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Realigning Multimodal Freight Networks in Response to International Capacity Expansion

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16. Abstract The widely discussed Panama Canal expansion project is expected to be completed by 2014. Following that expansion, container flows for imports and exports will likely shift to eastern and Gulf coast ports and the increased freight volumes may strain the already congested intermodal transportation system. This project will examine how expansion of the Panama Canal may redistribute trade volumes across the intermodal system, including ports, waterways, railroads, and highways. This research will assess potential effects of the Canal's expansion on the freight networks in the South and Midwest and identify rational strategies for the nation's multimodal network in response to this international capacity expansion. A promising opportunity for gaining economic competitiveness is the freight village concept. Freight villages and global logistics parks are planned distribution, logistics, and warehousing communities built around intermodal hubs with the expectation of exogenous and endogenous growth. However, partners at the University of Memphis and the University of Southern Mississippi have shown that not all intermodal facilities are significant job creators and that the reasons for different economic impacts need to be better understood.		
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FORWARD

This report provides a valuable resource to assist in making informed choices about the potential container freight flows and their impacts on transportation networks in the CFIRE region to foster economic development of the region fueled by the expansion of Panama Canal project. This CFIRE Research Initiative # 6 “Realigning Multimodal Freight Networks in Response to International Capacity Expansion” was conducted by researchers from the University of Southern Mississippi, University of Memphis, University of Alabama – Huntsville, University of Illinois – Chicago, University of Wisconsin – Superior, and the University of South Alabama under the direction of CFIRE executive management team. This document will be of particular interest to individuals who plan and evaluate container freight flows through the CFIRE region. Other audiences for this document include policymakers, transportation professionals, and students in related fields.

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EXECUTIVE SUMMARY

Widely discussed Panama Canal expansion project is expected to be completed by 2015. Following that expansion, container flows for imports and exports will likely shift to Eastern and Gulf coast ports and the increased freight volumes may strain the already congested intermodal transportation system. This research examined how expansion of the Panama Canal may redistribute trade volumes across the intermodal system, including ports, waterways, railroads, and highways within the CFIRE region that includes primarily Midwest and US South regions.

This research will provide decision makers with the information necessary to identify bottlenecks in the transportation network due to international capacity expansion and to identify/invest in targeted multimodal system improvements. This research will also provide communities, states, developers, and industry with the information and web-based tool to assess potential freight routes, intermodal sites and growth potential for freight village development resulting from changes in intermodal freight flows. It will also provide 3PLs, freight forwarders, and other logistics providers with the information and tools to select the best strategy for freight movement.

This research tried to assess potential effects of the Canal's expansion on the transportation network in the South and Midwest and identify rational strategies for the nation's multimodal network in response to this international capacity expansion. Some key activities of this research were to develop and analyze a comprehensive database of intermodal freight networks, freight distribution scenarios, optimized freight flows, and visualization of potential bottlenecks. Research activities also included transportation network analysis with possible scenarios of shifting intermodal hub locations. This research conducted capacity analysis of existing transportation infrastructures to identify the possibility of capacity expansion. This research also conduct economic development analysis to quantify the economic growth due to the increased freights movement and handling and developed a dynamic web-based information tools that can be used in assessing and selecting the best routes for freight movement and best location for freight facilities.

One of the key aspects of this research was to identify the bottleneck transportation network to efficient freight movement based on developed distribution scenarios. While developing the scenario based distribution model, this research focused on the top six Asian countries that contribute to 62% of the container imports. It also focused on the top 10 US ports and three more ports in the US that are critical to the study regions (Midwest and US South) of this research and 1 Canadian port which is also critical to the study region. It mainly focused on maritime transportation from six Asian countries to the US ports and intermodal transportation (Road and Rail) from these ports to the study regions.

As part of the distribution scenario analysis two approaches were considered in this research. The first approach was to consider six possible outcome of freight distribution due to Panama Canal expansion. This research didn't produce any forecasts, but took individual forecasts done by the US ports as a basis. Based on these six scenarios, this research analyzed the impact on transportation network and visualized using GIS tool. The second approach was to develop an optimized freight distribution within the CFIRE region. While developing optimized scenarios, this research considered several factors including cost of shipment, transit time, customs clearance time, labor union issues, sailing frequency, port and canal capacities, etc. in the distribution model. Distribution Scenario model can be helpful to identify the optimum scenarios while transportation network model help to identify best routes and visualizes the impact in transportation network. The output of these models can provide information to transportation stakeholders to devise necessary policies that will minimize the negative impact of freight redistribution.

Another major contribution of this research was to conduct economic development analysis to quantify the projected economic growth due to the modeled change in freights movement and handling. Specifically this part of the study converts the expected change in freight tonnage (thousand metric tons of containers) per region from the transportation model component into measures of economic competitiveness. Overall, there appears to be little economic impact on Memphis-South and Port States regions from the Panama Canal and the Port of Prince Rupert expansions. This research found that some port states will have to adjust their source ports for imports, but the impact on the overall regional economies will be insignificant. However, Chicago-North and other states regions will have significant impacts from the Panama Canal and the Port of Prince Rupert expansions under all three scenarios. Based on the economic development models, this research found that many areas will see insignificant development and some areas will see the largest increase in traffic and are prime targets for intermodal development. The cities including Fargo, ND; Joplin, MO; Meridian, MS; Bellevue, NE; St. Cloud, MI; Farragut, TN; Goodlettsville, TN; Prattville, AL; East Ridge, TN; Effingham, IL; and Hattiesburg, MS are expected to see significant increases in freight volume so are potential locations for intermodal facility development. The reality is that they all technically have some kind of intermodal facility, but they are smaller ones that can be expanded (theoretically). Criteria for selection were: <100K population, within 5 miles of a major rail and interstate, and will see heavy traffic due to a 2019/2020 increase in freight volume.

Finally, the dynamic web-based tool developed as part of this research project supports stakeholders' freight movement decisions in consideration of the impact of the Panama Canal expansion at three levels: 1- Port, 2- U.S Interior, and 3- Sensitivity Analysis. The Port Level Scenarios portion of the tool allows stakeholders to examine the impact of the Panama Canal Expansion for different portions of the country, West Coast Ports, East Coast Ports and Gulf of Mexico Ports. The U.S. Interior Optimized Scenarios portion of the tool allows stakeholders to examine freight movement from the major U.S. international port gateways to state's major container freight facilities using either truck or rail as the mode of transportation. The Sensitivity Analysis Scenarios tool allows the stakeholders to evaluate the impact on the freight movement due to deviation in the forecasted volumes associated with the expansion of the Panama Canal.

CHAPTER 1: PANAMA CANAL EXPANSION

1. Introduction

1.1 Background

The Panama Canal construction started on 1914 and completed on 1981 in two different phases. A 50 – miles long Panama Canal has a great impact on global freight operations, offering an efficient path from the Atlantic to the Pacific Ocean and vice-versa for ship carriers (Alvarez et al., 2006). However, according to various facts, provided by the Panama Canal Authority (ACP), the Canal will reach its maximum capacity between 2009 and 2012. In this case the Canal will not be able to serve the growing demand, and as a consequence, reduction in the competitiveness of the Panama maritime route will occur (Panama Canal Authority, 2006). Main competitors of the Panama Canal are alternative routes that allow transport of cargo between same geographic origin and destination points. The US intermodal system and the Suez Canal are two major competitors of the Panama Canal (R.K. Jones & Associates, Inc., 2005; Dannels-Ruff, K. and Watts, M., 2010; Walser, R., 2010; Sullivan, M., 2006 and 2011; Prince, T., 2005, etc.).

To address worldwide changes in cargo transport and freight due to increased demand, the related authorities and agencies suggested expansion of the Panama Canal. ACP forecasts that the levels of transported cargo through the Canal will increase at an average of 3% annually the next 20 years and will double on 2025 comparing to 2005. Additionally, increased US imports from China, passing through the Canal to ports of US East and Gulf coasts, will cause a considerable growth of the Panama Canal usage (Wilson, W. et al., 2004; Prince, T., 2005; Ralph, W., 2008, etc.).

The Panama Canal expansion project officially started on 2007 and is expected to double capacity of the Canal by 2014. Structure of the Canal will be significantly modified, so as to serve larger vessels. Major objectives of the expansion include: increase of contribution of the Canal to local society; ensure Canal's competitiveness; improve Canal's capability to serve growing demand; enhance the levels of Canal's safety and efficiency (Panama Canal Authority, 2006). Figure 1 shows the demand growth and the results of the Canal's expansion.

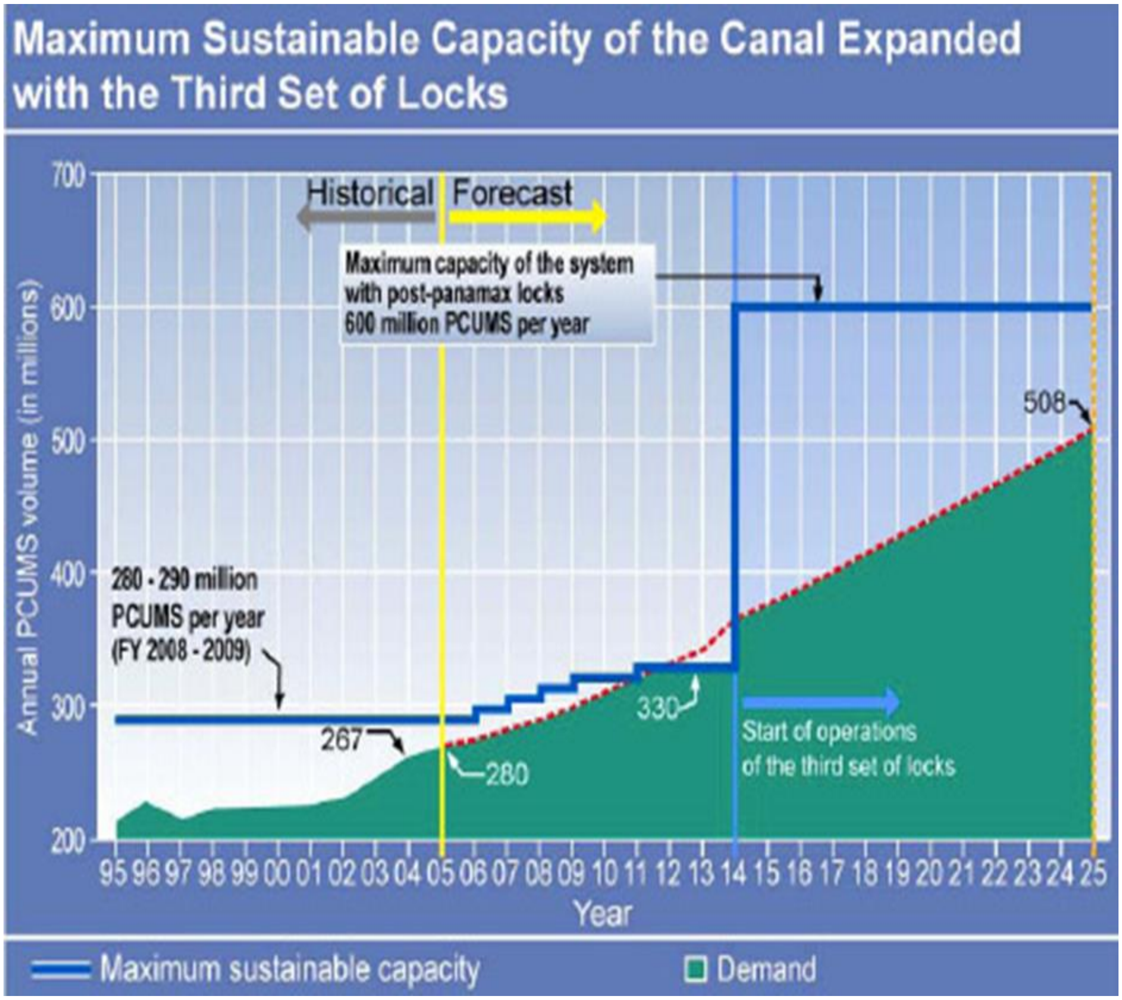

Figure 1 Maximum Capacity of the Expanded Canal
Source: Panama Canal Authority (2006)

