Hackett, 2012) and additional capacity expansions around the U.S. maritime networks including the Panama Canal and the Port of Prince Rupert, several studies about international freight flow have been introduced to estimate forthcoming flow trends around the U.S. These studies adopted a simulation based approach that optimizing annual freight flow with constraints of the condition of container liners and port facilities. (Fan et al., 2012; Leachman 2008; Blonigen and Wilson, 2006). Since these simulation models use the aggregate level data sources that is relatively easier than the disaggregate level one to obtain, a few research with various methods were introduced, and reasonably analyzed the international trade (Jong et al., 2004; Cullinane and Toy, 2000).

However, limitations still exist for an analysis with aggregate level data. It allows us to analyze overall flow and trends, but it is not possible to analyze shipments' influence on port choice. In the literature review, previous research approaching on a discrete choice model has been highlighted on export and domestic shipping mode choice. (Reis at al., 2013; Ungo and Sabonge, 2012; Moschovou and Giannopoulos, 2012; Levine et al.,

2009) Therefore, in this chapter, port choice behavior for containerized shipments into the U.S. that has not yet been tried by others will be introduced.

Proposed Methodology

As has been discussed in the previous chapters, finding a solid freight data source at the disaggregate level is not easy. There are several available sources at the aggregate level detailed by origin countries, by ports, by commodities, and by states. However, data sources at the disaggregate level are very limited and cost a lot to access for little information. Among the credible freight data sources at the disaggregate level, it was decided to use the Public Use Waybill Sample (PUWS) data. Even though it provides less information than the Private Use Waybill Sample data due to confidentiality issues, each record in the PUWS provides each shipments' port region, destination state, distance between port and state, transit cost, container size, value, weight, commodity types, and date of year.

However, among the given attributes in the PUWS, distance between port and state and transit cost are not provided for all records, and more than 50% of the records are veiled for distance and cost attributes due to confidentiality. Therefore, as introduced in the previous chapter, a rail distance matrix was matched with the PUWS data to replace the distance attributes. Once it is limited to obtain transit cost, the best alternate possible way to estimate the cost is to estimate based on distance. When the cost is estimated with distance unit cost, a problem arises that the distance variable is considered twice at the same time. Therefore, even though it is one of the most critical and primary factor in this port choice model, cost attribute is not considered for the port choice model. Also, capacity use by ports, channel depth, and additional fees are added to each record matching the date and port locations.

Based on the purpose of this analysis, a multinomial logit model is proposed to estimate the port choice model. A discrete choice model can be classified according to the number of available alternatives (Train, 2009). Binomial choice models have two available alternatives and multinomial choice models have three or more available alternatives. The multinomial choice models can be further classified according to model specifications: models assuming no correlation in unobserved factors over alternatives and models allowing correlation in unobserved factors among alternatives. Since the proposed model framework considers more than two alternatives and the assumption of no correlation in alternatives is acceptable, the port choice behavior will be estimated with the multinomial logit model.

For the proposed MNL structure, the probability that a shipment n choose port i becomes the following equation, where x_{nj} is a vector of observed variables relating to alternative j. More discussion on MNL models can be found in Train, 2009 and Hensher et al., 2005.

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}}$$

Model Estimation and Results

Since it is assumed that each shipment's port choice is independent of any other shipment's port choice, the probability of each shipment in the sample choosing the alternative to the one that it was observed to actually choose where β is a vector containing the parameter of the model. Then the log likelihood function will be the following equation, and the estimator is the value of β that maximizes the function.

$$\mathrm{LL}(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni} \, ln \, P_{ni}$$

Table 17 reviews the definition of explanatory variables used in the model. The retrieved data set from the PUWS provided valuable information about shipment characteristics. If the unveiled shipment characteristics such as maritime and rail transit cost, extra fees at port, and shipping distance were provided, it would be very helpful in estimating a more precise model.

Table 17 Variable Descriptions for Port Choice Mode

Variable Number	Variable Name	Explanation
1	port_chosen	Port chosen: 1 if NY/NJ, 2 if Norfolk, 3 if Charleston, 4 if Savannah, 5 if Miami, 6 if Mobile, 7 if Houston, 8 if LA/LB, 9 if Oakland, 10 if Tacoma, 11 if Seattle, and 12 if Prince Rupert
2~13	m_dist	Distance from origin country ports to the U.S. ports
14~25	s_dist	Distance from the U.S. ports to the states
25~36	port_use	Capacity Use by ports. Monthly imported container weight over maximum port capacity
37	port_dep	Depth of ports. (1 if over 50ft, 0 if less than 50ft)
38	port_fee	Additional fees (1 if applicable, 0 if not)
39	contr_size	Container size (1 if Twenty-Equivalent Unit (TEU), 0 if not)
40	value	Value of commodity in U.S. dollar
41	weight	Weight of commodity in Tons
42	com_type01	Commodity type 1
43	com_type02	Commodity type 2
44	com_type03	Commodity type 3
54	com_type04	Commodity type 4
46	com_type05	Commodity type 5
47	year	Year (1 if after 2009, 0 if not)

Model estimation results at convergence

The estimated model results at convergence are shown in Table 18, and the model was estimated for each port choice level. In terms of t-statistic values, all variables were tested and insignificant variables were removed in the final estimates. The table only shows significant variables used in the final estimates. Adjusted rho-square values including covariates showed improvements in the model's fit by 51.9%. The likelihood ratio test of this proposed and null model showed that the proposed model with covariates can enhance this model's fit significantly. The likelihood ratio test resulted in a value of 925,173.316, which is larger than the chi-squared statistic value of 67.328 with 57 degrees of freedom at a 99% significance level.

Table 18 Port Choice Model Estimates with Multinomial Logit Model

Independent Variable	Estimated Parameter (t-statistic)											
port_chosen	NY/NJ	Norfolk	Charleston	Savannah	Miami	Mobile	Houston	LA/LB	Oakland	Tacoma	Seattle	Prince Rupert
Variables that vary across alternate outcomes												
constant	- -	0.419 (15.55)	-0.189 (-2.49)	-0.27 (-3.93)	-0.828 (-20.36)	-0.506 (-6.55)	0.42 (-13.48)	0.441 (-13.74)	-1.1 (-28.19)	-0.453 (-9.15)	1.13 (39.51)	0.561 (17.05)
s_dist	0.48 (15.06)											
port_use	0.029 (5.17)											
Variables that does not vary across alternate outcomes												
port_dep	1.17 (33.27)											
port_fee	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
contr_size	- -	- -	-0.12 (-2.16)	-0.0714 (-1.29)	- -	-0.28 (-4.15)	0.413 (17.41)	0.256 (11.56)	-0.533 (-16.92)	0.0477 (0.0429)	0.983 (0.0477)	-0.571 (-23.81)
value	- -	0.00075 (14.49)	-0.00112 (-20.30)	-0.000297 (-9.67)	- -	-0.00253 (-2.12)	- -	- -	0.00097 (22.74)	- -	0.0005 (11.25)	0.00342 (15.33)
weight	- -	-0.0322 (-37.46)	0.0068 (15.45)	-0.0134 (-7.33)	- -	-0.0021 (-2.26)	-0.00114 (-20.20)	-0.00188 (-28.20)	-0.0047 (-18.11)	-0.00071 (-10.73)	-0.0378 (-70.35)	-0.00184 (-17.68)
com_type01	- -	- -	- -	- -	- -	- -	- -	- -	0.581 (7.41)	- -	-0.153 (-3.41)	- -
com_type02	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
com_type03	- -	- -	- -	- -	- -	- -	- -	- -	-0.094 (-1.51)	0.278 (5.05)	- -	0.674 (22.72)
com_type04	- -	- -	- -	- -	- -	- -	- -	0.0678 (1.07)	- -	- -	- -	- -
com_type05	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.109 (1.01)	- -	-0.054 (-0.76)
year	- -	0.239 (5.29)	- -	-0.204 (-3.17)	- -	-0.257 (-3.65)	0.324 (7.65)	0.0436 (1.03)	-0.628 (-13.48)	-0.409 (-7.79)	0.468 (11.32)	0.46 (10.33)
Number of observations	315,925											
Log likelihood at zero	-747,378.81											
Log likelihood at convergence	-359,489.21											
Adjusted Rho-square	0.519											

While the positive and negative signs of an alternative's covariates increase and decrease the chance of an alternative to be chosen, the following explanations could be concluded from Table

- When the shipping distance is considered as two parts of ocean and inland, only inland distance was significant but not the ocean distance.
- The ration of port capacity and usage was positively affected port selections.
- Ports with enough depth for the Post-Panamax size vessels receives more containerized freight.
- Containers in a twenty-foot equivalent unit (TEU) size are preferably sent to the ports of Houston, LA/LB, Tacoma, and Seattle.
- Commodities with higher value are more likely to use the ports of Norfolk, Oakland, and Seattle. But the magnitude will not be high.
- In terms of commodities, the ports along the East and Gulf Coast did not show significant attributes. But, the ports along the West Coast showed different significant attributes by ports. LA/LB receives more commodity type 4, Tacoma receives commodity types 3 and 5, and Prince Rupert receives type 3 more than the port of NY/NJ.
- In the recovery from the most recent economic recession, more shipments were sent to bigger ports: NY/NJ, Houston, LA/LB, Seattle, and Prince Rupert.

For measures of fit at the disaggregate level, the chosen port's probability with the highest predicted propensity was calculated. In 58% of cases, the model could correctly predict the highest probability for the port choice decision. If it is considered that many records were discarded due to missing values and hidden information due to confidentiality issues, a much more precise model could be estimated with a fully informed data source.

INLAND OPTIMIZATION MODELS

In the previous chapter, the port choice behaviors from Asian trading partner countries were estimated and significant attributes were found. The founding can support explaining and enhancing each port's current condition and enhancement measures for the near future. Since there have been announced capacity increases around the U.S. maritime networks, containerized freight flow in the U.S. will be changed and consequent distributions inside the U.S. will be different from now. Therefore, this Chapter discusses previously investigated results for containerized shipments into the U.S. which provided important perspectives: how the containerized cargos flow internationally and how and which ports are chosen.

Literature Review and Purpose

In addition to the overall intermodal freight literature reviews discussed in Chapter 2, more research on optimization approach on freight is highlighted. The Tioga Group, Inc. (2007 and 2008) and Wilson and Benson (2008) also analyzed port capacity and global trade in terms of containerized shipments. Active research and results have been discussed recently for the analysis of route optimization and selection. Leachman (2008) found that the container vessels are very sensitive to congestion along the West Coast ports, and they are very likely to shift their destination to less congested ports. But meanwhile, it is also found that San Pedro Bay will remain its vessel calls for the shipments from Asian countries when infrastructures are improved and congestions are relieved consequently securing lead time. Levine et al. (2009) introduced an origin-destination matrix of imported container freights into the U.S. using a linear program and gravity model. The anticipated matrix was based on Transportation Analysis Zones

(TAZ) unit area. Shintani et al. (2007) defined the calling sequences as the Knapsack problem, and introduced a solution using genetic algorithm-based heuristic approach. Lei Fan et al. (2010) suggested that the port of Prince Rupert will be a competitive alternative route for freight shpiments to the Midwest region. Also found that the route through the Panama Canal is less likely to impact the container flow between Asian trading partner countries and Midwest region. Considered attributes include vessel sizes, container carrier routes, and shipping corridor. Jula and Leachman (2011) estimated and found that the container fees at the San Pedro Bay ports are effective from the results of analytical model for long and short run supply chain approach. Included variables are estimates of container flow time based on volume, infrastructure, staffing level, and operating schedule of import shipments from Asian trading partner countries. Wilson et al. (2011) focused on the commodity type of grain shipment, and congestion estimates are evaluated with cost functions. Lei Fan et al. (2012) analyzed logistic system congestion with intermodal flow network model, and found capacity expansion would reduce congestion cost and waiting time for most ports where congestions are being observed. Per literature reviews in terms of optimization in the field of freight shipments, little research was found focusing on import freight shipment considering optimized route into and inside of the U.S.

The purpose of this effort is to analyze the imported container freight shipment distribution from seven Asian countries to the U.S Midwest regions. First of all, available data will be investigated: containerized cargo flows between the U.S. and trading partner countries; the capacities of the major ports in the U.S.; and the rail transit for imported container shipments inside the U.S. Also, additional relevant information to obtain cost data will be included. Based on these data, current distributions of imported container shipments to the U.S. Midwest regions will be analyzed and modeled with optimization process. Then the expanded capacity of the Panama Canal will be considered in the current model to analyze how the capacity change will affect distributions to the U.S. ports and the Midwest regions consequently. Next, the increased capacity at the Port of Prince Rupert will be considered in the current model for the analysis of distribution changes. Finally, both scenarios, expansion of the Panama Canal and the capacity increase at the Canadian port, will be considered at the same time to analyze how the import distribution into the U.S. is affected by their capacity changes.

Optimization Trial and Results

The purpose of this model is to distribute container freight flow through the least costly routes to the U.S. states as the final destination subject to a series of constraints. Objective function and constraints for the non-linear optimization procedure are discussed below.

Network Description

The networks of the import distribution are connections of Asian countries, the U.S. ports and the U.S. states. Based on the current container cargo flow between the Asian countries and the U.S. states, ocean and rail costs are considered for all possible origin-destination (OD) pair routes and optimized the total shipping cost to be the minimum according to assigned container cargo volume by commodity types on each route with constraints. It is summarized the current network in Figure 6 as below followed by descriptions of formulation and constraints.

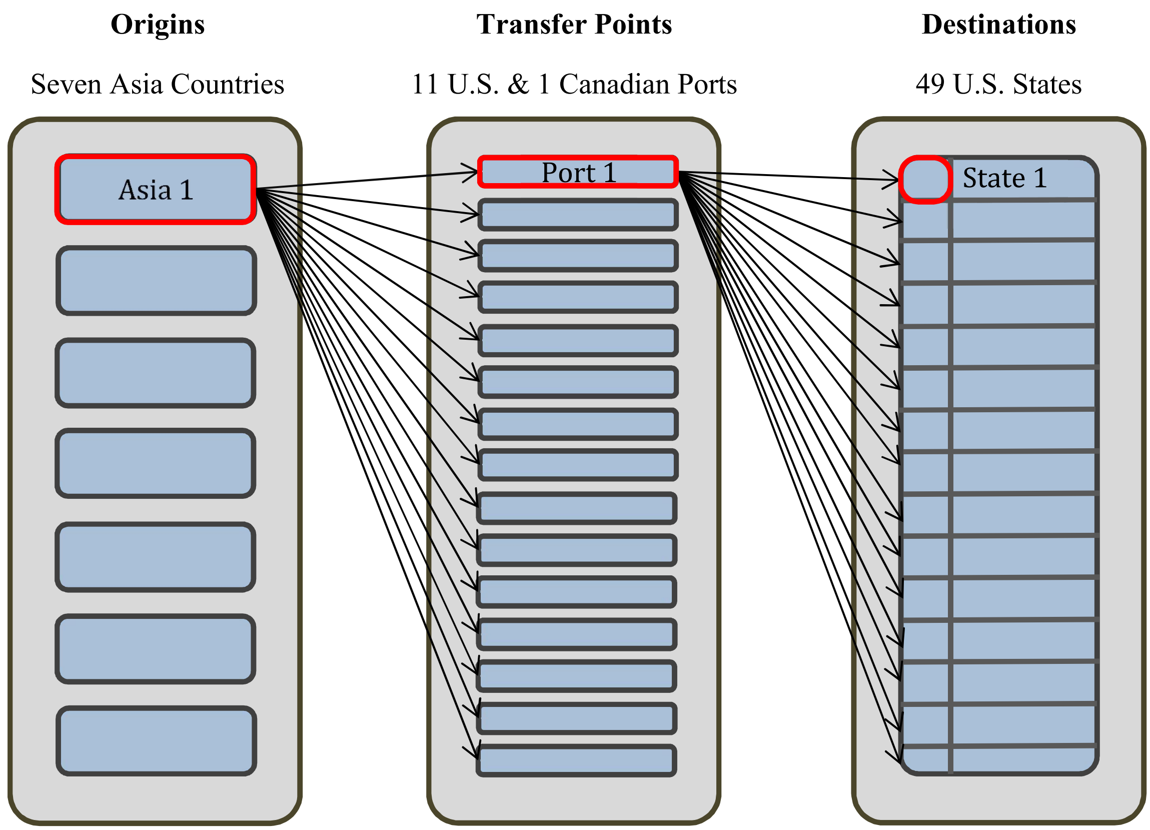


Figure 6 Container Flow Network from Asia to the U.S. States

Mathematic Formulation and Constraints

The objective function given below is to maximize auxiliary variable λ_j which is described in constraint (1). This auxiliary variable λ_j compromises the overall satisfactory level of total shipping costs of all possible OD pairs residing between upper and lower bounds at the jth objective. Since the auxiliary variable is cost value, the upper and lower bounds also should be cost value between OD pairs. The two bound values will be adjusted in calibration process, and its initial values can be estimated from the shipping costs. There are two reasons why the port location is subjected to optimizing the flow network: the first is that this thesis focuses on estimating the container freight distributions from Asian countries to the U.S. states through the ports and the second is that the forecasted origin-destination matrix can be estimated based on the global trade trends. Also, it assures a satisfactory level residing between the limits.

(Objective Function)

$$max \sum_{j=1} \lambda_j$$

(Constraint 1)

$$\lambda_j = \frac{(Upper_j - totalCost_j)}{(Upper_j - Lower_j)}, \quad (\lambda_j \leq 1)$$

Constraint (2) estimates the total cost, based on export amounts by commodity types from each origin ($export_{c,i}$) and proportions ($x_{c,i,j}, y_{c,j,k}$), at the *j*th port ($totalCost_j$) including costs between *i*th origin and *j*th port ($oceanCost_{ij}$) and costs between *j*th port and *k*th state ($inlandCost_{jk}$). Constraint (3) specifies that the distributed amount from an origin country to a port should not exceed the capacity of a port ($capacity_j$). Constraint (4) is a conditional statement for containers using the Panama Canal to be less than the Canal's capacity.

(Constraint 2)

$$totalCost_j = \sum_c \sum_i export_{c,i} \times x_{c,i,j} \times oceanCost_{ij} + \sum_c \sum_k \sum_i export_{c,i} \times x_{c,i,j} \times y_{c,j,k} \times inlandCost_{j,k}$$

(Constraint 3)

$$\sum_{c}\sum_{\mathrm{i}} \mathrm{export}_{\mathrm{c,i}} \times \mathrm{x}_{\mathrm{c,i,j}} \ \leq \ \mathrm{capacity}_{\mathrm{j}}$$

(Constraint 4)

$$\sum_{c}\sum_{j>7}\sum_{i} export_{c,i} \times x_{c,i,j} \leq PanamaCanalCap$$

Constraint (5) stipulates the container flow amount by commodity types to be the same between Asian origin countries ($att_{c,k}$) and U.S. destination states. Last, constraint (6) ensures that the total distribution for each commodity type probabilities become one between origin countries and ports and between ports and states respectively.

(Constraint 5)

$$att_{c,k} \ = \sum_{j}\sum_{i} export_{c,i} \times x_{c,i,j} \times y_{c,j.k}$$

(Constraint6)

$$\sum_{i} x_{c,i,j} = 1.0\,, \quad \sum_{k} y_{c,j,k} = 1.0$$

Data

Various types of datasets are required to estimate optimal container freight distributions from Asian trading partners to the U.S. states. In this part, the variables considered for the model will be discussed including container flows from Asian countries to the U.S. states, capacity of ports and the canal, and ocean, rail, and truck transit costs for the OD matrix.

- Container Flow from Origins to Destinations

Among the six primary Asian trading partner countries with the U.S. listed in US DOT report (US DOT, 2012), five countries are selected: China, Japan, Korea, Taiwan, and Hong Kong. From the list, Singapore is excluded and the two countries of Mongolia and Macao are included. Seven selected countries are categorized as an "East Asian" group by the United Nations, which is referred as one foreign origin region in the World Institute for Strategic Economic Research Trade (WISERTrade) database. The most recent data for these countries was retrieved from the WISERTrade database that provides extensive worldwide trade data including the amounts of U.S. imports and exports by individual port (World Institute for Strategic Economic Research, 2013). The selection criterion is the containerized cargo weights during 2012 and is listed in Table 19.

All the U.S. states are considered as destinations in this thesis, since the data of container volume flow from the Asian countries to each state in the U.S. is available from WISERTrade data. The states of Alaska and Hawaii are excluded since container flow to these states is assumed to be less affective from the capacity expansions at the Panama Canal and the Port of Prince Rupert. Once scenario analysis is completed, the Midwest regions will be divided into two groups of Chicago-North and Memphis-South. The Chicago-North region includes Illinois, Michigan, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin, and Memphis-South region includes Iowa, Indiana, Kansas, Missouri, Ohio, and Tennessee.

Table 19 Imported Container Amount from Seven Asian Trading Partners

Description	ANNUAL 2010	ANNUAL 2011	ANNUAL 2012
ALL PARTNER COUNTRIES	129,436.15	136,680.35	143,510.94
SEVEN ASIAN PARTNERS	60,340.20	61,511.82	63,371.95
China /Mongolia	47,922.02	48,494.10	48,933.49
Japan	4,355.06	4,675.29	5,339.20
South Korea	4,134.21	4,485.87	5,346.64
Taiwan	3,380.39	3,341.45	3,483.11
Hong Kong /Macao	296.67	268.41	269.51

* Retrieved from WISERTrade database
* Unit: Thousand Tons of Container (Metric)

- Capacity of the U.S. and Canadian Ports

In 2012, imported container cargo weights into the U.S. were 143.51 million tons and the port ranks are listed in Table 20 with selected ports highlighted in gray. In addition to the 13 selected U.S. ports on this list, the Port of Prince Rupert in Canada is included due to its capacity expansion. Among the 13 U.S. ports, Los Angeles and Long Beach in California and Newark and New York in New Jersey are considered as the same port due to their identical locations.

Container ports have various data and information available about capacity estimation. Recently, the TIOGA Group, Inc., has investigated container port capacity and utilization metrics (Tioga Group, Inc., 2010). Based on the five capacity dimensions of a container yard (CY), berth length, depth of the port, operating hours, and stacking height, the report proposed three types of measurements to estimate a port's capacity: land use, crane use, and berth use. They found that the U.S. ports have unused capacity inherent substantially in their maritime terminals and actual imported TEU (the twenty-foot equivalent unit) in 2008 reached about 50% or less of estimated capacity by types. (Only Los Angeles and Long Beach ports experienced 88% of CY utilization) An example of the West Coast capacity and utilization summary from the report is shown below with utilization percent. It is observed that the estimated port capacity by CY/cranes/berth exceeded actual TEU in 2008.

In this report, therefore, the capacity of each port is adopted from the results of the TIOGA Group's report. Since three different kinds of capacity estimations are suggested, the least capacity volume for each port is considered and listed below in Table 21. Also, the unit scale is converted from TEU to tonnage because the adopted volumes are estimated with a TEU scale and the WISERTrade database provides estimates in tonnage. The multiplied unit value for conversion from TEU to tonnage was seven tons per TEU (7 Ton/TEU). Even though the maximum capacity of the TEU is 21.6 tons, not all the containerized shipments use its capacity in full. Mitchell (2011) estimated one third for the averaged usage amount per TEU. This conversion unit value of 7 Ton/TEU will be applied to the shipping and rail cost estimation in the next part.

Table 20 U.S. Ports Import Amount of Containerized Shipment

Rank	Description	Annual 2012	Ratio (%)
	TOTAL ALL PORTS	143,510.93	100.00%
	TOTAL SELECTED PORTS	114,715.23	79.93%
1	Los Angeles, CA	34,291.99	23.90%
2	Newark, N.J.	21,800.99	15.19%
3	Houston, TX	8,790.36	6.13%
4	Savannah, GA	8,066.76	5.62%
5	Long Beach, CA	8,061.66	5.62%
6	Norfolk, VA	6,668.14	4.65%
7	Oakland, CA	5,631.55	3.92%
8	Seattle, WS	5,356.43	3.73%
9	Charleston, SC	5,355.36	3.73%
10	Baltimore, MD	3,843.12	2.68%
11	Tacoma, WA	3,809.49	2.65%
12	New York, N.Y.	2,758.42	1.92%
13	New Orleans, LA	2,663.62	1.86%
14	Miami, FL	2,422.83	1.69%
15	Pt. Everglades, FL	2,161.78	1.51%
16	Philadelphia, PA	2,034.23	1.42%
17	Mobile, AL	1,701.25	1.19%
18	San Juan, Puerto Rico	1,543.38	1.08%
19	Jobos, Puerto Rico	1,364.11	0.95%
20	Jacksonville, FL	1,339.89	0.93%

* Retrieved from WISERTrade database
* Unit: Thousand Tons of Container (Metric)

The capacity estimation of the Port of Prince Rupert in Canada is based on the TEU amount specified in the official webpage of the port, and is currently 500,000 TEU. The expected amount in 2020 with capacity expansion is advertised as 2 million TEU. The volume amount becomes 3.5 million tons that amount becomes three time more than the currently received at the Port of Prince Rupert.

Table 21 U.S. Port Capacity Comparison with Actual Imported Amount

No	Ports	Estimated Capacity by TIOGA report**	Imported Amount from Seven Asian Trading Partners in 2012	Usage Ratio by Seven Asian Trading Partners (%)
	TOTAL Capacity	325,899.26	61,599.11	18.90 %
1	NY/NJ, NJ	61,406.80	6,963.46	11.34%
2	Norfolk, VA	19,044.40	1,640.58	8.61%
3	Charleston, SC	9,686.80	1,151.83	11.89%
4	Savannah, GA	20,664.08	3,937.73	19.06%
5	Miami, FL	9,047.36	962.31	10.64%
6	Mobile, AL	6,287.68	347.91	5.53%
7	Houston, TX	21,889.28	1,587.53	7.25%
8	LA/LB, CA	114,391.87	31,477.80	27.52%
9	Oakland, CA	23,581.83	4,137.98	17.55%
10	Tacoma, WA	15,750.56	3,536.60	22.45%
11	Seattle, WA	20,648.60	2,690.71	13.03%
12	Prince Rupert, BC	3,500.00	3,164.67	90.42%

* Unit: Thousand Tons of Container (Metric)
** Least Capacity Estimated Amount

When the estimated port capacity is compared to the actual import amounts from the seven Asian countries, it is observed that almost all ports are currently using 30% capacity or lower. When the usage rate is considered by itself, it seems that port capacity is less utilized and operated inefficiently. However, if it is considered that the actual imported amount is only from the seven Asian trading partner countries taking about half of the total imported containerized freights into the U.S., port capacity is used in almost half full annually. And the seasonal variation is considered, the capacity usage is believed to be in efficient management. The only exception is found at the Port of Prince Rupert. Since the report from Tioga Inc. did not estimated the Canadian port and the capacity is assumed as provided by the port authority of Prince Rupert. Since this port provides lower costs and shorter shipping times for the containerized shipments from Asia, it is valid when the seven Asian trading partners consider ports.

- Capacity of the Panama Canal

The capacity of the Panama Canal is based on a report published by the Panama Canal Authority (2011). They reported all the vessel flows with origin and destination regions and total cargo amounts. From the report, container flows from the six Asian countries to the Gulf/East Coast are calculated.

- Ocean, Rail, and Truck Transit Cost

Transit costs for ocean, rail, and trucking are estimated based on the distance and the unit cost per mile in this report since every container shipping line carriers and rail companies make contracts with customers and keep the costs confidential. Also, to the best of the authors' knowledge with previous research (2014), there are few adoptable references to estimate ocean, rail, and trucking costs.

Table 22 The Panama Canal Capacity Trend for Asian Containerized Shipments

No	Description	Annual 2010	Annual 2011	Annual 2012
	Total	23,385.23	24,580.92	22,557.05
1	China/Hong Kong	12,845.15	13,275.80	11,471.70
2	Japan	3,863.97	3,279.60	4,055.19
3	Korea	4,922.06	6,287.91	5,329.43
4	Taiwan	1,601.89	1,586.32	1,619.49

Ocean Transit cost: First, distance tables from each country to each port are retrieved from the webpage "Portworld" which provide nautical mile distances from origin ports in Asia to U.S. ports. Unit costs of ocean shipments estimated by Mitchell (2011) were implied in this cost estimation. The unit cost value ($/mile/TEU) was separately estimated by the East/Gulf Coast and the West Coast. The East/Gulf Coast was applied with $0.26/mile/TEU and the West Coast was applied with $0.35/mile/TEU. From the obtained data, the distance is multiplied by the cost corresponding to its destination ports and the estimated ocean cost is calculated.

Inland cost: A rail and highway distance matrix of the U.S. was retrieved from the Oak Ridge National Laboratory database (2013). From the "Intercounty Distance Matrix," the distance between counties where major U.S. ports are located and container freight stations were obtained. The distances from the Canadian port to the U.S. states is obtained from distance calculators provided by major railroad companies (CN, BNSF, CSX, UP, and NS). Connections from the Port of Prince Rupert to the U.S. states is assumed only with rail network and highway connections are excluded. The unit cost value ($/mile/TEU) is adopted from the WebGIFT (Geospatial Intermodal Freight Transportation) freight model which was provided by the Rochester Institute of Technology and the University of Delaware using $0.81/mile/TEU for truck mode and $0.52/mile/TEU for rail mode (2013). The inland shipping costs in our model are estimated by multiplying the distance obtained from the Oak Ridge National Lab (ORNL) matrix by the unit cost.