1.2 Technical Characteristics

The expansion project focuses on the development of a new set of locks. The third set of locks will allow the Canal to handle the growing demand in future. According to ACP, the project will be based on the construction of two new lock facilities. Besides, the Expansion Project included widening and deepening of existing navigation channels or excavation of new ones, along with elevation of Gatun Lake's maximum operating level (US Army Corp of Engineers; Consorcio Post Panamax, 2004; WL | Delft Hydrolics, 2004, etc.). Various components of the Expansion Project are summarized in Figure 2 below.

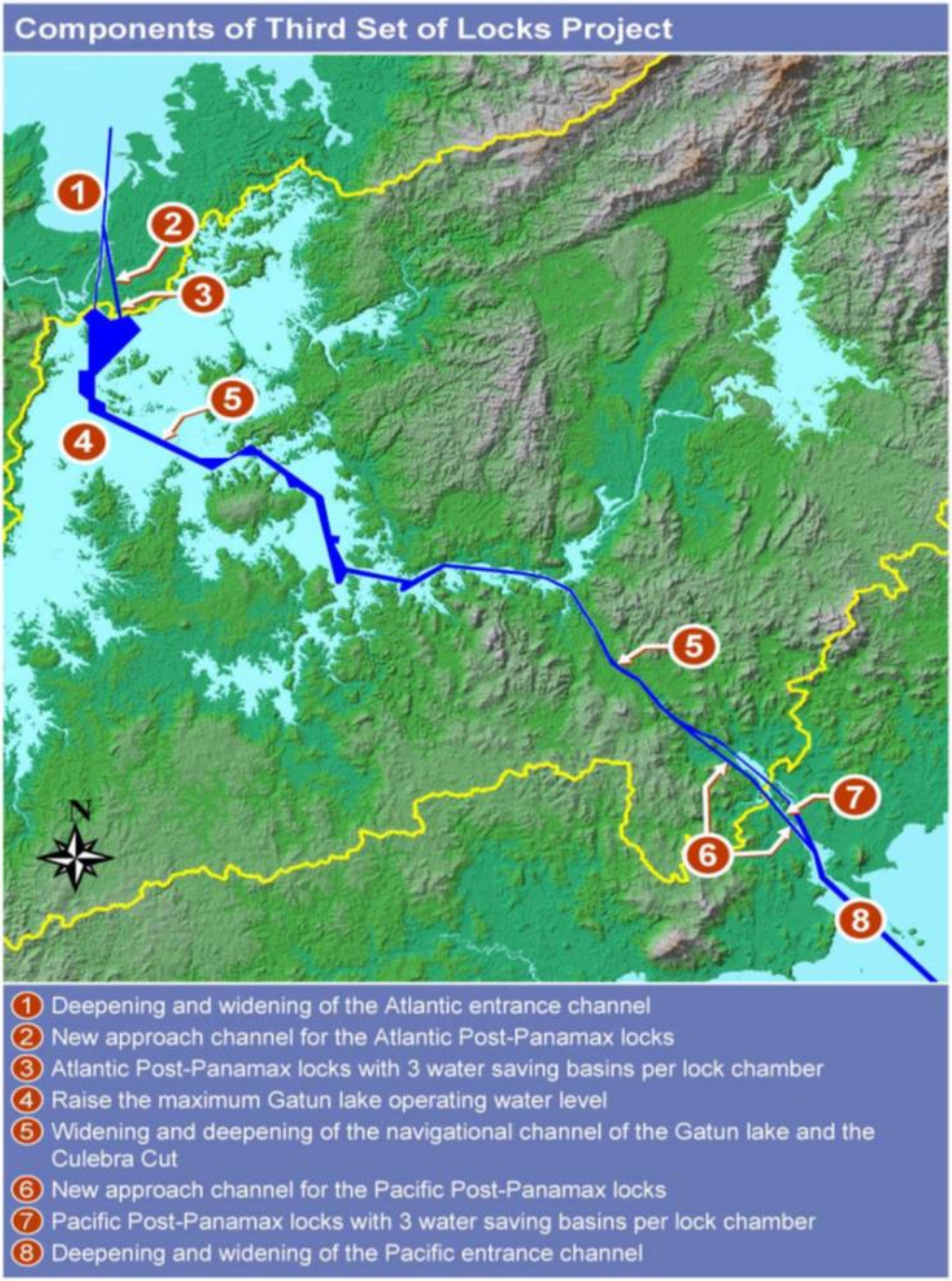

Figure 2 Panama Canal Expansion Program
Source: Panama Canal Authority (2006)

Every lock facility will have three chambers for moving ships from sea level to the level of Gatun Lake. The new lock chambers will be 400 ft long, by 180 ft wide and 60 ft deep. Each chamber will be accompanied with three water basins (Panama Canal Authority, 2006). Details are presented in Figure 3.

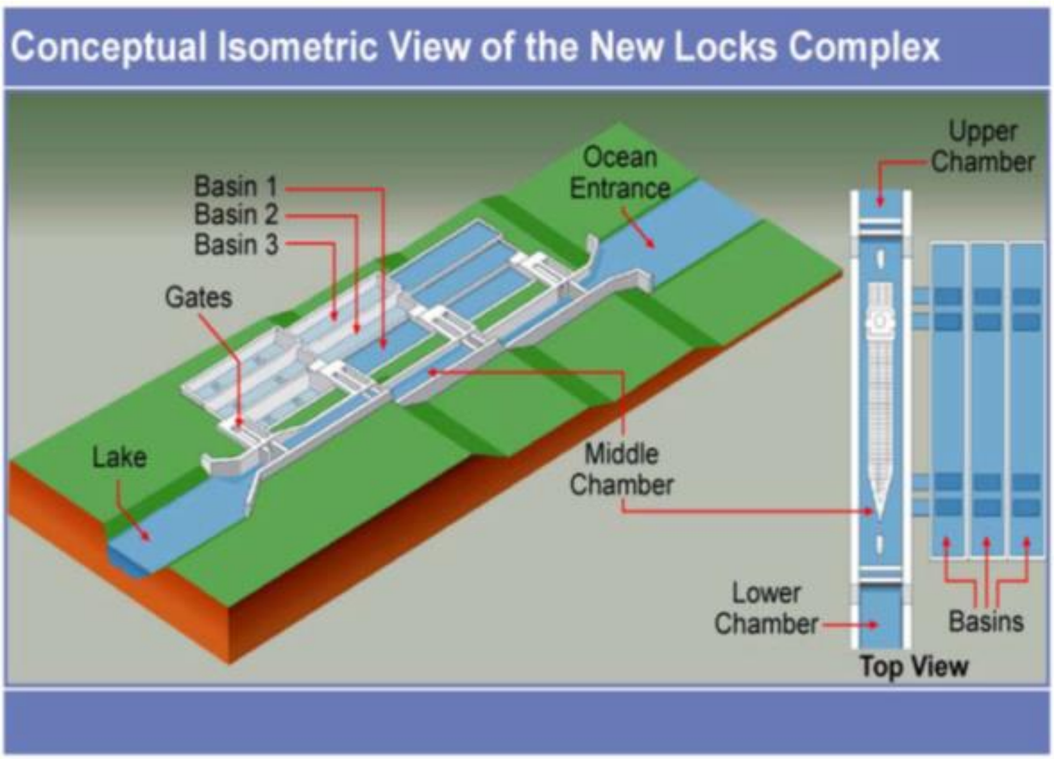

Figure 3 Lock Complex Details
Source: Panama Canal Authority (2006)

Regarding location of the new lock facilities, one will be located at the Atlantic and one on the Pacific side. A 2-mile long access channel will be developed to connect the new Atlantic locks with the existing sea entrance of the Panama Canal. Additionally, two new access channels will be built to connect the new Pacific side locks with existing channels. The north access channel (which is 3.9 miles long) will connect the new Pacific side lock with the Gaillard Cut. The south channel access (which is 1.1 miles long) will connect the new lock with the existing sea entrance on the Pacific Ocean (see Panama Canal Authority, 2006). Various locations regarding the location of new locks and channels are presented in Figure 4.