Model Validation

- Current situation

The estimated container freight flow from the seven Asia trading partners to the selected U.S. ports was compared with actual flow retrieved from the WISERTrade database as plotted in Figure 7. When the model result is compared to the actual flow, all of the estimated flows to ports is validated at an almost 90% ratio with actual container flow, and the results from this model were applied to the analysis of three scenarios. For the distributional comparison between the ports in the U.S. states, Upper is plotted with estimated amounts, and lower is plotted with PUWS data in weight. Figure 8 shows the inland flow from ports to states in the Midwest region. Upper graph is plotted based on the estimated from this optimization model, and lower graph is plotted based on the PUWS data that is introduced in Table 11. The Midwest region is divided into two: Chicago-North and Memphis-South. The blue bars indicate containerized shipments through each port to the Chicago-North region including Illinois, Michigan, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. The red bars indicate shipments through to the Memphis-South region including Iowa, Indiana, Kansas, Missouri, Ohio, and Tennessee. When both estimates and actual plots are compared, almost similar distributional patterns were observed, and the differences were within 20%. Based on the distributional comparison in two aspects in commodity types at ports and destination flows to the Midwest region, this model describes current freight flows into the U.S. and is believed to be applicable for forecasting flow trend in the near future.

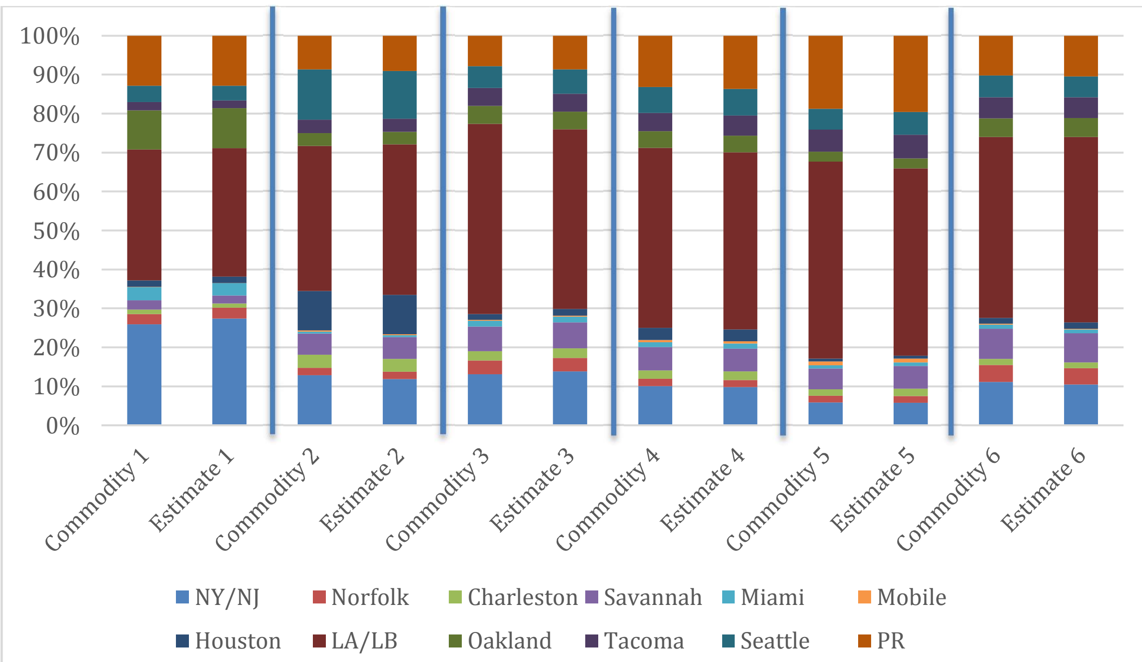
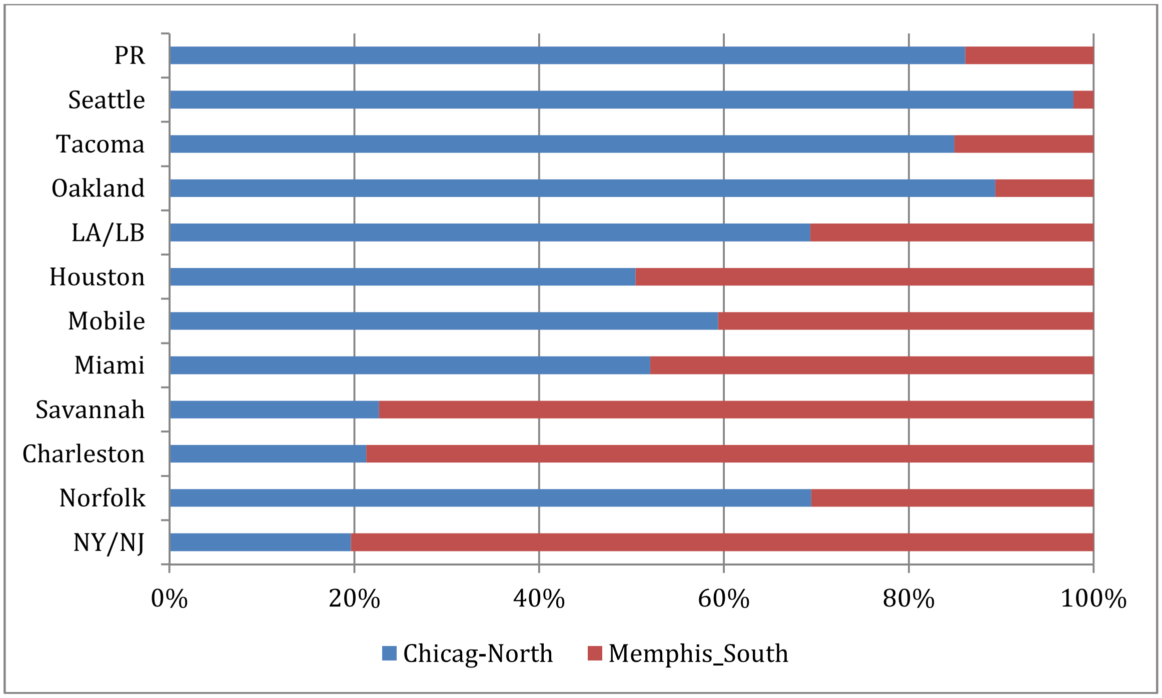
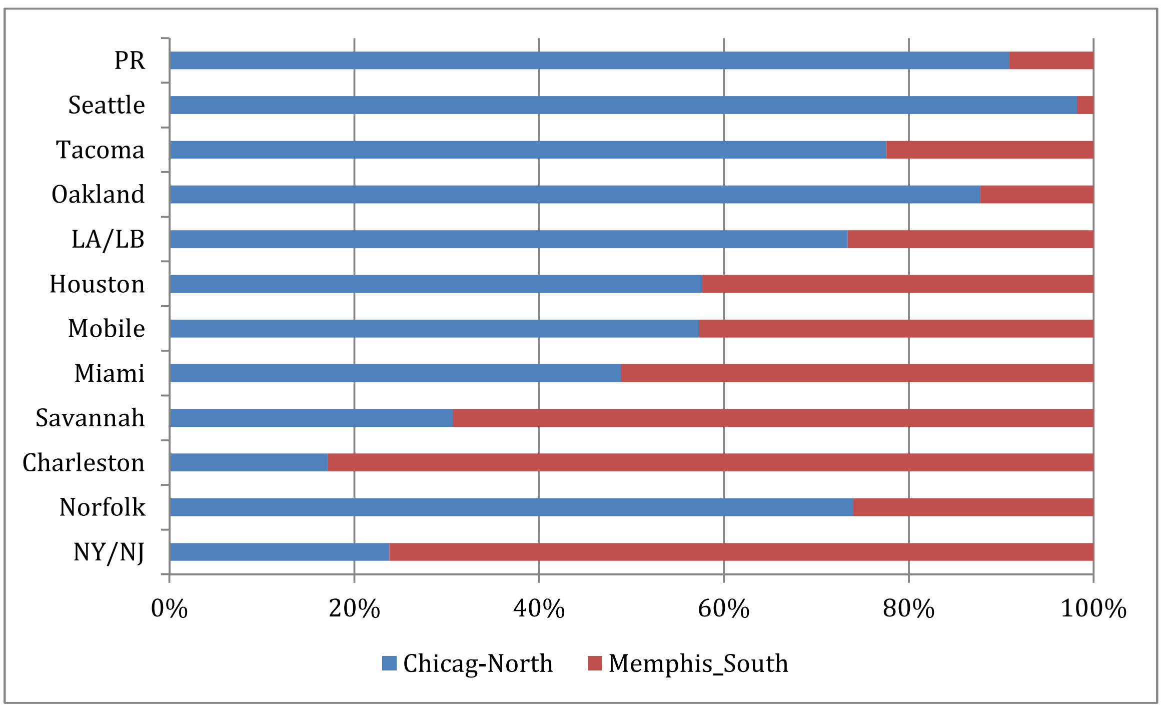


Figure 7 Actual and Estimated Container Freight Flow from Asia to the U.S. Ports





Upper is plotted with estimated amounts, and lower is plotted with PUWS data in weight.

Figure 8 Estimated Container Freight Flow from the U.S. Ports to Midwest

SCENARIO ANALYSIS OF CONTAINERIZED FREIGHT SHIPMENTS INTO THE U.S.

Scenarios Analysis and Results: Using the built optimization model for import container distribution into the U.S. Midwest region, three scenarios were analyzed: distributions under current capacity conditions, capacity expansions of the Panama Canal, and the Port of Prince Rupert respectively. The expanded Panama Canal is scheduled to initiate its service in 2016 and the Port of Prince Rupert will complete its capacity expansion project by 2020. For a closer comparison, the Panama Canal's expanded case is analyzed with 2019 data and the Canadian port expansion is considered with data for 2020. Also, all other variables are assumed to increase at a 3% rate annually based on several reports fixing the increase rate at around 3%.

Scenario I: Through the West Coast Ports

The first scenario analyzed freight flows through the West Coast ports with the container flow by 2012 assumed as current, 2019 with the Panama Canal Expansion, and 2020 with the Port of Prince Rupert Expansion, and are plotted in Figure 9. Los Angeles (LA) and Long Beach (LB) ports are identified as the biggest receiving ports from the seven Asian countries followed by Seattle and Prince Rupert. When the Panama Canal's expansion is assumed, the overall container flow through the West Coast decreases and this seems reasonable to believe that more shipment went through the other Coasts via expanded Panama Canal. On the contrary to this, two ports of Seattle and Prince Rupert experienced increased flow, and this seems illogical. When the final states are reviewed in Figure 10, majority of destination is identified as other states. When the final destination states are detailed from the two ports, it can be understood. Figure 11 and

Figure 12 show flow distributions from the two ports, Seattle and Prince Rupert to the states in percentage. From the two figures, it is not difficult to find that the destination states of the two ports are located closer from the West Coast ports than from those along the East and Gulf Coasts. And there also can be an assumption that the rail connection from the ports is systematically equipped and this is utilized to increase freight flows on the two ports. Thus, the increased amount for the two ports heading to other ports can be expected. As we assume this is a modeling approach to simulate freight flow, this flow may be possibly observed from any ports along the West Coast ports. Even though the LA/LB ports will receive more container cargos in 2020, all other ports on the West Coast will experience reduced container cargo arrivals. When Prince Rupert's capacity increase is assumed in 2020, more shipments will be sent to the Canadian port for all destination states including the Midwest regions, while the total import amount for the West Coast ports decline as in the case of 2019.

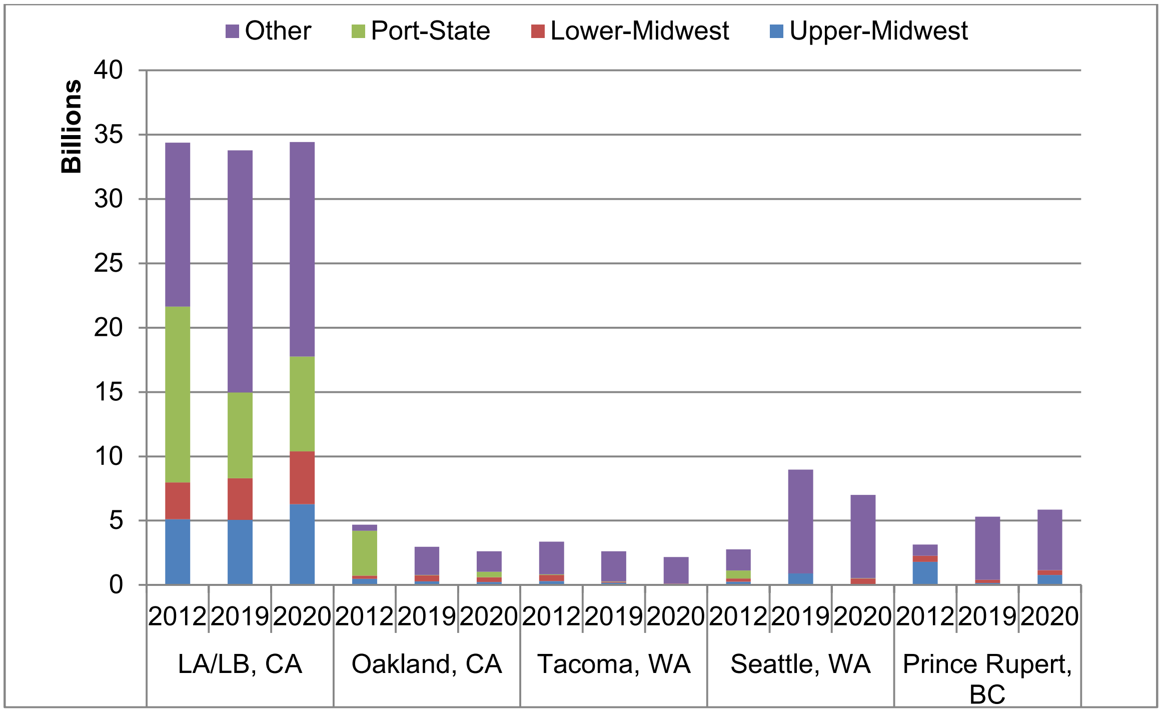


Figure 9 Scenario I: Freight Flow through the West Coast Ports

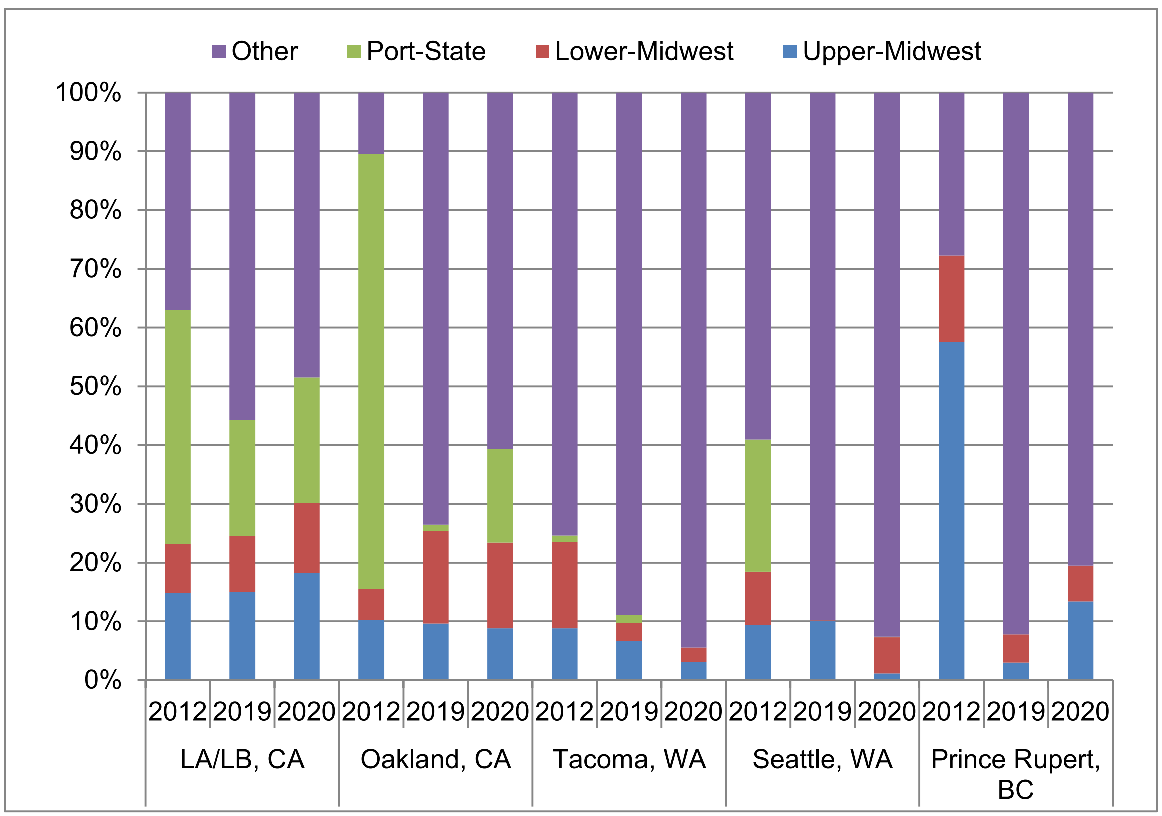


Figure 10 Scenario I: Freight Flow through the West Coast Ports - Fitted

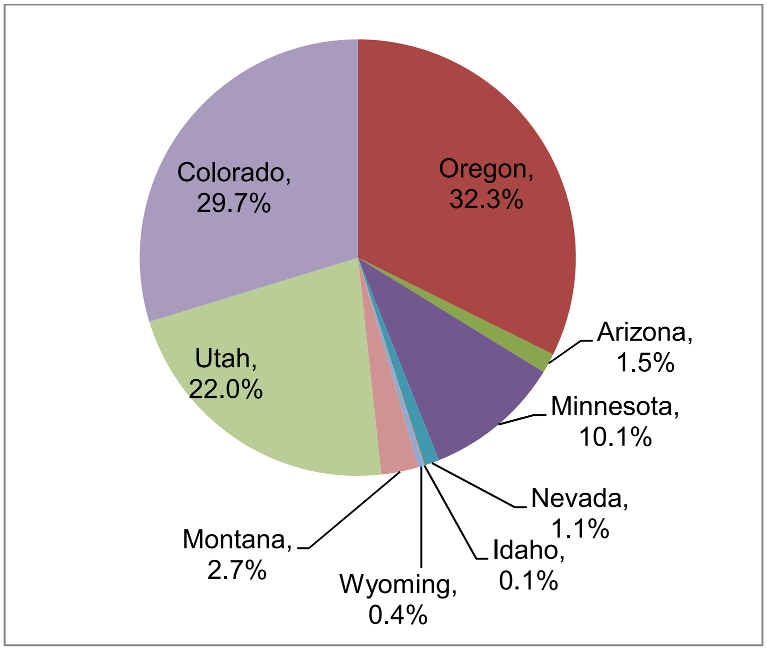


Figure 11 Freight Flow from Seattle to States in 2019

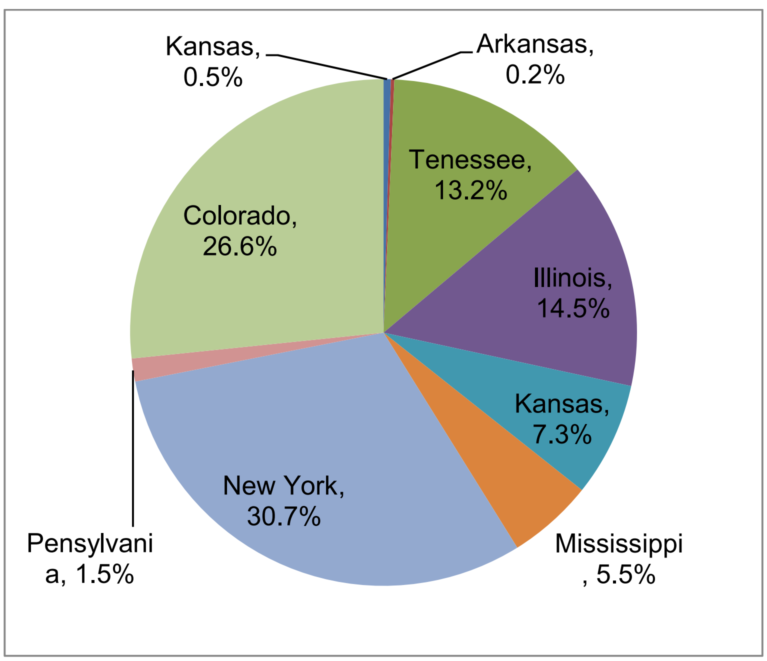


Figure 12 Freight Flow from Prince Rupert to States in 2019

Scenario II: Through the Gulf Coast Ports

The second scenario compared two cases of expansion at the Panama Canal and the Port of Prince Rupert to the current container flow of 2012 for the Gulf Coast ports. As indicated on the container flow volume plotted in Figure 13, few shipments are distributed from the Gulf Coast ports to the Midwest regions. When the Panama Canal expansion is assumed, however, the total flow into the Gulf Coast increases more than five times the current flow. Even though Miami experienced decrease of flow, increase amount from Houston and Mobile are significant. An obvious increased flow to the Midwest regions was also observed as well as a flow to other states. When Prince Rupert capacity increase is assumed, overall shipments coming into the Gulf Coast did not decrease but increased by more than 20% than the shipments in 2019. Even though almost half of the flow amount to the Midwest regions decreased, an especially large decrease is observed at Houston, but the flow to the Gulf Coast vicinity and other states is increased. The decreased flow amount for the Midwest regions from here is assumed to change the route to the ports of LA/LB along the West Coast ports.

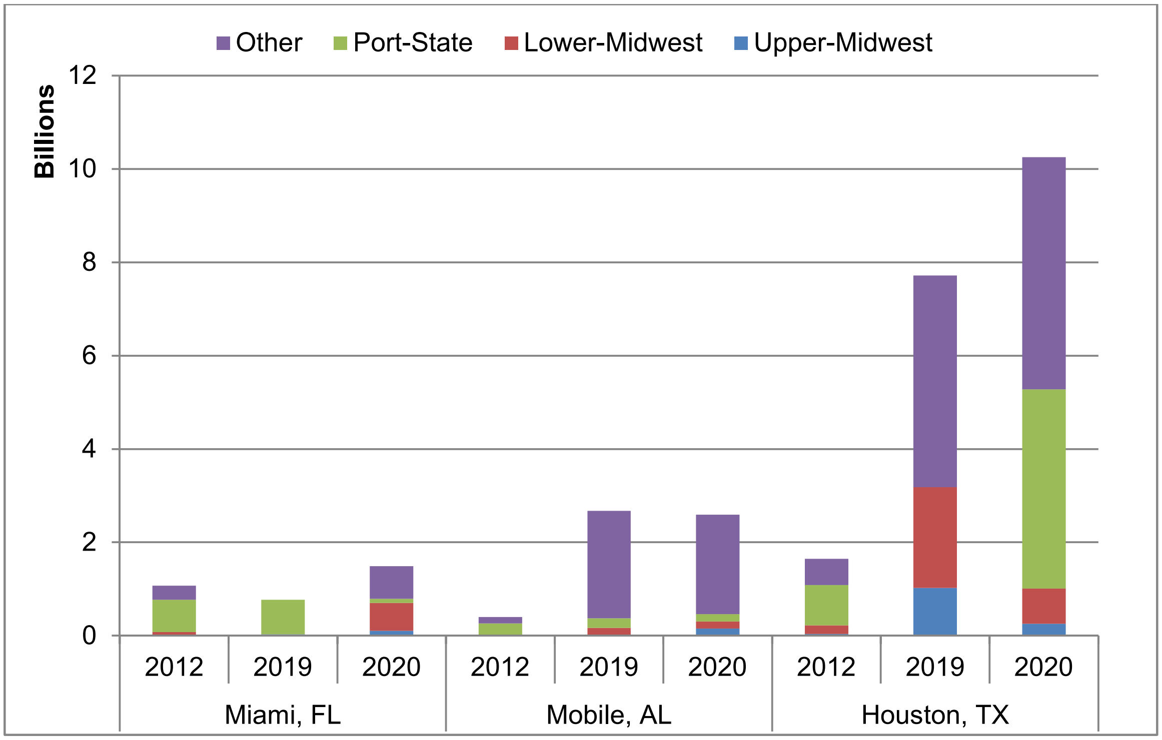


Figure 13 Scenario II: Freight Flow through the Gulf Coast Ports

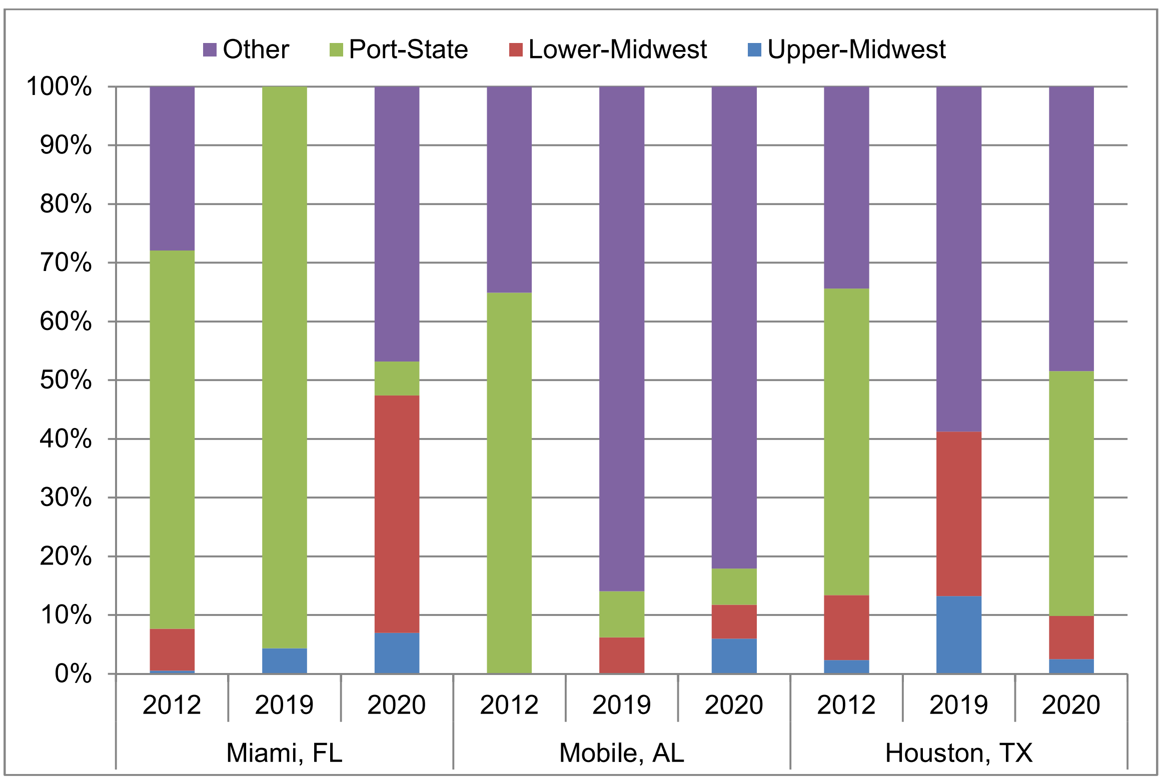


Figure 14 Scenario II: Freight Flow through the Gulf Coast Ports - Fitted

Scenario III: Through the East Coast Ports

The third scenario compared the two cases of expansion at the Panama Canal and the Port of Prince Rupert to the current container flow of 2012 for the East Coast ports as plotted in Figure 15 and Figure 16. When the Panama Canal expansion is expected, overall container flow into the East Coast increased by 30% but the flow assigned to the Midwest regions is not increased to that extent, as shown in the figures. This assumes that the increased capacity of the canal affects both flows to the Gulf Coast ports and to the East Coast ports. Though the significance is higher on the Gulf Coast ports, the East Coast ports also believed to be benefitted from capacity expansions on the Panama Canal. Also, when the Prince Rupert capacity increase is expected, assigned volumes to the Midwest regions and other states do not decrease but increase with significant changes. This can be explained that the Asian shipments to the East Coast ports are stable not affected by increased facility capacity on the West Coast, and markets on the East Coast may hold the shipment routes firm.