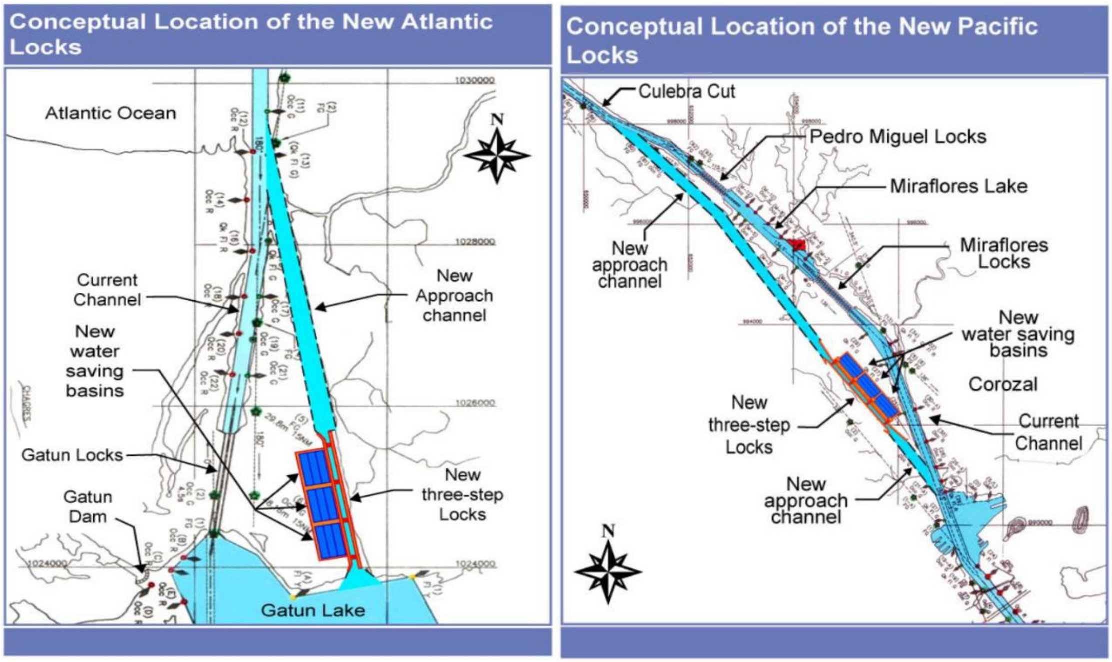

Figure 4 New Locks Location
Source: Panama Canal Authority (2006)

1.3 Literature Review Skeleton

Current work is directed to make a review of major existing studies, which are related to the Panama Canal Expansion Project. Literature review has been organized in seven separate sections. The first section (Introduction) describes existing conditions of the Panama Canal and plans for future Canal expansion. The second section (Global Market) includes studies which investigated the feasibility of the Panama Canal expansion, forecasted and compared the canal efficiency before and after changes. Section 3 (Capacity and Operations) focuses on capacity and operational features of the Canal, while section 4 (Technical and Engineering Aspects) discusses technical and engineering aspects of the expansion project. The fifth section (Financial and Economic Aspects) analyzes various economic parameters of the Panama Canal Expansion project and section 6 (Environmental and Social Aspects) investigates environmental impacts of the Panama Canal expansion. The last section concludes the literature review.

2. Global Market

This section describes major studies that have been conducted by various consulting companies and research institutions regarding the feasibility of the Expanded Panama Canal construction and its impact on the global market and competition. A forecast of the Canal Expansion effects is also included in this section.

One of studies was conducted by Merge Global (2000) and focused on modeling traffic of the Panama Canal. The model allowed analysis of current traffic conditions and forecast the future traffic, considering different parameters such as ship type and size. Economic impact and consequences of future Canal traffic could also be analyzed through the use of the developed model.

Richardson Lawrie Associates (2001) performed investigation of the Panama Canal demand considering its current capacity and future expansion for a time period until 2050. A major objective of this study was to identify the efficiency and feasibility of a potential Canal Expansion. The methodology was based on two different scenarios: a base case, which reflected existing economic conditions, and a risk scenario, which considered additional environmental parameters and relocation costs. For each scenario three different cases were taken into account (existing Canal characteristics; Expanded Canal; no ship size and volume restrictions).

DRI/WEFA (2002) estimated macroeconomic forecast for 2025 with the development of 3 alternative scenarios. The report included macroeconomic analysis, using the proposed methodology, for 14 selected countries in different regions of the world. Three possible scenarios were developed: Most Probable Case, Best Case, and Worst Case. The authors pointed out that for the Panama Canal the probability of Most Probable Case is 60%, Worst Case – is 25%, Best Case – is 15%.

Fearnley Consultants A/S (2003) focused on predicting cargo volumes for the Panama Canal at a macroscopic level, including a 25 year period, by applying specific economic methods. Analysis was based on data, provided by ACP considering current condition of the Canal. Authors concluded that the Expanded Canal will have significantly increased trade levels and efficient bunkering operations. Chemical cargo operations would not be strongly affected.

Nathan Associates (2003) investigated the potential of expanding dry bulk movements through the Panama Canal considering a forecast period until 2025. The study included prediction of traffic flows for three different scenarios: Most Probable Case, Best Case, and Worst Case. It was concluded that regarding the Most Probable Case scenario, related cargo transits for the Existing Canal were estimated to grow by 18% and for the Expanded Canal by 32%.

A similar study from Nathan Associates (2003) applied the same methodology in order to identify the capability of increasing grain cargo movements through the Panama Canal. Findings showed that corn production was expected to increase in specific sectors, which included Eastern Corn Belt, Western Corn Belt, and Central Plains. Also it was pointed out, that for the Most Probable Case regarding the Existing Canal, grain trade was predicted to increase by 67% from 2001 to 2025 and for the Expanded Canal by 77% at the same period.

Louis Berger Group (2003) tried to compare existing and future demand for container vessels, which served the Panama Canal. Methodology was based on the application of various forecast models under different scenarios. The liner container industry was found to have significant potential for further expansion. Additional findings were that TEU were estimated to increase by at least 250% from 2001 to 2025, while vessel crossings were projected to grow at least by 37%. Toll revenues were estimated to increase almost three times by 2025 comparing to values of 2001.

Global Insight (2003) made a forecast for the Conventional Bulk-Refrigerated (non-containerized) Cargo Market in terms of cargo demand and revenue tolls. All vessels were divided in two groups for modeling and forecasting purposes, where Group 1 referred to cargo ships, while Group 2 referred to the remaining vessels. It was generally found that the forecast demand could be served with the current Canal characteristics

ACP Integrated Demand Model has been created by Mercer Management Consulting, Inc. (2004) to develop a computer-based analytical tool that provided integrated market demand forecasts for the Panama Canal under different scenarios, pricing strategies, service standards, and economic factors with consideration of different cargo types. The model used the macroeconomic scenarios, proposed by DRI/WEFA, with corresponding probabilities, assigned to each scenario (Most Probable Case – 60%, Worst Case – 25%, Best Case – 15%).

A different study from R.K. Johns & Associates (2004), investigated the results of a further use of post-Panamax ships in freight operations through the Panama Canal. Methodology was based on interviewing executive members of specific global freight related firms. Research showed that 8,000 TEU vessels were more efficient and could reduce the operations cost.

Wilson, W. et al. (2004) created an optimization model, which aimed to minimize transportation cost based on longer term competitive equilibrium, to make projections in world grain trade and shipments from individual ports for a time period of 25 years. The model output indicated that world grain trade should increase by 47% with the fastest growth in China and Pakistan imports. It was pointed out that the Canal Expansion would considerably change world transportation of grain products. The Northern shipments of soybeans from Brazil would be moved to Asia and China via the Panama Canal.

Global Insight (2005) updated macroeconomic forecasts for the Canal, which were produced by the same company in 2001. Methodology was based on the application of specific forecast models in order to identify future economic and demand changes related to the Panama Canal under various scenarios. The main difference with the previous study was the assignment of specific probabilities to each considered scenario. Regarding the short-term world growth, a decrease from 4.2% in 2004 to 3.4% in 2005 and 3.2% in 2006 was predicted. For the medium-term world growth, an annual growth rate of 3.4% from 2004 up to 2008 was identified, whereas for the long-term world growth, tan annual growth rate of 3.1% for the time period up to 2025 was forecasted.

R.K. Jones & Associates, Inc. (2005) initiated study, related to the price forecast for the Suez Canal. According to findings, the Suez Canal Authority established annual toll fees two or three months in advance of implementation without debates. Containerships were indicated to be the largest users of the Canal. Around 20 containership transits were undertaken between Asia/India and Europe. In comparison with the Panama Canal, the Suez Canal charged about 25-30% more for transit of vessels. The report concluded that with or without a per-TEU pricing change the Suez Canal would continue to cost more per transit than the Panama Canal throughout the forecast period.

Harrison, Huston and Prasad (2007) focused on Texas seaports and their operations. Continued growth in container demand in the Gulf Coast, proposal of the Panama Canal Expansion, and disruptions at the Port of New Orleans considerably affected overall standing of Texas ports. Nevertheless, the authors pointed out that containership cargo would be concentrated around the Houston channel and might increase its capacity.

Florida Department of Transportation (FDOT, 2008) investigated the potential opportunities that arose for the greater area of Tampa Bay, as a result of the Panama Canal Expansion. Authors underlined the importance of the Panama Canal Expansion Project and its effect on Tampa seaports capacity. To meet the growing demand FDOT suggested deepening port's channels from 45 feet to 50 feet, improvement of port's infrastructure and upgrading other transportation modes (including rails). According to that study, the Panama Canal offered the Tampa Bay Region a great chance to connect with Asian market and attract larger vessels operations.

Ralph, W. (2008) made an overview on how the Panama Canal Expansion would affect American seaports. The list of top US ports by container volume included Los Angeles, Long Beach, New York/New Jersey, Savannah, and Oakland. According to the author, impact of the Panama Canal Expansion will be significant for American East, West and Gulf Coast as an important increase on container movements at the related ports up to 2025 was forecasted.

American Shipper Journal (2008) investigated different parameters that could affect the future profitability of American West Coast ports. Economic crisis or the non- productive cooperation with rail systems, were found to be crucial factors, while expansion of the Panama Canal and its impact on global market was identified as a major one.

CanagaRetna (2010) investigated the impact of the Panama Canal Expansion on operations and characteristics of major US ports. New worldwide economic conditions with the increased trade between China and US and technologic development with the construction of larger vessels were some of the major facts, which resulted in the Canal Expansion. Authors highlighted the significant changes that would take place to US ports' demand levels due to the Canal Expansion. It was found that East and Gulf coast ports would probably benefit more, while on the other hand many ports of the West Coast were expected to face a profit decrease. These new market conditions led authorities of many East and Gulf coast ports to focus on improving port facilities and characteristics, i.e. increase of water depth in order to serve the increased vessel volumes.

Capitol Ideas Journal (2010) focused on potential market changes as a result of the Panama Canal Expansion Project. The main conclusion was that freight traffic could be reduced in regions such as the American West Coast and alternative ports in South or East United States could benefit by increasing their operations. Port of Savannah, one of the largest US ports with approximately 2.6 million container demand in 2008, was considered as one example of the new market changes because of the Canal Expansion. Advancement and update of Savannah port's equipment by introducing new cranes for Super Post-Panamax ships or new gantry cranes, and the overall increase at the ports capacity have been caused the Panama Canal Expansion. Similar facilities improvement took place in additional ports of South US in order to adjust new market conditions.

Cambridge Systematics (2011) focused on the future impact of the Panama Canal Expansion at the greater area of Texas and related transportation facilities. The potential increase of vessels demand on Texas ports was one of the major results of the Canal Expansion. Authors suggested different ideas for the Texas transportation authorities, aiming to gain more profit from future market conditions. The authors proposed to upgrade of port equipment, improve road facilities, and provide more efficient cooperation between different transportation modes.