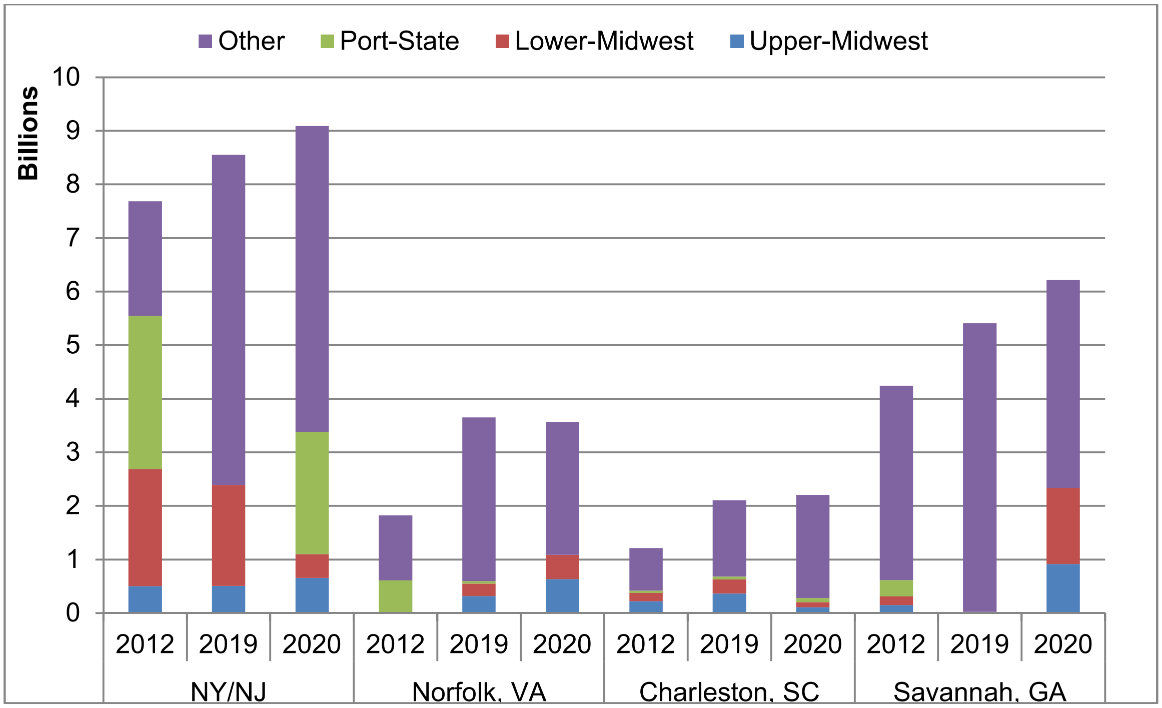


Figure 15 Scenario III: Freight Flow through the East Coast Ports

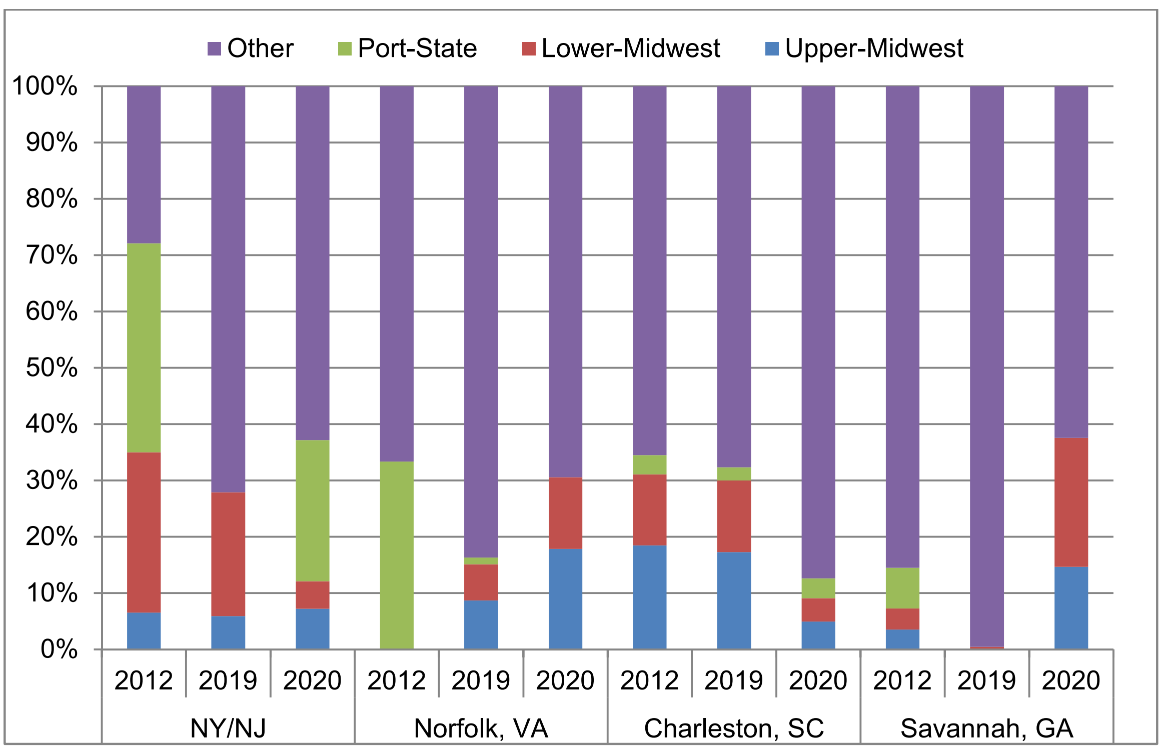


Figure 16 Scenario III: Freight Flow through the East Coast Ports - Fitted

Results

Two capacity increase cases of the Panama Canal and Prince Rupert are considered in this analysis based on current container flow between the seven Asian trading partners and the U.S. states. When the increased service capacity for the Panama Canal is assumed for the trading condition in 2019, many shipments changed their routes to the ports on the Gulf/East Coast. At the West Coast ports, inbound shipment volume decreased for the Midwest regions. Also shipments to other states did not show significant increase even though a 7-year time period is considered for capacity changes. On the other hand, the Gulf Coast ports experienced an increased container flow with huge amounts for both the Midwest regions and other states. At the East Coast ports, overall shipment volume increased and volume for the Midwest regions also increased. For the container flow to the Midwest regions according to capacity increase at the Panama Canal, the Gulf Coast ports experienced increased flow.

When the Port of Price Rupert was expected to complete the capacity increase project in 2020, changes in the shipment volume for the Midwest regions is not assumed. At the West Coast ports, LA/LB ports showed a dominant flow increase to the Midwest regions and other states, but the Port of Prince Rupert experienced little increased shipments to the Midwest regions. At the Gulf Coast ports, total flow amount is increased for other states. However, the flow to the Midwest regions decreased and this is assumed to be route changes for the West Coast ports. At the East Coast ports, shipments to the Midwest regions increased in amount, also overall shipments and shipments to other states were increased. This can be explained in that the Canadian port is geographically too far from the East Coast and its capacity increase affected the flow to the Midwest regions but not as much for other states.

As it is summarized from the results of optimization about containerized freight distributions into the U.S. by scenarios, expected capacity increase on two facilities of the Panama Canal and the Port of Prince Rupert changed freight amounts arriving on ports from the Asian trading partner countries and distributions from the ports to the U.S. states. The overall conclusion was introduced that the capacity increase of the Panama Canal resulted in a container flow increase at the Gulf/East Coasts to both the U.S. states and the Midwest regions. And for the Midwest region shipments, the capacity increase at the Port of Prince Rupert showed changes to the West Coast ports, but it did not shift shipments from the East and Gulf Coast ports to the West Coast ports significantly. This can be understood that the Panama Canal's expansion allowed more and larger vessels to be utilized for the shipments going to the U.S. through the East and Gulf Coast ports, but capacity increase on the Port of Prince Rupert was not attractive for the shipments to the East and Gulf Coast ports. Rather, shipments destined to the U.S. East through the West Coast ports are seemed to change their routes passing by the expanded Panama Canal. Based on the results and discussion, it can be concluded that the expansion of the Panama Canal affects the containerized freight shipments and its distribution than capacity increase on the Port of Prince Rupert.

PORT ENHANCEMENT MEASURES BASED ON RESULTS OF THE PORT CHOICE AND THE OPTIMIZATION MODELS

From the previous chapters, we estimated a port choice model and simulated containerized freight flows from the ports to the U.S. states from the Asian trading partner countries. The attribute affecting port choice behavior were separately estimated by port as shown in Table 23, and arriving freight amounts by scenarios are shown in percentage fitted by 2012 in Table 24. Based on the two results, in this chapter, it will be tried to introduce possible enhancement measures by port. Although here lies a critical assumption that the port choice behaviors for the Asian containerized freights into the U.S. keeps their attitude shown 2012 until 2020, it is believed to be valuable to propose a framework of port enhancement measures.

The port choice behavior analysis used the Public Use Waybill Sample (PUWS) data from 2007 to 2012, and the optimization model used WISERTrade data of 2012. Since the time frame for both data sources are contemporaries, an adjustment of the scope of application will not be necessary. As shown in Table 24, almost all ports on the East and Gulf Coast ports received more containerized freights in 2019 and 2020 than 2012. Miami experienced import decrease in 2019, but it is recovered in 2020 with more amounts than 2012. However, on the contrary, the ports along the West Coast received less containerized freights into the ports in 2019 than 2012. Although Seattle and Prince Rupert showed more container freights received in 2019, the actual amount is less than the increased amount on the East and Gulf Coast ports. In 2020, LA/LB recovered from the decrease, but the amount was almost the same to the one in 2012. Also Seattle showed decrease and Prince Rupert showed decreased rate of increase.

Table 23 Estimates of Port Choice Behavior for Asia Container Freights

	Positive (Estimated Parameter)	Negative (Estimated Parameter)
Common	- s_dist (0.48) - port_use,(0.029) - port_dept (1.17)	- N/A
NY/NJ	Base	Base
Norfolk	- value (0.00075)	- weight (-0.0322)
Charleston	- weight (0.0068)	- contr_size (-0.12) - value (-0.00112)
Savannah	- N/A	- contr_size (-0.0714) - value (-0.000297) - weight (-0.0134) - year (-0.204)
Miami	- N/A	- N/A
Mobile	- N/A	- contr_size (-0.28) - value (-0.00253) - weight (-0.021) - year (-0.257)
Houston	- contr_size (0.413) - year (0.324)	- weight (-0.00114)
LA/LB	- contr_size (0.256) - com_type04 (0.0678) - year (0.0436)	- weight (-0.00188)
Oakland	- value (0.00097) - com_type01 (0.581)	- contr_size (-0.533) - weight (-0.0047) - com_type03 (-0.094) - year (-0.628)
Tacoma	- contr_size (0.0477) - com_type03 (0.278) - com_type05 (0.109)	- weight (-0.00071) - year (-0.409)
Seattle	- contr_size (0.983) - value (0.0005) - year (0.468)	- weight (-0.0378) - com_type01 (-0.153)
Prince Rupert	- com_type03 (0.674) - year (0.46)	- contr_size (-0.571) - weight (-0.00184) - com_type05 (-0.054)

Table 24 Arriving Containerized Freight Amounts at Port Compared by Scenario Period

Port	2012	2019	2020
NY/NJ	100.0%	111.3%	118.3%
Norfolk	100.0%	200.5%	195.9%
Charleston	100.0%	173.5%	182.2%
Savannah	100.0%	127.5%	146.5%
Miami	100.0%	71.9%	144.7%
Mobile	100.0%	664.2%	879.2%
Houston	100.0%	468.0%	560.3%
LA/LB	100.0%	98.3%	100.2%
Oakland	100.0%	63.1%	56.0%
Tacoma	100.0%	78.1%	64.3%
Seattle	100.0%	322.4%	252.2%
Prince Rupert	100.0%	169.6%	186.6%

It is needles to highlight the measures for enhancements on the East and Gulf Coast ports since all the ports along the coasts experienced increase significantly. Yet, it will be informative to secure and develop operational policy of port. For ports on the West Coast experienced unstable and unsecured import amount changes by the capacity increases on the Panama Canal and the Port of Prince Rupert, the measures will be of help to enhance port usage rate from the Asian countries.

- Commonly, rail distance, port usage rate, and depth of port are positively affected for selecting ports. Since the shipments were intermodal trans-loading from the vessel to the rail, equipped connection to rail will positively affect. More popular ports will be competitive than other and enough channel depth will allow larger and full-loaded vessels at port.

- Higher value and less weight commodities visited Norfolk. From Table 8, it can be found that type 4 and 6 are the major commodities and the items are Textiles, Footwear, Machinery, and Electricals.
- On the other hand, Charleston was chosen by much weight and less value commodities in larger container box than TEU. Charleston receives commodity type 4 of Textiles and Footwear items more than other, and this can be understood that markets nearby the port is specialized using commodity type 4.
- Savannah and Mobile have weaknesses of reluctance from TEU, valuable, and weighted commodities. Even though the model forecasts showed increased amounts on the ports, those disadvantages would be better to resolve for enhancement.
- Houston was visited by TEU and recently, but weighted commodities were less likely to use this port. Since Houston dominantly receives Mineral/Chemical and Textile items, it will lose more freights unless appropriate improvement is not anticipated.
- LA/LB was more likely to be chosen by TEU, commodity type 4 (textiles and headgears), and recently. As like Houston, weight commodities were less likely to use this port. Since the commodity type 5 (Stone and Metals) are biggest portion among other commodity types at LA/LB, negative preferences on weight commodities will be an obstruction for enhancement.
- Valued commodities and commodity type 1 (Food Stuffs) showed more preference on Oakland. However, TEU, weight, and type 3 commodities (Plastic and Woods) were less likely to choose this port. Also after the recent economic

recession, this port was less likely to be chosen. But the commodity type 3 and 4 are the biggest items handled in Oakland, it will lose more freight amounts unless improvement is anticipated.

- Tacoma was chosen with TEU, type 3 (Plastic and Wood), and 5 (Stone and Metals) commodities more, but weigh commodities was not likely to use this port. Also less likely to be chosen after 2009. Commodity type 4 and 5 are major items at this port, but also same to Seattle. But more preference is observed on Tacoma, specializing the commodity type 3 and 5 may make this port popular.
- Seattle was preferred by TEU and valued commodities. After 2009, more shipments were likely to use this port. However, weight and type 1 commodity were less likely to. Since the commodity type 1 is least item handled, focusing on other commodities will vitalize containerized freight into this port.
- Prince Rupert is also preferred after 2009 with commodity type 3. But TEU, weight, and type 5 commodities were less likely to choose this port. The commodity type 5 is dominantly handled item on other and it is necessary to prepare means to maintain commodity type 5 items.

As itemized and discussed, the positive and negative attributes are compared with current commodities by port. Unlikely ports along the East and Gulf Coasts, ports on the West Coast showed little discrepancies between significant attributes and actual major commodities. Even though the Panama Canal's expansion is not considered at this point of time, it would be necessary to find activation plans specialized by port.

CONCLUSION

Summary

Recovering international trade and initiated plans to increase the capacities of maritime network facilities around the U.S. encouraged local governments and economic parties to attract international trading partners, especially from Asia which exports 60% or more of the container freight to the U.S. Identifying attributes affecting port choice is important for policy and decision making processes to improve the sustainability of international trade and of containerized freight flow. This dissertation, therefore, considered a model for port choice behavior to find significant attributes affecting its behavior, and a optimization simulation is modeled for scenarios with considerable changes along the containerized freight networks. Lastly, found attributes from the port choice model are applied to find measures for port enhancement.

To overcome the data limitations, several sources are referred to for discrete choice and optimization analysis. The first source is The Public Use Waybill Sample (PUWS) data that contains OD regions, sizes, weights, values, and commodity types. For precise port choice models, an additional attribute of distance is matched from the Oak Ridge National Laboratory, and additional fees and channel depths are surveyed from the major port authorities. The next source is WISERTrade, which is based on census data. It provides periodical containerized cargos by origin countries, ports and states in the U.S., volumes, weights, and commodities.

In Chapter 6, a multinomial logit (MNL) model was applied to estimate port choice behaviors of shipments from seven Asian trading partner countries. To the best of my knowledge, this chapter is the first to analyze port choice behavior from international trading partner countries of the U.S. The main reason for MNL adoption for the port choice model is that the proposed model framework considers more than two alternatives, and the assumption of no correlation in alternatives is acceptable. The model used data based on the PUWS, and estimated parameters were significant and validated the model with 58% prediction probabilities. The results showed that each port has significant attributes for choice by distance, capacity use, depth, additional fees, size, value, weight, commodities, and year.

In Chapter 7, a heuristic model was proposed to optimize the distribution of containerized freight flow through the least costly routes to the U.S. states as the final destination subject to a series of constraints. Constraints include freight flow from origin countries to the U.S. states, port and the Panama Canal capacity, annual flow by port and commodity, maritime and inland distances, and additional fees at ports. The goal function was set to minimize the shipping costs and cost is estimated based on the distance by unit cost. Among the constraints, commodity types were initially prepared and mathematized in this chapter, but the results were not confident enough to be considered as describing the current containerized freight flow. Therefore, the commodity type was excluded to finalize the model. The WISERTrade database was used for this model, and the estimated model was validated at 90% of actual containerized freight flow into the U.S. ports.

In Chapter 8, using the WISERTrade database and estimated optimization model, two capacity increase cases of the Panama Canal and Prince Rupert are considered in this chapter for scenario analysis based on current container flow between the seven Asian trading partners and U.S. states. When the increased service capacity from the Panama Canal is assumed, many shipments were observed to change their routes to the ports on the Gulf/East Coasts. At the West Coast ports, inbound shipment volume decreased for the Midwest regions. On the other hand, the Gulf Coast ports experienced a huge increase in container flow for both the Midwest regions and other states. At the East Coast ports, overall shipment volume increased and the volume for the Midwest regions also increased. For the container flow to the Midwest regions according to capacity increase at the Panama Canal, the Gulf Coast ports experienced an increased flow. When the Port of Price Rupert was assumed, at the West Coast ports, the LA/LB ports showed a dominant flow increase to the Midwest regions and other states, but the Port of Prince Rupert experienced little increase in shipments to the Midwest regions. At the Gulf Coast ports, total flow amount increased for other states. However, flow to the Midwest regions decreased and this is assumed to be due to route changes from the West Coast ports. At the East Coast ports, shipments to the Midwest regions increased, also overall shipments and shipments to other states increased. This can be explained in that the Canadian port is geographically too far from the East Coast and its capacity increase affected the flow to the Midwest regions but had less of an affect on the flow to other states.

In Chapter 9, based on the found attributes from the port choice model and distributions from the optimization models by scenario, enhancement measures were proposed by port. All ports are recommended to utilize rail connections and to deepen the channels enough to receive more vessels flawlessly. By port, different measures were anticipated since the significant attributes were different. Especially, ports on the West Coast were recommended to specialize by commodity types whether it is dominantly handling items or it is positively significant.

Contributions

This dissertation develops two models: port choice and distributional optimization. The port choice model begins with provision of possible data sources for discrete choice approach. By combining and matching with Census based data source, attributes affecting port choice behavior were estimated by port respectively. Even though various research navigated containerized freights, this model is the first effort finding attributes by ports using publicly available data source.

The optimization model was proposed and this model was applied to a scenario analysis. As expansions on the Panama Canal is imminent and the Port of Prince Rupert is expecting capacity increase in five years, estimating containerized freight flow changes around the U.S. is important. Even though there is limited information about distributions inside the U.S., this model predicted how overall freight flow will change its distributions inside the U.S. from ports to states when capacity expansions are assumed with 90% accuracy compared to Census based and PUWS data sources.

Based on the results from these two models, port enhancement measures are discussed differently by port. Since the measures for port enhancement aiming at 2019 and 2020 is proposed with attributes based on 2012, it may be less persuasive. However, this framework provides possible means to investigate critical factors what ports can be prepared for. Within a similar framework, various ports and maritime network differences can be applied to prepare anticipating policies.

Future Direction

This dissertation holds two implicit assumptions to resolve for an accurate analysis: data enrichment and modeling elaboration with external variables. From the beginning of the port choice model, it has been difficult to obtain important information about shipment records. A typical value is shipping cost. This information was not accessible due to confidentiality and costs a lot for a short term data. In the optimization model, it leaves much to be desired that the commodity types are not properly equipped. Due to the voluminous differences between China and other Asian countries, it was not appropriately simulated. Once the data source for shipping cost is available and approach for optimization with commodity types is feasible, much improved results would be available.

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APPENDICES I

Survey Letter

Email: marketinginfo@portla.org

Title: Data support from your port authority.

Dear Los Angeles Port Authority marketing manager,

First of all, wish a successful business on your port authority of Los Angeles.

Our transportation research lab at University of Illinois at Chicago (http://www.travelbehavior.com/) has been dedicated to research on transportation topics including freight planning and models.

As a part of current research on freight analysis, intermodal containerized shipments into the U.S. (import only) has been investigated with its behavioral aspects, and would like to ask your support of preciously valuable information and data from your port authority. Detailed questions are as below:

1. Does your port authority (or container port operator) charge additional fee which is not included in the rate? And if so, what is the cost by container types? (per TEU or FEU)
2. Has your port authority (or container port operator) experienced congestion? (That is, container vessels waiting at the seashore until their unloading operation.) When and how many hours or days had they waited to start unloading operation?

3. Had your port authority (or container port operator) experienced labor strike or dispute and stop operation? And if so, please let us know the dates.

4. Post- and New- panamax sizes and Ultra Large Container Vessel (ULCV) have been started their voyage. Is your port authority (or container port) ready to receive these size container vessels? Are your port's cranes ready for these size vessels? What is the depth of your port's channel?

We definitely acknowledge that these information and data contains business confidential facts which cannot be shared with others. So we promise your answers will be used only for research purposes and none of them will be shared with any kind of institutes or organizations without your permission which will be asked before it is attempted. If any publications from your authority or organization have been published, it will be really appreciated once it is advised.

Again, we do appreciate your favor and support, and hope a prosperous business.

Thank you and Sincerely,

APPENDICES II

Annual Containerized Freight Shipments from the Six Asian Countries by States (in kgs)

2008	China	Hong Kong	Japan	Korea	Singapore	Taiwan
Alabama	296,217,873	1,898,816	80,790,099	252,429,732	12,566,041	20,046,653
Arkansas	418,111,889	2,753,663	12,794,768	18,283,788	1,120,685	20,501,014
Arizona	238,425,424	1,608,708	6,916,950	9,267,785	525,389	20,557,883
California	13,430,045,904	102,203,500	1,362,209,133	998,827,848	44,911,164	1,051,806,319
Colorado	220,030,930	1,034,995	3,560,488	105,914,950	2,277,773	18,280,587
Connecticut	320,274,963	3,858,402	25,993,558	22,925,481	1,724,828	19,623,906
District Of Columbia	3,605,987	44,592	152	101,407	118,598	97,979
Delaware	41,415,055	407,947	2,530,329	970,938	262,136	2,608,060
Florida	1,620,707,027	18,885,419	67,079,161	45,104,726	3,509,744	73,680,833
Georgia	2,639,019,934	11,778,327	269,570,602	152,553,562	32,152,388	147,734,759
Iowa	217,823,095	1,610,661	23,570,564	15,546,127	419,364	31,354,408
Idaho	21,178,086	72,753	2,514,358	3,004,023	605	1,190,333
Illinois	2,717,913,418	13,657,726	399,398,172	173,361,478	20,981,992	310,863,387
Indiana	742,086,454	5,327,867	222,220,416	36,028,939	11,486,114	55,133,893
Kansas	365,332,136	1,121,061	11,190,108	13,457,487	490,168	20,346,116
Kentucky	399,092,118	5,310,260	295,462,880	27,373,720	4,722,647	21,797,214
Louisiana	239,319,108	7,638,096	10,074,186	18,269,391	3,516,858	32,124,467
Massachusetts	769,233,187	11,973,742	32,322,614	27,816,545	4,163,447	37,903,793
Maryland	419,935,131	3,739,118	25,334,350	47,642,125	4,051,086	19,189,267
Maine	24,804,080	190,998	2,232,747	1,359,513	2,719	1,682,082
Michigan	595,647,472	8,339,151	167,124,552	120,105,682	4,734,999	66,253,623
Minnesota	1,445,937,553	5,233,636	16,756,424	25,399,288	10,746,472	56,261,224
Missouri	615,563,964	3,891,777	22,168,639	24,306,570	2,364,281	43,056,625
Mississippi	416,486,406	2,288,445	13,693,334	27,230,965	955,068	30,514,250
Montana	17,335,719	41,693	481,602	1,458,107	7,627	1,973,029
North Carolina	1,372,588,880	10,291,242	157,065,393	118,777,496	2,954,944	103,523,583
North Dakota	9,775,343	79,963	4,501,224	1,291,315	1,084,215	706,940
Nebraska	151,472,275	468,660	6,986,916	6,649,606	13,356	8,594,035
New Hampshire	41,359,658	381,448	3,084,091	1,841,158	39,698	3,632,715
New Jersey	2,519,628,807	42,803,426	169,619,899	200,284,321	37,771,005	402,064,684
New Mexico	20,089,003	20,572	1,706,009	1,192,320	20,276	876,973
Nevada	186,938,367	1,234,519	2,517,967	8,805,335	154,641	7,795,489
New York	2,885,791,686	66,067,610	261,482,055	196,515,532	20,839,851	270,873,884
Ohio	1,496,296,120	12,494,652	395,506,631	84,644,003	22,016,670	177,725,641
Oklahoma	307,156,117	1,062,580	7,438,830	10,895,507	1,398,482	15,552,494
Oregon	552,493,370	3,586,147	147,860,024	49,884,544	3,888,953	36,266,101
Pennsylvania	1,408,604,721	11,595,810	71,830,379	76,558,941	8,993,121	119,315,294
Rhode Island	142,007,803	1,920,001	2,410,118	12,840,357	296,127	8,490,902
South Carolina	702,223,893	14,256,278	204,334,802	48,076,634	5,092,466	44,117,985
South Dakota	23,189,368	171,870	493,792	4,092,959	2,176	1,251,676

Tennessee	1,439,682,889	5,884,584	250,968,478	72,083,649	7,528,614	89,577,907
Texas	4,548,202,613	19,188,884	241,826,289	525,501,671	21,265,996	250,611,773
Utah	302,002,585	1,055,016	2,981,004	4,813,185	831,439	30,052,335
Virginia	874,181,794	11,186,221	77,540,877	28,874,247	11,524,876	32,020,638
Vermont	11,532,861	864,780	3,762,093	2,210,582	40,608	431,535
Washington	1,376,628,917	6,072,625	111,856,478	99,951,525	3,468,310	96,037,807
Wisconsin	726,035,381	10,867,242	33,845,446	24,280,320	4,095,857	64,868,563
West Virginia	33,367,383	386,831	29,351,226	1,462,360	31,552	750,869
Wyoming	28,261,542	27,483	965,242	2,387,895	-	505,595
Total	49,395,054,289	436,879,797	5,265,925,449	3,752,655,639	321,165,426	3,870,227,122
2009	China	Hong Kong	Japan	Korea	Singapore	Taiwan
Alabama	254,888,177	1,898,816	42,192,054	227,526,501	7,557,391	11,669,238
Arkansas	354,531,880	2,753,663	12,294,788	32,004,062	245,944	16,231,377
Arizona	189,074,512	1,608,708	13,455,376	6,056,510	344,720	12,257,993
California	11,517,810,818	102,203,500	974,752,008	831,398,479	40,000,940	856,987,932
Colorado	171,904,001	1,034,995	3,086,331	54,401,659	1,573,513	12,498,982
Connecticut	250,043,694	3,858,402	9,985,862	17,237,191	827,098	16,259,644
District Of Columbia	2,786,436	44,592	16,222	305,984	36,011	81,756
Delaware	35,003,792	407,947	1,908,330	1,292,658	102,631	3,705,710
Florida	1,318,356,455	18,885,419	27,244,344	42,362,715	2,448,230	63,764,113
Georgia	2,259,943,155	11,778,327	149,392,580	172,259,188	11,675,905	109,035,696
Iowa	161,550,242	1,610,661	17,322,011	9,034,351	164,351	24,119,889
Idaho	21,403,432	72,753	874,317	3,061,581	265,038	2,089,250
Illinois	2,141,780,483	13,657,726	215,892,216	145,672,471	13,285,644	210,467,525
Indiana	587,653,717	5,327,867	175,474,178	23,979,096	8,067,931	35,026,919
Kansas	298,006,702	1,121,061	5,367,227	8,538,982	405,539	12,741,239
Kentucky	259,156,939	5,310,260	197,397,428	17,008,578	4,865,603	14,266,037
Louisiana	174,199,059	7,638,096	13,760,851	11,123,765	5,080,146	11,608,576
Massachusetts	569,008,011	11,973,742	17,000,920	10,736,716	2,788,630	34,702,474
Maryland	347,435,693	3,739,118	14,212,520	27,951,497	2,432,407	18,451,072
Maine	22,713,616	190,998	1,268,791	1,371,051	3,092	1,276,052
Michigan	416,180,127	8,339,151	96,874,541	70,668,919	2,289,421	46,933,267
Minnesota	1,389,330,008	5,233,636	11,670,103	19,699,003	9,622,226	36,565,584
Missouri	474,661,136	3,891,777	15,415,808	21,729,958	1,989,432	33,689,178
Mississippi	352,781,579	2,288,445	12,230,905	24,650,038	1,056,444	20,656,284
Montana	9,707,658	41,693	129,000	796,460	5,434	1,152,644
North Carolina	1,007,969,966	10,291,242	145,173,345	79,092,013	2,783,639	81,299,667
North Dakota	12,906,393	79,963	2,489,523	2,675,716	1,032,060	1,230,945
Nebraska	110,590,396	468,660	3,722,865	7,109,330	1,658,458	6,147,560
New Hampshire	45,368,404	381,448	2,947,571	1,369,690	21,079	4,184,227
New Jersey	2,173,150,157	42,803,426	107,543,490	166,600,226	26,277,848	376,985,860
New Mexico	23,846,399	20,572	1,501,699	763,235	37,143	1,483,702
Nevada	162,774,123	1,234,519	2,352,438	8,592,912	131,032	7,621,251
New York	2,513,531,660	66,067,610	216,584,656	149,909,032	15,412,263	196,804,451