The Journal of Commerce (2011) included opinions and thoughts of people who were closely related to the Panama Canal Expansion Project. According to the paper, the Panama Canal will be important part of the world transportation system greatly affecting freight operations between west coasts of North and South America, and Caribbean. Different aspects of the Canal Expansion Project were also highlighted, such as the increase of the Canal capacity or the general benefit of the local economy in general. Environmental concerns and the related actions in order to save fresh water consumption or the logic behind the increase of the Canal tolls were also discussed.

Williams and McMillian (2011) focused on the potential opportunities of economic growth for Florida because of the Panama Canal Expansion and the increase of Florida’s ports shipping demand. Authors suggested the upgrade and improvement of ports facilities in order to make them able to serve larger cargo ships and, as a result, maximize the related economic benefits. The benefits of local society and economy were highlighted as the increase in freight operations could create opportunities for cargo business and new jobs in total.

Memphis Business Journal (2011) investigated the major results of the Panama Canal Expansion Project and its impact on global market. Increased capacity of the Expanded Canal was underlined. Several opinions of experts were presented focusing on the potential impact, such as the increased demand in the Gulf of Mexico. Regarding the effects on other modes of transportation, some views highlighted the shorter truck trips or the small impact on railroad operations. Also some concerns regarding the uncertainty of the new transportation market after the expansion were expressed.

Mohr (2011) analyzed the competition between USA, Panama and Canada seaports and the consequences of the Panama Canal Expansion. The reduced job and business opportunities at the West Coast Ports were identified as a major consequence of the increased investments to the Panama Canal Expansion Project.

Perez (2011) described the characteristics of Panama economy, focusing on the Panama Canal Expansion Project. Author carried out an analytical description of the project by including various information regarding construction time framework, technical characteristics and related costs. The increased capacity of the Canal after the facilities expansion and the ability of serving larger ships were also mentioned.

Castle Journal (2011) included various views regarding the Savannah Harbor expansion project, which was developed as a result of the Panama Canal Expansion. Authors also pointed out the strong impact of the Expansion Project on transportation systems worldwide.

Another study regarding the expansion of the Panama Canal and its effects on cargo market and US ports demand was conducted by Morrison (2012). Author concluded that the major reasons for Canal expansion were introduction of vessels with larger sizes, need for reduction of cargo movement cost from and to US, and objective of Panama authorities for further economic development. The major impact of Canal Expansion was found to be the increased cargo demand at East and Gulf Coast ports. However, the size of impact could not be precisely identified. Many US ports are expected to upgrade their facilities and equipment in order to meet the growing demand, caused by the Panama Canal Expansion.

Joyce (2012) discussed the potential chances for economic benefits that arose from the Panama Canal Expansion in 2014. Texas ports were expected to have more incoming cargo, because the American West Coast seaport most likely would not be able to handle the growing ship volumes. The need for additional research regarding the development of port infrastructure and upgrading of road facilities was pointed out. Author also underlined the importance of the Panama Canal Expansion Project and its impact at transportation systems in general.

AECOM (2012) conducted research to investigate the influence of larger vessels that will be developed because of the Panama Canal Expansion, at the container shipping industry and market. The main objective of this study was to find out if the introduction of larger vessels could be cost effective, comparing economic profit with operational costs and tolls. It was observed that 12,000 TEU new containerships with half load approximately had the same operational costs as a 4,000 TEU existing containerships that were 80% loaded.

3. Capacity and Operations

This section focuses on capacity issues of the Panama Canal and its potential expansion. Various operational features of the Panama Canal are described.

One of studies regarding increase of the Panama Canal capacity was conducted by Raymond and Rush (1999). The whole improvement of Canal infrastructure by developing new lock facilities or by introducing environmentally friendly systems for reducing water consumption was analyzed in this study. Methodology was based on assessment of the containers traffic impact on lock facilities. The pressure on lock systems due to ship movements was pointed out and different mitigation measures were suggested. However, additional research and field testing were recommended.

US Army Corp of Engineers (2002) evaluated the possibility of increasing allowable draft of vessels, which would result in higher Panama Canal capacity. Methodology was based on comparison of alternative feasible solutions, which included raising the water levels in Gatun and Miraflores Lakes or reducing sill elevations of lock systems. Authors concluded that an efficient decision for draft increase should be a combination of different alternative solutions. Especially, it was found that a combination of increasing lake water levels by 0.25 ft with reducing sill elevation by 1ft, could improve canal's capacity by increasing draft with approximately 1.25 ft.

Rodrigue and Browne (2002) described the results of new Post-Panamax vessels utilization for the Expanded Panama Canal. Authors concluded that the Panama Canal Expansion Project and introduction of larger vessels (Post-Panamax and Neo Panamax) would help to achieve higher capacity and allow the Panama Canal to become a game player on the international transportation market.

Alvarez, Cano, and Diakanda (2006) developed a simulation model for the Panama Canal in order to identify effects of a potential expansion. Simulation analysis included the consideration of various parameters such as Canal's growing capacity, use of different number of reservoirs, and socio-economic factors. The maximum time horizon was set to be 25 years. Accuracy of the results was ensured after validation procedure. Authors concluded that the Panama Canal Expansion might be beneficial according to the model output. The Expansion Project will increase competitiveness and provide benefits to local economy.

Rodrigue and Guan (2008) carried out a study regarding ports which were located at the Eastern Seaboard of US and considered the impact of the Panama Canal expansion on those ports. The Canal's Expansion and introduction of larger containerships would greatly affect maritime transportation routes and ports demand. Authors concluded that the Panama Canal Expansion would cause significant changes to the North American ports and to related freight operations in general.

Latin Business Chronicle (2009) tried to investigate if the Panama Canal Expansion would be profitable for South American countries. Increasing of the Canal capacity, utilization of larger vessels, and improvement of the Canal competitiveness were pointed out as some of the most important benefits. Additional advantages included economic benefits for local economies by developing new business and jobs. Also it was reported that the Panama Canal Expansion would greatly affect freight operations worldwide. It will lead to an increase of 3% to the trade from Asia to Eastern U.S.

Rodrigue (2010) made a comprehensive study on the Panama Canal Expansion Project, focusing on the potential effects at various market segments, including economy, operations and competiveness. Author concluded that future impact of the Panama Canal Expansion cannot be precisely identified. However, according to this study the Expansion project will affect global freight market as it will increase competiveness by providing alternative routes and development of new cargo hubs.

Lim and Herrmann (2012) developed a hybrid simulation model of the Panama Canal operations in order to identify how a potential expansion of the Canal would affect salinity of Gatun and Miraflores lakes. Volumes of the related lakes were estimated using neural networks modeling technique. Simulation results were validated by comparing with other forecast models and real data.

Prince (2012) conducted investigation on the Panama Canal Expansion aiming to evaluate its impact on the world maritime trade. Author focused on the reasons, which created necessity of expansion, such as serving larger vessels and increased capacity to allow the Canal remain competitive at world market. Bulk containers demand was also found to have potential for further increase. It was concluded that the Panama Canal Expansion would significantly affect global cargo movements. However, the level of impact was not obvious because of the alternative competitive routes existence.

Scott (2012) analyzed the impact of the Panama Canal Expansion on world trade and shipping industry. It was found that the Expanded Canal could potentially reduce trading distances and, as a result, also decrease emissions. New vessels, which would serve the Canal, will have specific design characteristics. Larger vessels will provide more efficient freight routes and economic profits, as additional benefits to the market thanks to the Panama Canal Expansion.

Shi and Voss (2012) generally evaluated impact of the Panama Canal Expansion Project on global container industry. Study described different vessel types and their capacities. Several issues which were related to the Panama Canal Expansion included the development and use of larger vessels and the identification of the related costs. Authors concluded the Panama Canal Expansion would make liner shipping companies to update and improve operation strategies in order cope with the new market conditions.

4. Technical and Engineering Aspects

This section is divided in three sub-sections: locks, navigation channels and water. Configuration of new locks, proposed for the Panama Canal Expansion Project, and particularities of Post-Panamax vessels dimensions will be discussed. In addition, this section includes several studies, related to salinity of water. Construction of new facilities in order to increase capacity of the Canal will be addressed. Also certain simulation models, applied for estimation of specific parameters for the Panama Canal will be presented.

4.1 Locks

One of studies regarding update of the ships positioning system at the Panama Canals locks was conducted by Howze et al. (1999), aiming to improve the Canal’s operational standards and face the existing systems wear. The main objective was to develop a methodology for an optimal positioning of vessels to make the Canal be able to serve increased demand and ships of larger size. Analysis included the application of a simulation model for identifying the impact of different parameters such as delay.

Syncrolift (2000) initialized a study to check the efficiency of Syncrolift ship lift system regarding its ability to handle the growing demand at the Panama Canal. The proposed system increased the Canal capacity. Efficiency of the specific system was confirmed and its ability for significant water savings was highlighted.

US Army Corp of Engineers (2000) focused on the water quality of the Panama Canal. The major objectives of this study were to apply different tools for accurately identifying salinity levels and to suggest various mitigation measures in order to retain the proper salinity levels after the future Canal Expansion. Authors concluded that the suggested methodology can save 60% of fresh water consumption and can efficiently result in retaining waters salinity standards.

Montgomery Watson Harza (2000) carried out en evaluation of 24 alternative lock alignments, in order to identify the optimal ones for the future Panama Canal Expansion. Evaluation procedure was based on the combination of different criteria and comparison techniques (Kepner-Tregoe methodology). Conducted study underlined the four most efficient alignment alternatives, two for the Pacific and two for the Atlantic side, which could potentially be used to handle future demand. The four best alternatives were selected based optimizing the related operational, construction and cost parameters.

Concorcio Post-Panamax (2002) described design characteristics of a lift lock system for the new Post Panamax locks facilities of the Panama Canal, which were located at the Pacific side. Different areas that were taken into account in this study included design criteria, construction parameters, optimal lock alignment, and cost estimation.

Another study regarding the identification of an optimal ship positioning system for new larger vessels, serving the Panama Canal was carried out by Maritime Operations Department of the Panama Canal Capacity Projects Division (2003). Study focused on tug assisted locks vessel positioning system and its efficiency for future use was tested. It was concluded that various adjustments should take place in order a tug positioning system to be a feasible and productive solution and additional field tests were required.

Milchert (2003) conducted a study to check the feasibility of lock chamber enlarging for the Panama Canal. The report described typical parts of design, i.e. design of hull form, resistance and engine power prediction, choice of arrangement and subdivision, calculation of lightweight and deadweight, freeboard, tonnage, design of mid ship section and steel weight estimation, calculation of typical loading conditions including hull longitudinal strength and stability for intact and damaged conditions. The approximate cost of the designed vessel was calculated to be around $70 million.

WL Delft Hydrolics (2003) built a simulation model to analyze water's salinity levels of the Panama Canal for both present and future conditions after the introduction of new lock facilities. The model predicted the water salinity on Miraflores and Gatun Lakes after expansion of the Panama Canal with new Post-Panamax Locks addition. Validation process was based on real field data. It was observed that salinity levels were lower at Gatun than Miraflores Lake. It was also concluded that salinity was closely affected by seasonal parameters.

US Army Corp of Engineers (2003) investigated the application of double-lift lock system for the Panama Canal Expansion Project. A suggested combination of this lock system combined with water basins could result in a 50% water saving. The report focuses on the economic part of the project with estimation of the related construction and design costs. . The construction cost for each lock system was expected to reach the value of $840,000,000.

Japan Bank for International Cooperation (2004) focused on the Panama Canal Expansion Project and the construction of the new lock facilities. Study investigated different construction techniques and the related costs of the whole project. Cost estimates on gates construction and maintenance were produced for a period of 100 years and it was found that that a two lift gate system was a more cost effective alternative.

Another study regarding the Panama Canal Expansion, which focused on the establishment of new locks was conducted by the Panama Canal Authority (2004). Study focused on technical characteristics of the locks and the related project's costs. Methodology included the evaluation of different lock alternatives based on changing design characteristics such as width, depth and length. Authors pointed out that the use of smaller equipment was not preferable, because it would require more labor, maintenance, and other expenditures.

WL | Delft Hydraulics (2005) focused on the impact of new lock systems of the Panama Canal on salinity levels of water. The major objective of this study was to suggest various measures in order to mitigate the effects of the new 3-lift lock system on waters salinity. It was observed that in cases with adequate water amount, the best option was the construction of the new lock systems without water saving basins. It would also limit the further salinity of water.

A different study from the Panama Canal Authority (2005) investigated the impact of the Expanded Panama Canal on the road traffic of the closely related area and suggested various solutions to mitigate the effects. Study area had new lock facilities on the Atlantic side of the Canal. Various alternative crossing solutions were evaluated in order to find the optimal one comparing the related costs for a 25 year period. It was concluded that the development of new ferry lines would be the best option in terms of minimum cost, comparing with other alternatives, which included bridge or tunnel facilities construction.

PB/MHW/Social Enterprise Consulting (2005) conducted a workshop to discuss various ways of increasing the Panama Canal capacity to meet growing cargo carrying demand along major international trade routes. Workshop produced 267 ideas, which were converted into series of working lists. Proposals, made at the workshop, were expected to reduce the overall project cost by $720 million.

Panama Canal Authority (2005) initiated study to evaluate the cost estimate methodology, the scheduling methodology, the basic premises and assumptions behind the estimate and schedule, and the overall cost estimating and scheduling process for the Panama Canal Expansion Project. Cost estimation was performed with consideration of risk analysis.

Payer (2005) tried to identify if the Expanded Panama Canal and its facilities would be able to serve new larger vessels, focusing on the adequacy of the new lock systems. Author concluded that size of the new lock facilities was sufficient enough to accommodate current large vessels. It was also observed, that the Expanded Canal could even admit even larger ships.

4.2 Navigational Channels

Moffatt & Nichol Engineers (2001) investigated the efficient use of excavated land due to the Panama Canal Expansion for developing an artificial island at the Canal’s entrance, which was located at the Pacific side. Technical and environmental parameters related to this project were discussed. Various information regarding lock facilities configuration or the location and technical characteristics of the new island were presented. Additional analysis was carried out regarding the construction procedure, timeline and related costs.

A similar study regarding the use of the excavated material from the Panama Canal Expansion was conducted by JETRO (2003). Two alternative solutions, which included the development of an artificial island and a peninsula, were investigated. Different parameters such as technical characteristics and construction costs were estimated. Overall cost of the artificial island construction was found to be more profitable from the economic standpoint.

Panama Canal Authority (2003) made a technical analysis regarding the deepening of the Canal's entrance channels at the Atlantic Side. Investigation included different scenarios of depth expansion. Various parameters such as vessels demand, area and duration of works, and required equipment were considered. Additionally, the overall cost which consisted of the dredging, drilling and blasting costs was estimated for each scenario.

Panama Canal Authority (2003) evaluated the Canal's internal channels widening for one way vessel movements from the north end of Gamboa Reach to the south end of Paraiso Reach. It was found that the one way channels widening would result in excavation of large amounts of land materials. Costs of different works for the project were also estimated.

Moffatt & Nichol Engineers (2003) evaluated different potential locations for disposal of excavated land materials in order to identify the optimal ones. The major evaluation criteria that were used in the analysis included the capacity of the candidate location and the related costs. Amador Causeway East was found to be the best option for disposal location for the Canal's entrance at the Pacific side.

A similar study regarding the evaluation of potential disposal locations for the excavated material that were produced due to the Panama Canal channels expansion was conducted by Panama Canal Authority (2004). Environmental concerns regarding the disposal locations were the major focus of this study.

Great Lakes Dredge & Dock Company (2004) initialized a study to investigate the quality of dredging operations as part of the general Panama Canal Expansion Project. Authors confirmed the efficiency of the related equipment and labor, however it was highlighted that better planning could result in more productive operations.

JETRO (2005) updated the study of JETRO (2003), focusing on the development of a new island at the Pacific side of the Panama Canal, using excavated material from the Expanded Canal. Authors confirmed the feasibility of the specific project considering its technical characteristics and the estimated cost. Also it was concluded the environmental impact would be limited.

Moffatt & Nichol Engineers (2005) evaluated the decision of establishing new port facilities at the Palo Seco/Farfan land location. Various parameters, which included along with others technical characteristics, land use, topography and accessibility to transportation networks were analyzed. It was concluded that the specific location met the main criteria from technical point of view and had considerable limited environmental, social and economic impact.

Panama Canal Authority (2006) conducted a study on improving the existing Panama Canal navigation channels and construction of new ones on the Atlantic and Pacific side as part of the future Canal Expansion. Authors considered various parameters in the related analysis, including technical characteristics, equipment and operations disposal areas. The total cost of the related projects was also estimated.

Noonan and Rucker (2011) initialized study on improving dredging methods for deepening and widening of the Panama Canal as part of the Expansion Project. It was stated that dredging operations were greatly affected by the rock type and hardness. The analysis provided a comprehensive dataset and techniques, which could potentially be used to develop an efficient and time saving dredging method for application in the Panama Canal Expansion Project.

4.3 Water

Hydrologic Engineering Center (1999) tried to develop a new simulation model for evaluating the efficiency of the existing Panama Canal reservoir system and investigate the potential of future improvement. The study included analysis of different parameters such as the value, the reliability, the resiliency, and the vulnerability of the existing reservoir system. Methodology was based on data collected from Maden and Gatun reservoirs.

US Army Corp of Engineers (1999) conducted evaluation of projects for the Panama Canal Commission. The research included literature review, collection of the existing data, and development of data for projects sites, site visits and implementation of various simulation tools to determine the water yield for proposed projects. The initial list comprised 33 projects, but after evaluation 3 of them had been rejected.

Montgomery Watson Harza (2001) carried out a 60-year period forecast of water supply needs for the greater area of the Panama Canal. Forecast methodology was based on demographic and water use trends along with Geographic Information System and historical data. It was found that the need for water supply would increase by 39% in 2020 and by 105% in 2060. The increased water requirements will require additional water sources. Different mitigation measures were suggested such as the establishment of additional reservoirs for supplying water to Gatun Lake.

Moffatt & Nichol Engineers (2002) conducted a study regarding new water basins systems as part of the Panama Canal Expansion Project. The major objective was the development of basin systems, which could potentially reduce water consumption. Four different system designs were evaluated and the optimal characteristics of each alternative were identified. Major criteria, used in that investigation, were the waters levels and the lock size at the related areas, where the basin system would be applied.

The Geotechnical Advisory Board (2002) made a research on Lower Trinidad Dam, the Channel Deepening Program (CDP), and on Landslide Control Program. Members of the Board pointed out high quality of CDP and potential slope stability analysis in 2002. Nevertheless, overall strategy for decision making in the LCP was subject for questions and required a strong synthesis between experience and development of integrated strategy. Additional geological studies were recommended in the area of Zion and Hodges Hill. The Geotechnical Advisory Board also proposed to improve drainage of the slope, try to make only minor excavations, provide stabilization of Purple Rock. Most of all, members offered to conduct a feasibility study and cost estimates of the Lower Trinidad Dam project and compare it with other possible alternatives.

US Army Corp of Engineers (2002) conducted a general evaluation of the new Lower Trinidad Dam development and its characteristics. After a thorough description of the project, authors highlighted difficulties regarding project accomplishment. Various construction issues were identified as the major problem. The increased Project’s cost which reached the value of $811,400,000 at an initial phase was found to be the major consequence. However, the benefits of the Lower Trinidad Dam completion were obvious as it could ensure the continuity and the quality of Canal's operations by providing an extra water source in case of low water supply.

Another evaluation of the Lower Trinidad Dam project peculiarities was initiated by Parsons Brinckerhoff and Montgomery Watson Harza (2003). Authors firstly confirmed the accuracy and the sufficiency of the collected data and the feasibility of the project in general. Then the technical and construction difficulties were pointed out. Trinidad Dam construction was found to have less social and environmental impacts comparing to similar projects. However, some concerns regarding cost levels were expressed. An estimate of the project's cost comprised around $600 million.

Montgomery Watson Harza (2003) focused on evaluating the Panama Canal Expansion Project and especially the infrastructure development at Rio Indio location, which included construction of a new dam and a water transfer tunnel. Analysis confirmed the accuracy of the designed technical characteristics and the optimality of the selected location. The benefits on the Canal operations were pointed out. It was mentioned that Rio Indio facilities could become a great alternative for water supply. However, due to the lack of data, the project's cost could not be accurately estimated and the need for an environmental impact analysis was highlighted.

Bellier (2003) conducted a study in order to identify how feasible is the completion of the Rio Toabre Project, which aimed to increase the water supply for the Panama Canal. It was concluded that the suggested technical characteristics and the location of the project were optimal. However, concerns were expressed regarding the estimation of the total cost due to insufficient data. Also different suggestions for the potential dam construction technique were provided.

Montgomery Watson Harza (2003) conducted a study regarding the Panama Canal Expansion Project, focusing on the construction of a new reservoir at Rios Cocle del Norte area and some adjustments at Cano Sucio reservoir. The major objective of this study was to identify the rightness of developing the specific project. Authors confirmed that Project's characteristics and location selection were proper, and pointed out the potential benefits, including the increased water availability. However, various concerns were expressed regarding the increased costs and the lack of economic data for a more precise identification of the total project cost. Due to these concerns, authors didn't suggest the development of the specific project at this time period.