Ohio	1,173,423,872	12,494,652	256,850,535	76,627,039	15,958,250	115,825,421
Oklahoma	257,339,337	1,062,580	5,552,628	9,810,015	769,040	11,866,657
Oregon	386,355,664	3,586,147	88,746,995	53,828,049	2,044,857	22,860,946
Pennsylvania	1,109,504,293	11,595,810	46,286,436	52,581,450	9,262,484	88,488,712
Rhode Island	127,424,376	1,920,001	3,442,887	6,762,868	291,590	5,768,115
South Carolina	622,433,931	14,256,278	105,414,021	44,444,844	3,719,710	33,490,651
South Dakota	15,094,500	171,870	354,277	4,152,905	11,097	814,430
Tennessee	1,088,546,971	5,884,584	170,574,666	67,986,071	7,379,384	54,629,253
Texas	2,900,605,062	19,188,884	179,165,658	342,744,590	20,258,350	173,807,923
Utah	262,344,561	1,055,016	2,660,902	2,135,613	733,578	24,272,819
Virginia	713,062,180	11,186,221	52,253,434	33,885,301	5,784,833	22,827,632
Vermont	10,778,726	864,780	1,493,265	1,043,117	73,125	303,919
Washington	1,117,713,399	6,072,625	45,835,893	95,902,347	2,195,343	95,000,664
Wisconsin	601,722,292	10,867,242	21,058,660	24,802,132	2,895,448	42,480,985
West Virginia	38,202,780	386,831	31,442,975	1,313,492	96,912	3,484,103
Wyoming	23,124,204	27,483	623,301	1,081,654	-	271,673
Total	40,077,724,968	436,879,797	3,523,290,831	3,016,081,054	235,961,244	2,978,189,997
2010	China	Hong Kong	Japan	Korea	Singapore	Taiwan
Alabama	320,167,198	1,998,594	56,254,922	418,743,379	251,122	12,647,268
Arkansas	397,689,660	946,948	11,273,325	29,405,234	130,050	17,312,501
Arizona	223,143,489	718,040	9,777,709	5,511,877	311,901	19,598,568
California	13,297,556,255	68,398,017	964,820,734	1,076,465,060	52,322,891	983,367,439
Colorado	233,881,617	671,800	4,835,015	43,657,161	919,197	16,586,715
Connecticut	319,034,148	1,335,525	12,954,522	11,221,078	752,531	23,017,123
District Of Columbia	17,100,209	131,390	21,335	184,076	1,833	141,078
Delaware	42,262,029	1,078,255	2,243,035	1,359,454	396,092	2,768,855
Florida	1,585,057,424	14,818,503	44,545,751	60,253,173	1,865,584	70,980,305
Georgia	2,854,632,767	5,013,402	206,690,089	286,489,792	16,198,823	145,730,106
Iowa	207,219,563	714,536	11,939,597	11,806,516	209,208	30,115,879
Idaho	23,265,381	588,158	1,145,961	2,695,997	140,286	3,187,906
Illinois	2,485,477,916	10,005,919	322,347,997	214,123,447	11,097,861	293,178,465
Indiana	762,588,602	3,313,417	219,916,276	31,240,485	7,472,084	54,957,542
Kansas	349,529,962	279,211	6,581,814	24,066,627	4,160,467	20,404,610
Kentucky	356,662,560	2,488,258	290,228,940	28,048,756	6,471,534	15,166,172
Louisiana	196,591,864	6,166,517	10,617,413	36,952,882	4,058,605	12,408,968
Massachusetts	651,265,656	3,634,925	19,627,118	21,769,100	2,516,445	36,360,189
Maryland	500,435,649	2,272,413	16,138,543	68,211,771	3,583,167	25,928,343
Maine	34,646,368	201,192	1,723,237	916,249	22,900	770,000
Michigan	540,305,529	2,754,319	155,963,850	135,618,715	5,936,026	54,952,445
Minnesota	1,493,307,827	1,883,270	16,065,196	21,025,197	694,506	48,669,307
Missouri	568,594,375	3,059,778	14,909,793	23,094,166	988,340	40,156,738
Mississippi	385,206,261	1,027,908	19,506,580	22,204,879	1,439,216	23,333,244
Montana	9,053,436	136,601	162,802	1,491,010	4,879	1,390,493
North Carolina	1,174,463,044	4,957,155	127,298,999	93,154,909	3,888,825	105,913,940

North Dakota	31,730,882	75,436	2,194,996	1,956,977	508,368	2,376,441
Nebraska	159,082,268	914,464	4,526,890	10,222,778	12,365	6,616,099
New Hampshire	59,746,520	73,171	2,812,043	1,863,812	59,110	6,407,218
New Jersey	2,497,187,038	36,642,857	146,143,024	304,051,308	37,798,453	230,421,599
New Mexico	35,425,449	37,165	2,174,059	338,276	69,382	1,755,758
Nevada	176,526,606	932,279	2,139,136	4,044,063	162,036	10,354,920
New York	3,103,739,456	37,515,086	226,360,631	141,120,194	20,459,872	223,378,776
Ohio	1,417,875,881	4,531,936	379,703,270	116,393,864	16,646,656	146,803,570
Oklahoma	324,838,620	997,602	5,550,166	12,429,430	589,672	16,682,450
Oregon	424,284,612	1,891,149	106,480,420	32,631,554	1,068,774	32,603,156
Pennsylvania	1,336,300,297	6,653,759	66,810,152	90,855,279	6,573,759	99,209,852
Rhode Island	138,934,981	332,146	4,584,411	5,339,999	485,221	4,590,118
South Carolina	803,856,952	1,875,319	147,974,032	48,619,883	6,485,958	42,272,258
South Dakota	19,929,199	38,876	1,011,407	320,908	31,946	1,641,210
Tennessee	1,275,345,642	3,063,366	255,449,814	66,139,062	6,328,093	76,752,880
Texas	3,338,752,040	8,759,893	238,636,405	477,582,433	19,194,040	197,253,344
Utah	343,767,231	1,580,709	3,727,428	3,515,203	709,158	22,009,759
Virginia	834,267,403	4,656,741	65,882,332	26,942,321	2,630,335	34,861,613
Vermont	13,465,738	139,593	1,892,353	1,796,521	167,457	1,168,258
Washington	1,541,273,850	3,194,587	64,473,349	59,727,995	2,103,254	78,984,782
Wisconsin	675,116,919	5,177,267	26,039,080	35,923,142	607,938	56,801,059
West Virginia	62,836,507	89,481	33,557,274	1,795,615	25,127	4,919,741
Wyoming	25,532,442	26,145	432,006	946,195	36,000	269,328
Total	47,668,955,322	257,793,078	4,336,145,231	4,114,267,802	248,587,347	3,357,178,388
2011	China	Hong Kong	Japan	Korea	Singapore	Taiwan
Alabama	326,693,039	629,136	50,279,819	484,079,793	730,601	10,981,702
Arkansas	393,425,921	1,138,356	6,385,736	10,919,858	278,112	13,789,154
Arizona	241,110,898	651,483	10,236,688	13,727,635	475,311	18,988,631
California	13,104,181,247	70,457,103	1,199,283,042	1,039,228,158	42,861,717	933,768,867
Colorado	215,690,319	1,252,930	4,905,488	54,950,215	456,460	15,756,795
Connecticut	341,208,943	2,011,611	13,684,460	12,195,976	919,545	23,339,567
District Of Columbia	2,284,200	115,584	26,210	220,029	41,992	116,937
Delaware	43,945,191	569,168	3,728,814	2,032,490	536,735	3,496,302
Florida	1,600,707,541	15,757,660	52,516,890	78,898,685	2,006,108	61,477,502
Georgia	2,910,601,885	6,817,478	275,154,804	317,386,466	11,654,455	155,511,753
Iowa	216,802,508	459,847	23,511,875	17,201,468	411,186	28,354,889
Idaho	35,157,220	43,429	710,665	1,380,701	183,180	1,849,349
Illinois	2,513,940,589	9,948,740	367,158,551	181,201,566	10,318,343	299,357,792
Indiana	741,313,418	3,249,822	204,838,680	43,541,498	7,893,338	61,884,838
Kansas	367,124,601	168,199	7,400,581	29,577,554	6,236,191	13,374,305
Kentucky	391,206,247	4,827,084	230,522,783	32,773,804	6,728,741	19,855,814
Louisiana	272,666,333	3,623,902	9,630,852	9,494,791	8,305,252	12,036,447
Massachusetts	620,178,555	3,676,170	18,670,019	18,035,533	3,006,195	33,254,421
Maryland	557,205,962	3,821,973	23,462,361	41,505,785	2,882,936	24,576,537

Maine	32,270,068	115,672	1,239,417	681,077	7,801	985,440
Michigan	657,157,241	3,885,423	196,710,264	169,340,750	4,030,216	60,966,923
Minnesota	1,340,594,114	1,144,506	19,743,836	16,056,161	757,945	55,157,337
Missouri	600,540,887	1,848,918	19,734,048	24,143,248	4,165,222	40,608,248
Mississippi	432,197,929	3,974,968	27,239,420	22,335,052	1,488,074	29,361,499
Montana	20,130,622	99,616	234,550	1,085,916	5,471	1,642,559
North Carolina	1,158,072,386	5,261,079	126,577,856	101,091,482	3,499,414	106,717,227
North Dakota	65,664,800	73,330	4,289,912	3,914,068	464,382	405,134
Nebraska	178,804,286	970,000	4,579,843	10,079,108	34,398	5,912,929
New Hampshire	65,303,817	146,755	3,501,735	3,978,223	4,268	6,907,865
New Jersey	2,646,665,360	36,898,532	137,864,821	381,401,936	28,308,894	192,373,346
New Mexico	39,188,760	98,642	949,158	616,026	63,344	1,648,422
Nevada	165,175,286	602,243	2,997,840	4,624,087	306,599	9,179,886
New York	2,893,045,269	41,045,860	210,451,427	146,321,629	17,601,907	217,465,397
Ohio	1,404,983,290	4,401,960	343,966,100	114,438,867	18,671,967	157,103,234
Oklahoma	366,055,140	669,884	3,271,630	10,363,681	544,017	20,912,506
Oregon	450,719,035	1,008,041	91,309,320	24,233,072	1,493,712	31,127,953
Pennsylvania	1,341,409,558	8,615,445	95,196,090	64,930,036	6,001,999	105,805,696
Rhode Island	172,746,625	463,466	3,261,004	6,279,829	174,179	6,723,764
South Carolina	868,148,353	2,247,306	150,540,035	62,544,977	5,286,601	52,150,899
South Dakota	19,027,819	12,345	524,083	948,632	280	1,493,659
Tennessee	1,303,431,777	1,956,255	292,212,404	58,465,561	8,747,958	68,504,575
Texas	3,641,725,819	31,183,918	196,169,869	655,482,605	18,057,822	216,050,663
Utah	315,013,344	846,825	3,876,613	6,325,517	1,001,536	24,208,406
Virginia	888,253,616	6,902,543	66,410,745	28,796,486	6,950,129	32,949,434
Vermont	17,196,779	106,642	1,739,997	903,304	128,340	424,252
Washington	1,513,263,734	4,193,916	69,156,063	122,976,485	2,520,866	76,784,613
Wisconsin	688,904,494	6,664,617	23,758,808	25,896,597	7,625,480	55,110,503
West Virginia	47,912,932	33,478	34,143,368	1,278,096	1,247	5,969,108
Wyoming	26,911,408	5,164	448,295	381,663	3,977	561,038
Total	48,255,959,165	294,697,024	4,634,206,869	4,458,266,176	243,874,443	3,316,984,117
2012	China	Hong Kong	Japan	Korea	Singapore	Taiwan
Alabama	341,727,748	1,394,463	52,801,370	538,210,902	834,852	14,753,792
Arkansas	374,160,439	764,211	8,051,430	63,055,569	181,620	14,587,976
Arizona	251,496,162	1,409,237	13,776,109	13,547,657	562,718	16,182,828
California	13,665,897,946	64,310,960	1,258,944,327	1,155,292,653	38,266,514	970,646,486
Colorado	189,143,920	1,089,483	8,564,413	88,072,052	176,696	18,099,979
Connecticut	329,800,758	955,955	15,690,396	15,484,170	499,565	22,598,746
District Of Columbia	3,417,624	45,410	65,266	249,251	22,900	106,300
Delaware	43,868,266	394,062	4,361,708	3,191,783	757,777	3,282,459
Florida	1,630,379,693	12,921,829	55,575,081	74,259,216	1,830,793	66,497,116
Georgia	3,147,555,331	10,128,216	286,671,977	396,493,141	13,230,274	133,297,600
Iowa	210,508,479	650,158	33,768,557	16,241,952	600,597	20,779,173
Idaho	30,532,881	62,371	557,155	3,772,136	171,109	1,427,606

Illinois	2,367,182,508	13,495,998	416,786,231	177,947,658	11,443,902	308,601,791
Indiana	721,102,273	2,952,497	222,553,563	50,116,923	4,453,033	51,537,226
Kansas	362,078,410	606,997	7,630,496	24,844,939	167,710	14,291,119
Kentucky	427,062,127	1,634,135	254,752,031	35,528,753	3,933,518	40,547,278
Louisiana	199,999,167	2,607,288	9,651,656	15,398,029	8,854,887	12,207,852
Massachusetts	553,645,089	3,614,784	21,054,528	23,310,089	3,096,051	34,602,126
Maryland	548,160,195	3,787,798	28,566,706	40,609,242	2,692,410	27,050,007
Maine	22,760,318	143,996	348,033	841,246	1,522	1,646,860
Michigan	568,663,558	4,168,190	263,141,010	172,089,301	4,245,829	57,044,437
Minnesota	1,307,457,107	1,294,894	22,609,220	14,825,004	761,756	52,206,246
Missouri	757,048,351	1,454,102	19,657,879	25,532,401	2,906,018	46,570,567
Mississippi	415,142,131	2,902,001	49,379,960	18,601,135	435,170	24,996,357
Montana	28,635,628	41,178	216,892	1,127,007	22,885	1,160,122
North Carolina	1,185,821,479	3,067,025	136,966,166	144,442,591	5,415,725	116,130,197
North Dakota	98,241,052	67,381	5,033,462	3,004,025	69,120	317,620
Nebraska	184,970,376	84,387	5,156,672	9,309,553	3,206	5,217,694
New Hampshire	66,433,998	85,181	2,195,922	2,725,842	44,171	6,082,189
New Jersey	2,694,609,251	22,918,038	140,008,219	439,579,124	43,098,885	215,132,951
New Mexico	32,573,643	137,797	1,496,006	1,060,389	43,916	1,748,872
Nevada	204,683,434	464,372	2,767,234	5,064,537	306,189	11,094,335
New York	2,878,468,206	41,283,512	195,342,371	164,987,995	14,663,861	272,279,111
Ohio	1,394,073,182	2,945,327	390,003,040	121,359,939	19,513,325	159,133,068
Oklahoma	387,893,561	788,899	3,529,495	11,364,297	566,460	23,534,901
Oregon	459,916,479	1,222,056	106,091,319	58,949,826	1,303,566	29,687,898
Pennsylvania	1,352,257,115	6,523,078	71,532,462	81,321,753	7,300,779	98,170,568
Rhode Island	154,743,892	460,917	3,884,305	4,721,798	76,680	6,490,818
South Carolina	869,651,051	1,806,751	159,942,964	69,466,521	3,091,133	54,084,069
South Dakota	39,669,590	767	836,612	809,399	-	942,813
Tennessee	1,204,539,927	3,142,472	638,269,691	73,706,524	7,578,122	69,083,662
Texas	4,013,217,179	30,422,777	215,355,861	596,249,123	15,401,181	243,692,543
Utah	329,713,782	1,163,220	3,467,672	5,068,098	1,001,646	19,416,024
Virginia	878,856,646	6,687,028	71,064,694	36,756,548	16,034,570	35,328,138
Vermont	14,082,263	55,757	924,624	1,079,053	291,522	372,149
Washington	1,245,867,182	3,641,691	62,143,043	514,391,858	2,710,767	102,402,415
Wisconsin	692,287,151	5,944,483	24,185,687	28,679,413	4,743,695	48,918,879
West Virginia	29,566,550	287,092	43,025,100	2,711,342	6,263	8,745,448
Wyoming	23,928,283	102,962	801,083	1,189,782	-	378,903
Total	48,933,491,381	266,133,183	5,339,199,698	5,346,641,539	243,414,888	3,483,107,314