Hayes (2003) reviewed of existing HEC simulation models for the Panama Canal Expansion Project and provided different ways to improve those models. As a result, HEC-5 FORTRAN code was modified, which allowed the model to consider water consumption per lockage, power generation and printing codes, temporary percentage reduction in lockage water consumption as reservoirs reach minimum level, priority use for any month, print intermediate computations, etc. (see Hayes, R., 2003).

Montgomery Watson Harza (2003) evaluated the technical feasibility of the Upper Charge Water facilities development. Authors concluded that the Upper Charge Project was technically feasible. Also the selected location for the projects development was found to be optimal. However, the overall project cost and the future cost of the supplied water from the Upper

Charge after the project completion, led the authors to suggest the development of alternative water supply.

Moffat & Nichol Engineers (2004) expanded the study of Moffatt & Nichol Engineers (2002) regarding the development of new water saving basins for the Panama Canal facilities. The main difference of the new study was the evaluation of new basins alternatives, which were designed for smaller sizes of lock systems and water levels. Such adjustments were made for economic reasons. Among different alternatives, authors concluded that a three lift lock system with basins on one side of lock was the most efficient choice in terms of water saving. However, the cost of this alternative was found to be higher. The consideration of various parameters which included among others lock design, safety and water use, was suggested.

WL | Delft Hydrolics (2004) analyzed the impact of recycled water on salinity levels of Gatun and Miraflores Lakes of the Panama Canal and suggested different mitigation measures. Analysis was based on simulation modeling and data, provided by ACP. Authors concluded that water recycling at the Canal's Pacific side increased significantly salinity levels in considered lakes. Also, the need for additional water recycling at the pacific side was pointed out.

Consorcio Post Panamax (2004) focused on water recycling at the new lock facilities, which were constructed as part of the Panama Canal Expansion. Analysis focused on the lock facilities of the Canal's Pacific area. Water recycling alternatives were based on variations of pumping systems depending on the selected water source. Simulation conditions considered everyday vessel volumes and various lock systems.

Moffat & Nichol Engineers (2005) initialized a study regarding the safety levels of Gatun Lake in the Panama Canal in extreme cases, which included floods or earthquakes. Stability and capacity of lakes spillway and dam were the major parameters, which were analyzed. Also, environmental and economic effects of the suggested mitigation measures were included in that study. Authors identified the need for updating and enhancing the lakes spillway considering the consequences of a potential dam flood case. Different parts of the spillway facilities such as the spillway gates or piers were found to need upgrade. The related costs of the various mitigation measures were also provided.

Consorcio Post Panamax (2005) focused on the design characteristics of the new Panama Canal lock facilities. An alternative lock system design was suggested and evaluated. The major characteristics of the recommended design were the combination of three lock chambers with two water basins per chamber. This design was found to result in 83% water saving per vessel.

5. Financial and Economic Aspects

Some of financial and economic aspects were discussed in previous sections. In this section several studied related to risk assessment of the Panama Canal Expansion Project will be addressed. Besides, the research related to aggregate business enterprise value of the Panama Canal Authority will be presented. The Panama Canal Expansion impacts will be considered relatively to various countries (i.e., the United States, China, Japan, Chile, Ecuador, and Peru).

Valuation Research Corporation (2005) performed investigation and evaluation of the aggregate business enterprise value ("BEV") for the Panama Canal Authority. BEV analysis had been conducted according to certain standards, established by the International Financial Reporting Standards (IFRS), the International Accounting Standards Committee (EASC), and the US Securities and Exchange Commission (SEC). BEV was calculated using discounted cash flow (DCF) analysis. The report included the following parts: 1) identification of the assets appraised and summary of the implemented methodology; 2) presentation of validation approach; 3) exhibits highlighting the consolidated financial statements of the Company. It was found that the BEV range for the Panama Canal Authority comprised \$6.5 million dollars - \$7.3 billion dollars. More details are provided in the actual report (see Valuation Research Corporation, 2005).

Mercer Management Consulting (2005) initialized study for the Panama Canal Authority to assess and understand the impact of different pricing options on the economies of stakeholder countries. The ACP chose six countries for analysis: the United States, China, Japan, Chile, Ecuador, and Peru. It was concluded that the United States, Japan, and China would not have major effects regarding the Canal transit cost increases, because economies of those countries have are dependent on the Panama Canal. Those countries carry only small commodities through the Canal, which present not significant portion of countries GDP. Chile, Ecuador, and Peru have higher sensitivity to the Panama Canal cost growth, especially for export commodities. Nevertheless, the economies of Chile, Ecuador, and Peru would not significantly impact the Canal toll increases.

AON Enterprise Risk Management (2005) carried out a risk analysis regarding the Panama Canal Expansion Project. Among of a set of different risks-concerns, five of them were identified as the most important. Significant issues were mentioned regarding schedule's tightness, existence of qualified employers and project's objectives. Additional concerns included the potential of budget overcome or the disruption of the Canal's operations. Authors evaluated the potential project's completion delay as the most important concern and different mitigation measures were suggested.

Hanily, Alvarado and Ungo (2006) built a risk model and performed a risk analysis regarding the Panama Canal Expansion Program. Different areas of concerns that were considered, included among others, operational and execution issues, market impact and environmental-political risks. The developed model was based on the application of Monte Carlo simulation methodology. Three different scenarios were considered: Pessimistic, Probable, and Optimistic. Authors indicated four steps for dealing with project's risks: avoid exposure to risk, accept risk, transfer risk and mitigate or prevent risk.

6. Environmental and Social Aspects

This section deals with environmental impacts of the Panama Canal Expansion project. Several simulation models to assess environmental influence will be presented by several studies. Impact on flora, fauna and population of construction areas will be discussed.

Black &Veatch (2002) conducted a field observation for Gatun Lake to estimate the environmental impact of the water supply project for the Panama Canal in the close area. The project was expected to provide additional storage to Gatun Lake and 17.29 additional lockages in one day. The different areas of impact were analyzed, including land use, infrastructure, flora, fauna, historical places, air and water. It was underlined that Project's impact on the areas of Lower Trinidad and Rio Indio close to Gatun Lake would probably be significant. Relocation of people and animals was found to be one of the first consequences. Reduction of forests size or effects on water quality would probably occur. Also, socio-economic impact of the Panama Expansion Project was found to be considerable.

Montgomery Watson Harza (2003) conducted a study in order to identify the impact of Panama Canal water supply increase project on the Canal's lakes water quality. Analysis was based on a water quality model, which allowed the simulation of water operations of the Canal's reservoirs. Calibration of results was executed using various sets of real data. Investigation included six different scenarios, four for Rio Indio reservoir and two for Gatun Lake. The measure to identifying water quality was the level of dissolved oxygen. High quantities of dissolved oxygen were reported in cases, where reservoirs were not filled. Regarding the cases of filled reservoirs low quantities were found at the bottom areas. In general the levels of dissolved oxygen varied considerably, depending on each different scenario characteristics. However, the impact on waters quality was obvious.

URS Holdings (2005) focused on the consequences of the Panama Canal Expansion on the waters salinity due to the increased vessels volumes. The major objective of the study was to set the maximum allowable salinity levels after the completion of the expansion project. Results showed the impact of expansion works on flora, fauna and the ecosystem of the area in general. The major findings of this study clearly indicated the optimal salinity levels of Canals' waters in order to minimize the environmental effects. Various mitigation measures in this direction were suggested

Laurence (2007) pointed out environmental impacts of the Panama Canal Expansion Project. It was indicated that approximately 700 hectares of rainforest would be destroyed. Infrastructure and facilities construction and overheated development were identified as major reasons. In addition, the consequences of forests destruction on flora and fauna were also highlighted.

Brittner, Braird and Adams (2012) stated that the Panama Canal Expansion Project would make a considerable influence at the global climate change. Data regarding US imports and exports of freight movements were collected from various sources. According to findings, maritime transportation mode showed the lowest amount of emissions in comparison with trucks, rails and intermodal facilities. The results of conducted analysis indicated that approximately 25.6 billion kg CO_2 was emitted by the transportation of goods from East and Southeast Asia in 2007. The absence of the Panama Canal Expansion would cause 50.2 billion kg CO_2 by 2025.The total amount of emissions after the Canal Expansion project implementation was expected to decrease by 2.69 percent per ton compared to the no-build scenario. The paper concluded that the Panama Canal Expansion project would help ports, fleet operators, and shipping organizations to control the environmental impacts of international shipping.

GFDRR (2012) focused on the natural hazards that potentially could affect the greater area of Panama and the Panama Canal. Due to the high exposure to potential hazards and the forecasted climate changes, authors suggested that the Panama Canal Expansion Project should be ensured against natural disasters in order to prevent people and environment from negative consequences.

7. Conclusions

The Panama Canal Expansion Project is expected to be one of the most important construction projects in recent years. It will increase almost twice the Canal capacity from 340 million tons up to 600 million tons a year by 2014. The project includes introduction of the third set of locks, deepening and widening and changing of vessel configuration. Post-Panamax vessels will have capacity of 8,000 TEU and Neo-Panamax vessels will have capacity of 10,000 TEU. Considerable investments are involved in the Panama Canal Expansion. The approximate cost of the project comprises $5.25 billion. The Panama Canal Authority contracted numerous consulting companies, research institutes and independent experts in order to forecast future demand and capacity of the Canal, after expansion, estimate the potential impact and the related costs.

The Panama Canal Expansion Project attracted major global maritime market participants. Relationships between Panama and its competitors were discussed. One of the major results of the canal's expansion is that it will increase demand at the Eastern American ports. US Department of Transportation makes huge investments to develop infrastructure of seaports and intermodal transportation.

The Panama Canal Expansion will alter not only the world maritime transportation but will impact the world environment. Experts highlight that this project will require around 700 hectares of timber, huge excavation and rock drilling works. Deterioration of forests will influence flora and fauna of the country. Most of all, Panama is located in seismic zone, something which creates additional concerns. Also, expansion is expected to increase rainfall and affect the world global temperature.

Finally, from the conducted literature review we can state that the Panama Canal Expansion Project can be considered as controversial: some experts believe that the project will improve the global maritime transportation and help other ports to develop their capacities. However, others think that the project will negatively impact operations of particular ports, and the world environment in general. Thus, we can be either negative or positive relatively to the Panama Expansion Project, but we cannot reject the fact that it will bring notable changes.

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CHAPTER 2: MULTIMODAL FREIGHT DISTRIBUTION IN THE US

1.0 Introduction

The recent economic recession has seen a decrease of containerized shipment in the United States. According to data published by U.S. Department of Transportation, the metric tons of shipments recorded 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. dominantly by rail or truck. Since the container shipments transfer the transportation modes at the receiving port, various factors such as dwelling time in the ocean, shipping cost, congestion expectancy, rail or trucking cost, etc. are very important for decision makers of the cargo shipment to determine a route from several alternatives routes.

When the path of a containerized shipment to a location in the U.S. is considered, it almost always utilizes a connection between port and rail or highway system. Depending on the arrival port in the U.S., alternative routes would be different from each other. Currently, the most popular such connection routes are between ports in the Pacific coast and interstate rail and/or highway systems. The second most popular connection is between ports on south and Gulf coasts and rail and highway systems, while the third connection is between ports in Canada and rail systems into the U.S.

Currently, ports on the Pacific coast receive most vessel calls from Asia since the size of the vessels arriving in California and Washington states is larger than the Panama Canal's lock size. In addition, these routes are less congested. These imported containerized shipments change their mode to rail or truck and reach as far as the east coast of the U.S. Once the Panama Canal's expansion project is complete and its increased capacity and enlarged lock system are provided, it is expected that there will be a change of vessel distribution to all ports of the U.S. as more and larger vessels may use the canal. Consequently, containerized shipments which currently arrive in ports on the Pacific coast and are destined the Midwest or South of the U.S. can be re-routed to the ports on the Gulf coast.

In addition, as a competitive alternative outside of the U.S., the port of Prince Rupert in Canada has increased its capacity and promoted rail connections reaching the Midwest, South, and East of the U.S.

Thus, considering the current trade circumstances and international capacity expansion around Panama and the U.S., it will be worthy to find the impact on the containerized shipments distribution and expected economic results in the U.S. In this document, the condition of containerized shipments in the U.S. is briefly investigated. Then the facility conditions of the ports and the Panama Canal, as well as those factors that affect decision process for containerized cargo are reviewed and summarized.

2.0 Containerized shipments in the U.S.

2.1 Recent Trend of Container Freight in the U.S.

The importing and exporting of maritime shipments to and from the U.S. is usually conducted by six types of vessels: Container, Tanker, Dry Bulk, Ro-Ro, General, and Combo. Among these types, containerized shipments handle 16.2% of imports and 29% of exports in terms of weight. However, when value of the items is considered as shown in Table 1, containerized shipments cover 58.9% of imports and 65% of exports of maritime shipments of the U.S.

Table 1 2005 Waterborne Databank National Percentages (Wilson and Benson, 2009)

Year 2005	Weight		Value	
	Import	Export	Import	Export
Containerized	16.2	29.0	58.9	65.7
Non-Containerized	81.7	64.7	34.6	25.7

* Sum of each column does not satisfy 100% since data from Waterborne Databank has missing or miscellaneous errors, as indicated by Wilson and Benson.

For further detailed analysis of the distribution of containerized shipments, total container volume is divided into import and export shipments from year 2007 and 2010 and plotted in Figure 2. It is interesting to note that import shipments have been influenced and have fluctuated with the global economic status. The amount of imports since 2007 has decreased, corresponding with the world-wide economic recessions. While 131.7 million metric tons were recorded in 2007, this declined to 122.7 million metric tons in 2008, and kept decreasing to 103.4 million metric tons in 2009. (U.S. Department of Transportation, August 2011). It is worthy to note that in 2010, the figure rebounded 118.1 million metric tons were recorded. A report from HIS Global insight, Inc. in 2009 concluded that containerized ocean freight movement into the U.S. has increased by 51% when the record of years 2004 and 2009 are compared. In a macroscopic view for the inbound containerized freight movement, even though the economic recession impacted containerized shipment movement, it is still predicted that volumes of containerized trade into U.S. ports will double by 2020.

The amount of export container shipments indicates modest changes, recording 102.2 million metric tons in 2007, 107.2 million metric tons in 2008, 102.1 million metric tons in 2009, and 111.7 million metric tons in 2010. Unlike with import container shipments, export container shipments were less sensitive to global economic status for the given period.

When the weights of container shipments are compared by imports and exports, it is obvious that the weight of import shipments is larger than the weight of export shipments. The difference becomes obvious when they are viewed in the 'Twenty-foot Equivalent Unit's (TEUs), standard counting units of containers as in Figure 3.

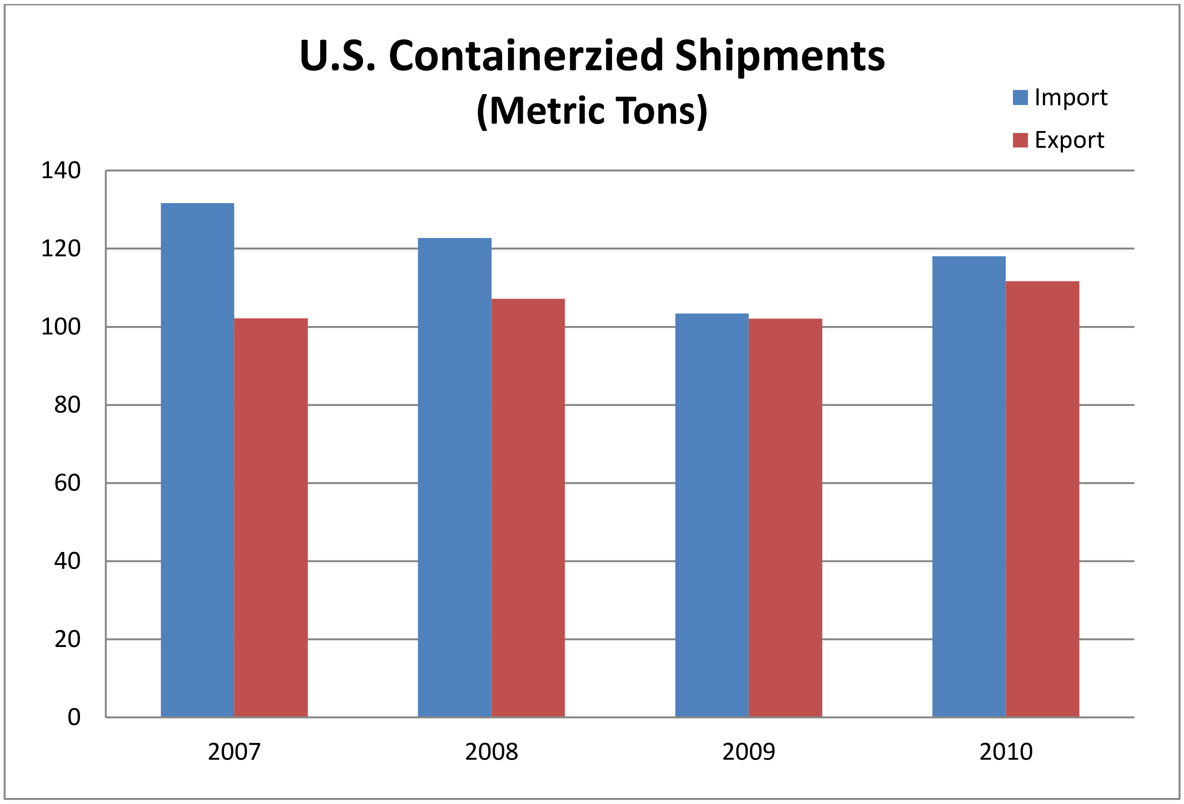

Figure 2 U.S. Containerized Shipments (Metric Tons). Source: U.S. DOT Maritime Administration

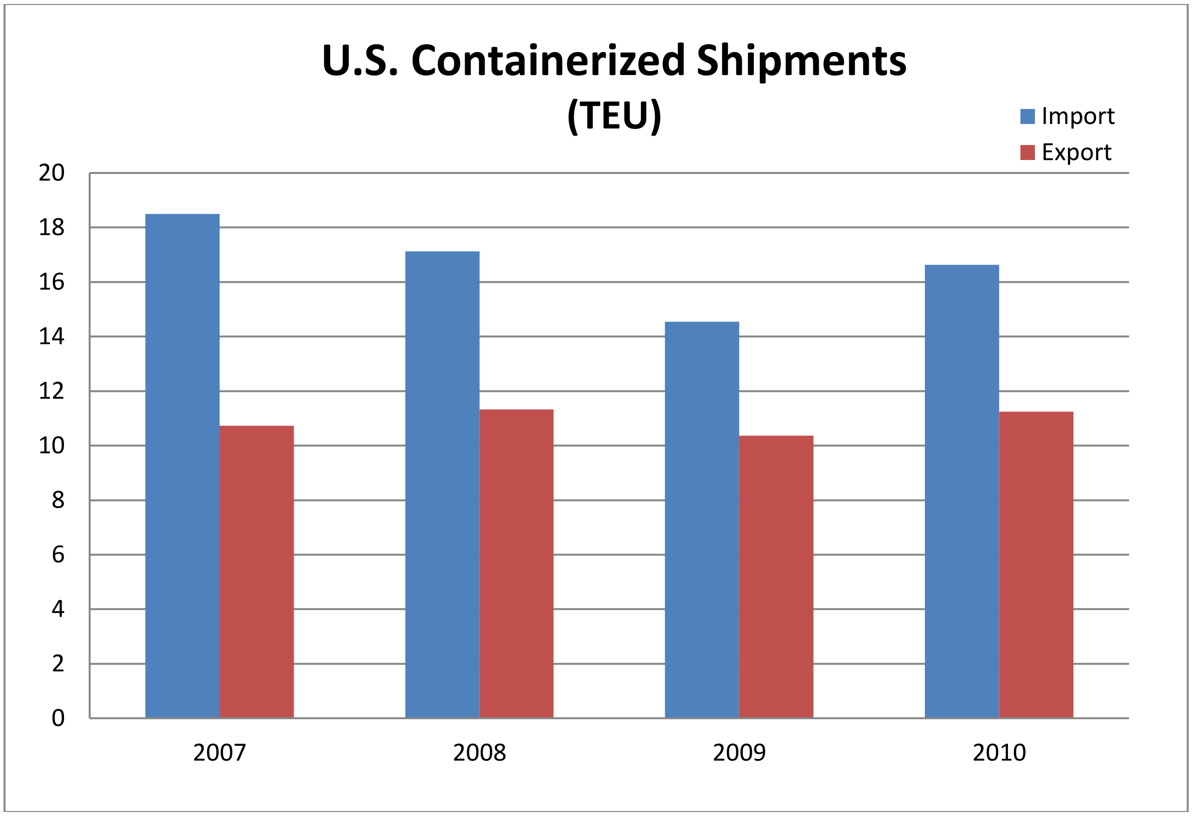

Figure 3 U.S. Containerized Shipments (TEU). Source: U.S. DOT Maritime Administration

2.2 Trade Partners of the U.S.

According to a US DOT report (January 2011), the U.S.'s primary trade partner in terms of inbound container shipments into the U.S. is China, accounting for 25% of the total containers imported by volume in 2000 and reached 48% in 2009. Furthermore, the top five partners for containerized import trading to the US in 2009 were all in Asia: China, Japan, South Korea, Taiwan, Singapore, and Hong Kong. In Table 2, the weight and value of maritime freight from six Asia countries (Hong Kong is separately considered in trade partners) and the U.S. total are listed. Weights of ocean freight from these six Asian countries make up 10% of U.S. total imports amount between 2007 and 2010. However, the values amount to 40% of the total ocean freight values coming into the U.S. from 169 countries.