APPENDICES III

Containerized Freight Commodity Distribution at Ports (kgs)

2007	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	780,855,064	389,624,533	1,304,528,073	1,879,621,327	793,810,184	1,201,585,060
Norfolk	83,352,890	70,143,132	356,885,140	382,464,276	354,647,115	525,348,301
Charleston	30,193,212	121,857,452	207,266,960	459,423,968	316,565,033	250,005,690
Savannah	91,272,787	172,582,090	690,159,005	1,205,509,432	690,572,815	971,476,678
Miami	95,239,398	24,208,943	115,943,365	205,839,766	115,249,906	96,099,310
Mobile	810,517	9,168,780	10,343,665	20,822,886	88,282,427	3,979,916
Houston	39,493,729	882,849,429	106,277,823	391,225,785	138,996,758	166,143,997
LA/LB	1,179,348,255	1,564,883,527	6,437,840,780	0,404,915,320	9,733,645,532	6,592,531,905
Oakland	320,498,574	124,668,655	577,390,546	928,254,000	664,099,573	545,537,327
Tacoma	65,074,654	121,125,093	629,501,336	1,041,749,301	1,010,530,025	686,938,023
Seattle	147,064,235	212,786,278	722,012,151	1,075,799,849	998,359,189	702,126,618
PR	307,509,511	271,664,169	639,864,934	2,291,828,628	4,963,166,235	926,457,917
Total	3,140,712,826	3,965,562,081	1,798,013,778	0,287,454,538	9,867,924,792	2,668,230,742
2008	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	894,379,175	416,486,028	1,370,441,575	1,855,664,699	867,578,865	1,160,232,054
Norfolk	71,099,823	79,850,308	358,396,710	413,046,871	319,196,028	478,581,163
Charleston	31,272,073	138,536,195	215,798,410	456,434,436	297,304,042	231,931,568
Savannah	99,232,610	223,819,286	712,218,829	1,186,960,965	736,085,870	938,805,119
Miami	152,100,813	22,075,180	128,207,217	221,991,973	146,488,405	83,883,188
Mobile	478,582	5,715,675	16,386,337	37,529,781	118,560,568	6,601,599
Houston	38,173,498	536,890,975	117,906,810	478,389,746	128,939,362	155,783,382
LA/LB	1,208,868,729	1,593,186,172	5,726,735,463	9,278,802,044	9,209,371,187	5,620,504,610
Oakland	338,641,283	113,437,604	496,469,117	769,657,818	595,565,048	466,170,741
Tacoma	75,646,062	103,283,138	577,222,871	1,052,074,996	976,952,117	642,339,248
Seattle	118,652,946	246,429,515	559,916,263	834,576,958	908,338,649	601,535,425
PR	323,717,752	372,356,923	631,909,491	2,542,566,674	5,191,407,684	916,841,245

Total	3,352,263,346	3,852,066,999	10,911,609,093	19,127,696,961	19,495,787,825	11,303,209,342
2009	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	795,266,774	368,750,621	1,213,450,602	1,621,635,927	769,049,272	1,003,772,539
Norfolk	68,341,240	73,050,832	324,119,378	323,195,035	241,278,461	361,474,339
Charleston	33,702,819	106,541,870	172,390,153	310,776,966	183,871,444	142,367,286
Savannah	85,751,766	191,078,827	611,681,696	957,178,745	600,207,621	732,037,072
Miami	109,019,717	18,504,709	116,608,517	163,147,410	122,105,047	77,679,037
Mobile	408,757	4,243,165	19,683,329	48,587,057	92,027,278	6,655,121
Houston	56,458,964	284,707,564	111,021,179	312,082,494	101,829,628	139,256,204
LA/LB	1,086,926,141	1,295,619,897	4,727,306,022	7,350,265,660	7,339,144,668	4,342,007,103
Oakland	263,811,688	84,345,361	458,819,918	617,950,755	448,835,169	419,805,041
Tacoma	55,048,250	80,356,860	419,125,475	678,986,934	636,301,099	478,381,973
Seattle	119,784,526	298,372,373	497,345,210	777,015,599	673,783,897	598,047,687
PR	308,740,368	323,501,500	554,119,003	1,861,709,003	3,825,615,197	788,469,021
Total	2,983,261,010	3,129,073,579	9,225,670,482	5,022,531,585	15,034,048,781	9,089,952,423
2010	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	821,474,431	524,615,897	1,351,148,991	2,012,578,307	957,205,759	1,215,716,821
Norfolk	71,657,242	94,333,525	375,822,242	352,822,838	286,084,354	431,562,668
Charleston	43,410,714	149,677,495	211,595,865	398,217,780	226,536,048	155,765,551
Savannah	84,187,834	228,654,060	713,265,082	1,222,302,312	813,800,237	871,368,029
Miami	102,747,088	18,637,679	112,485,379	199,683,645	148,273,655	98,933,508
Mobile	268,552	8,821,836	18,507,352	40,674,381	112,605,383	10,484,216
Houston	49,926,152	423,097,620	118,233,727	333,929,538	91,972,855	137,542,333
LA/LB	1,105,757,816	1,316,017,850	5,349,829,164	8,663,443,904	8,861,824,069	5,309,843,362
Oakland	267,320,281	97,731,229	522,888,048	800,846,420	522,432,715	511,395,507
Tacoma	46,323,237	94,628,171	408,946,765	751,915,209	773,913,752	464,799,196
Seattle	132,134,765	523,859,577	781,349,101	1,281,358,563	1,157,862,914	845,008,808
PR	350,775,267	492,345,008	689,572,386	2,109,385,499	2,957,347,271	933,814,259
Total	3,075,983,379	3,972,419,947	10,653,644,102	18,167,158,396	16,909,859,012	10,986,234,258

2011	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	808,983,625	581,257,183	1,382,383,846	2,016,115,802	1,070,969,923	1,145,209,422
Norfolk	82,272,181	95,723,324	358,405,285	377,832,639	300,324,496	435,078,782
Charleston	44,127,020	155,146,892	249,660,766	401,120,195	261,165,323	145,647,315
Savannah	80,468,160	257,298,297	657,342,104	1,214,180,469	925,780,110	825,569,822
Miami	105,312,221	20,361,247	134,933,319	235,310,528	166,919,575	100,104,757
Mobile	305,191	9,835,338	29,794,371	68,663,115	174,749,762	24,571,309
Houston	45,091,333	510,217,250	102,269,638	382,267,759	124,291,342	130,083,851
LA/LB	1,119,777,209	1,555,818,503	5,370,642,498	8,890,696,201	9,647,843,055	4,999,798,369
Oakland	279,070,542	122,692,786	505,681,886	760,130,551	542,604,745	491,112,773
Tacoma	36,610,909	98,434,322	357,166,284	780,877,566	809,772,011	458,556,153
Seattle	129,030,102	495,973,895	625,604,924	1,236,392,505	1,046,722,706	619,275,207
PR	406,653,232	561,311,948	791,392,972	2,370,423,606	3,035,369,892	885,106,752
Total	3,137,701,725	4,464,070,985	10,565,277,893	18,734,010,936	18,106,512,940	10,260,114,512
2012	Commodity 1	Commodity 2	Commodity 3	Commodity 4	Commodity 5	Commodity 6
NY/NJ	847,057,574	562,910,131	1,454,997,199	1,959,893,145	1,151,257,351	1,159,356,523
Norfolk	86,365,198	81,959,222	392,696,169	383,898,537	340,323,911	459,116,594
Charleston	37,676,324	145,079,001	270,741,707	408,708,194	328,630,422	157,237,792
Savannah	76,433,010	239,612,120	701,157,579	1,174,348,113	1,046,417,604	811,907,563
Miami	112,311,089	21,284,744	160,813,607	251,519,411	169,091,105	107,182,006
Mobile	382,739	12,695,402	26,767,638	113,066,533	185,671,648	23,946,088
Houston	54,924,950	441,947,604	165,379,236	612,345,072	152,196,582	159,878,946
LA/LB	1,097,576,593	1,628,727,148	5,432,898,512	9,030,497,569	9,959,169,561	4,844,005,594
Oakland	328,639,681	143,969,537	510,671,777	845,530,498	498,541,666	497,537,041
Tacoma	70,459,154	149,638,763	517,476,878	907,305,039	1,122,347,786	567,236,918
Seattle	136,134,646	564,564,479	617,785,838	1,314,273,811	1,052,296,292	583,071,580
PR	420,387,890	379,358,072	874,261,599	2,573,863,819	3,695,621,267	1,064,291,318
Total	3,268,348,848	4,371,746,223	1,125,647,739	9,575,249,741	9,701,565,195	0,434,767,963

VITA

SANGHYEON KO

Education

- Ph.D. in Civil & Materials Engineering, Transportation Program
  - University of Illinois at Chicago – June 2015
- M.S. in Civil & Environmental Engineering, Transportation Program
  - University of Wisconsin at Madison – July 2009

Professional Experience – Highlight of Project Accomplishments

University of Illinois, Chicago - Research Assistant (2012 - Present)

- Analyzed imported container freight into the U.S. in terms of port selection and inland distribution by finding attributes affecting port selection and simulating inland distribution by scenarios
- Retrieved data from several sources and analyzed with records of 3.6 million and 35 variables for each record
- Research funded by US DOT: Research Initiative 6: Realigning Multimodal Freight Networks in Response to International Capacity Expansion sponsored by National Center for Freight and Infrastructure Research and Education (CFIRE)
- Technical analysis of transportation data and information utilizing ArcGIS and CUBE to form the basis for recommendations and other deliverables
- Optimized container freights by scenarios based on capacity expansions around the U.S. maritime network
- Visualized optimized flow on the rail and highway networks by scenarios

Khan Trans, Inc. - Logistic Coordinator (2009 - 2011)

- Leaded logistical management with freight distribution and monitoring supply chain, and interna-tional freight managements via various modes including containers, bulks, air, and rails
- Negotiated with container liners and airline carriers to develop business models for compet¬itive routes and costs
- Handled special freights of oversized/weighted machines, hot shots for urgent shipments, and show deliveries on limited time window

University of Wisconsin, Madison - Graduate Assistant (2006 - 2009)

- Employed statistical analysis in evaluating and analyzing crash frequency, traffic volume, weather conditions and drivers attributes through exit ramp designs
- Performed various duties such as analyzing and retrieving ramp area crash data from highway crash data pool from Wisconsin DOT
- Conducted data collection and on-site analysis for a project of A Five-Year Analysis of the Safety Impacts of Crossover Median Crashes in Wisconsin
- Georeferencing and Geocoding crash locations in ArcGIS as well as calibrating crash/photo log/highway log data obtained from Wisconsin DOT to identify crash locations

Teaching Experiences

Guest Lecturer August to December 2014

- Advanced Travel Demand Analysis (CME 503): Introduction of OR and Optimization in Transportation. Lectured optimization theorem including specific modeling techniques of Linear/Non-Liner/Fuzzy programming. Also provided software usage with R and Matlab.

Teaching Assistant August to December 2012

- Transportation Engineering (CME 302): Course focused on fundamentals of transportation engineering. Included design, operations and planning of transportation systems of various technologies, emphasizing road and public transit. Assisted but not limited to provide problem set solution, lab experiment support, and grading.

Professional Publications and Presentations

- Sanghyeon Ko, Jaehoon Kim, Michael D. Anderson, Kouros Mohammadian. Changes of Containerized Freight Distribution by Capacity Increase on the Maritime Network into the U.S. 2015 TRB 94rd Annual Meeting of the Transportation Research Board. Washington D.C. January 11-15th 2015.
- Sanghyeon Ko. Behavioral Analysis of Containerized Freight Shipment into the U.S. Doctoral Student Research in Transportation Modeling workshop. 2015 TRB 94rd Annual Meeting of the Transportation Research Board. Washington D.C. January 11-15th 2015.
- Sanghyeon Ko, Kouros Mohammadian. Analysis of Changes in Freight Distribution from Major Capacity Expansion Projects, Symposium of Panama Canal Expansion: Local, Regional, and National Impacts. Chicago, 2014.
- Sanghyeon Ko, Behzad Karimi, Kouros Mohammadian. Review for the U.S. Containerized Import Freight Network with Peripheral Capacity Expansions. 2014 TRB 93rd Annual Meeting of the Transportation Research Board. Washington D.C. January 12-16th 2014.
- Sanghyeon Ko, Behzad Karimi, Kouros Mohammadian. Scenario Analysis of Containerized Freight Distribution into the Midwest Region in Response with Capacity Expansions. 2014 TRB 93rd Annual Meeting of the Transportation Research Board. Washington D.C. January 12-16th 2014.
- Sanghyeon Ko, Behzad Karimi, Kouros Mohammadian. Analysis of Changes in Freight Distribution from Major Capacity Expansion Projects. 2013 INFORMS Annual Meeting. Minneapolis, MN. Conference Presentation. October 6-9th 2013.
- Sanghyeon Ko, Behzad Karimi, Kouros Mohammadian, Kazuya Kawamura. Analysis of Imported Containerized Shipment Distribution to the Midwest Regions with Expected Capacity Expansion Projects. 2013 METRANS International Urban Freight (I-NUF) Conference. Long Beach, CA. Conference Presentation. October 8-10th 2013.

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