Table 2 Maritime Import Amount From Six Asian Countries (Source: U.S. DOT Maritime Administration)

Units	2007		2008		2009		2010	
	Metric Tons (Thousand)	Dollars (Million)	Metric Tons (Thousand)	Dollars (Million)	Metric Tons (Thousand)	Dollars (Million)	Metric Tons (Thousand)	Dollars (Million)
China	69,343	236,836	64,046	250,796	45,803	210,599	53,892	250,729
Japan	14,223	106,481	12,293	102,928	7,917	67,165	9,755	84,704
South Korea	15,564	31,590	10,686	30,358	9,265	23,202	11,720	29,998
Taiwan	8,419	22,727	5,824	21,975	4,420	15,389	5,090	19,022

Singapore	789	3,359	504	3,957	419	3,452	504	3,729
Hongkong	610	4,110	460	3,398	274	1,653	365	1,813
Asia Total	108,947	405,102	93,812	413,412	68,098	321,459	81,326	389,996
US Total	949,888	1,023,395	892,133	1,152,481	749,955	795,336	783,255	978,799
Percentage of Asian Originating Containers (%)	11.47%	39.58%	10.52%	35.87%	9.08%	40.42%	10.38%	39.84%

Table 3 Container Import Amount From Six Asian Countries (Source: U.S. DOT Maritime Administration)

Units (Thousands)	2007		2008		2009		2010	
	Metric Tons	TEU	Metric Tons	TEU	Metric Tons	TEU	Metric Tons	TEU
China	52,139	8,810	47,861	8,048	40,814	6,948	46,940	8,041
Japan	5,241	782	4,733	707	3,172	483	4,030	575
South Korea	4,065	565	3,965	568	3,287	482	4,244	631
Taiwan	4,017	560	3,786	516	2,935	411	3,495	480
Hong Kong	3,054	644	2,751	566	2,071	422	2,609	537
Singapore	607	73	532	64	414	49	550	68
Asia Total	68,516	11,361	63,096	10,405	52,279	8,746	61,318	10,264
US Total	131,704	18,502	122,725	17,121	103,416	14,542	118,030	16,629
Percentage of Asian Originating Conatiners (%)	52.48%	61.80%	51.85%	61.14%	50.95%	60.48%	52.42%	62.13%

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 significant portion of the total weights and volumes of container cargos into the U.S. In Table 3, weights and volumes of importing container shipments into the U.S. are compared from 2007 to 2010. This shows Chinese shipments make up almost 40% of weights and 50% of volumes of the total importing container shipments into the U.S. and the numbers in the row "Asia Originating Countries" show over 50% meaning that one in two containers imported into the U.S. is from the six Asian countries.

2.3 Import and Export by Coast Area and Ports

When the huge container shipment volumes from Asia are considered, it is very important to know the routes over shich the containers are transported. Depending on the routes, available ports along the U.S. coast can be divided into two groups. One group constitutes the ports along

Pacific coast and the other constitutes ports along Gulf and Eastern coasts. The reason why the ports can be divided into two groups is that the Panama Canal should be used for the vessels from Asia to call the ports along Gulf and Eastern coasts. When container vessels pass the canal and call the ports on Gulf and Eastern coasts, dwelling time in the ocean, shipping cost, available number of ports, and connected rail networks increase relative to when the vessels call the port on Pacific coast.

Data from U.S. DOT reported the general distribution of container freight volumes of import and export recorded between 2007 and 2010 by coast and is listed in Table 4. West coast ports imported 9 million TEU and exported 4.7 million TEU, and East and Gulf Coast ports imported 5.5 million TEU and exported 4.6 million TEU in 2010. A significant volume difference is observed in import amount while the export amount showed less difference between ports in West Coast and East and Gulf Coast in 2010 and as well as from 2007 to 2009.

Table 4 Container Import and Export Amount in the U.S. By Type, Year, and Coast

Million TEU	2007		2008		2009		2010	
	Import	Export	Import	Export	Import	Export	Import	Export
National	18.5	10.7	17.1	11.3	14.5	10.4	16.6	11.2
Total	29.2		28.4		24.9		27.8	
Top 10 Ports in US								
West	10.3	4.3	9.2	4.6	7.7	4.4	9.0	4.7
East-South	5.9	4.4	5.7	4.7	4.9	4.2	5.5	4.6
SubTotal	16.2	8.7	14.9	9.3	12.6	8.6	14.5	9.3
Total	24.9		24.2		21.2		23.8	
% of Nat'l	87.57%	81.31%	87.13%	82.30%	86.90%	82.69%	87.35%	83.04%

Data source from U.S. Department of Transportation, Maritime Administration. Available at http://www.marad.dot.gov/library_landing_page/data_and_statistics/Data_and_Statistics.htm

Among the ports in the U.S., the top 10 busiest ports handled more than 85% of containerized shipments from 2007 to 2010. Those include five ports from West coast (Los Angeles, CA, Long Beach, CA, Oakland, CA, Seattle, WA, and Tacoma, WA) and five ports from East and Gulf Coast (New York, NY, Savannah, GA, Norfolk, VA, Houston, TX, and Charleston, SC). US DOT published a report in 2009 about freight transportation gateways including ocean trade for both imports to and exports from the U.S. and is summarized in Table 5 and Table 6.

Table 5 Activity of Four Major Ports on Pacific Coast in 2008

Ports on the Pacific (4 Ports)	Unit	Total Amount	Import			Export		
			Amount	Major Country	Weight	Amount	Major Country	Weight
US Trade by Water	Value	1,623,863	1,152,327	China	70.45	471,536	China	36.65

	Weight	1,519	983			536		
	TEU	28,309	17,032			11,277		
Port of Los Angeles, CA	Value	243,910	209,086	China	15.43	34,823	China	4.16
	Weight	75	54			22		
	TEU	5,611	4,014			1,598		
Port of Long Beach, CA	Value	91,537	59,938	China	15.03	31,599	China	5.63
	Weight	48	22			26		
	TEU	4,553	3,114			1,439		
Port of Seattle, WA	Value	39,989	30,049	Canada	3.62	9,940	Japan	3.39
	Weight	22	8			13		
	TEU	1,080	656			423		
Port of Oakland, CA	Value	38,698	26,299	China	2.65	12,400	China	2.09
	Weight	19	10			9		
	TEU	1,388	726			662		
Pacific Ports	Value	414,134	325,372			88,762		
	Weight	164	94			70		
	TEU	12,632	8,510			4,122		
Percentage of Pacific vs. US total	Value	28.6%	28.2%			18.8%		
	Weight	10.8%	9.6%			13.1%		
	TEU	44.6%	50.0%			36.6%		

* Value: US Dollars, Millions
** Weight: Short tons, Millions (Multiply by 1.1023 to Metric Tons)
*** TEU: TEUs, Thousands
**** Value and Weights includes all maritime mode records
***** Record of Tacoma, WA is not available from America's Freight Transportation Gateway report by RITA

Inferred from Table 5, the two ports of Los Angeles and Long Beach handle more than 40% of total container freight volumes into the U.S. and the inbound containers are distributed to destinations throughout the U.S. by using 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 (L.A.)/Long Beach, CA and Chicago, IL. (IHS Global Insight, Inc., January, 2009).

Table 6 Activity of Five Major Ports on Gulf and East Coasts in 2008

Ports on Gulf & East (5 Ports)	Unit	Total Amount	Import			Export		
			Amount	Major Country	Weight	Amount	Major Country	Weight
US Trade by Water	Value	1,623,863	1,152,327	China	70.45	471,536	China	36.65
	Weight	1,519	983			536		
	TEU	28,309	17,032			11,277		
Port of New York,	Value	185,385	134,817	Canada	15.58	50,568	China	2.17

NJ	Weight	90	68			23		
	TEU	3,956	2,542			1,413		
Port of Houston, TX	Value	147,695	78,873	Mexico	21.91	68,821	Mexico	7.24
	Weight	150	93			57		
	TEU	1,363	574			789		
Port of Charleston, SC	Value	62,332	40,051	Brazil	1.34	22,281	Germany	7.05
	Weight	19	12			8		
	TEU	1,326	690			635		
Port of Savannah, GA	Value	58,987	36,150	Trinidad and Tobago	3.45	22,838	China	1.68
	Weight	36	19			17		
	TEU	2,106	1,086			1,020		
Port of Norfolk, VA	Value	53,950	30,023	China	1.40	23,927	Italy	2.36
	Weight	39	10			29		
	TEU	1,585	807			778		
Gulf & East Ports	Value	508,349	319,914			188,435		
	Weight	334	202			134		
	TEU	10,336	5,699			4,635		
Percentage of Gulf & East vs. US Total	Value	31.3%	27.8%			40.0%		
	Weight	22.0%	20.5%			25.0%		
	TEU	36.5%	33.5%			41.1%		

* Value: US Dollars, Millions
** Weight: Short tons, Millions (Multiply by 1.1023 to Metric Tons)
*** TEU: TEUs, Thousands
**** Value and Weights includes all maritime mode records

2.4 Port Capacity

The container vessel calls in the U.S. are concentrated in the top 10 ports as shown in Table 7. It is observed in this table that almost 80% of the U.S. port capacity is accounted by 10 ports and top five ports are handling more than 50% of the vessel calls.

Table 7 Top 10 U.S. Port Capacities in 2009

Coast	Port	Capacity (dwt*, thousands)
West	Los Angeles/Long Beach, CA	147,347
	San Francisco, CA	111,546
	Seattle, WA	39,029
	Tacoma, WA	30,284
	Subtotal	328,206
Gulf & East	New York, NJ	124,997
	Savannah, GA	95,709
	Virginia Ports, VA	84,943

	Charleston, SC	68,035
	Houston, TX	38,380
	Subtotal	412,064
Top 10 Port Total Capacity		740,270
US Total Capacity		913,978
Percentage of Top 10 ports		80.99%

* dwt: deadweight ton

Container vessels calling U.S. ports have been increasing in vessel sizes for several decades, and a comparison plot of the vessel sizes in 2004 and 2009 seen in Figure 4, shows the differences clearly. Vessels sized of 5,000 TEU and greater have doubled in number from 2004 to 2009 and smaller vessels have been used less frequently for calling U.S. ports.

The number of container vessel calls at U.S. ports has demonstrated a constant trend between 2002 and 2009 compared with the fluctuation of all vessel calls as shown in Figure 5. Resulting from this trend, containerships as percent of total vessels accounted for 33 percent of the total calls by all vessel modes, up from 30 percent in 2002.

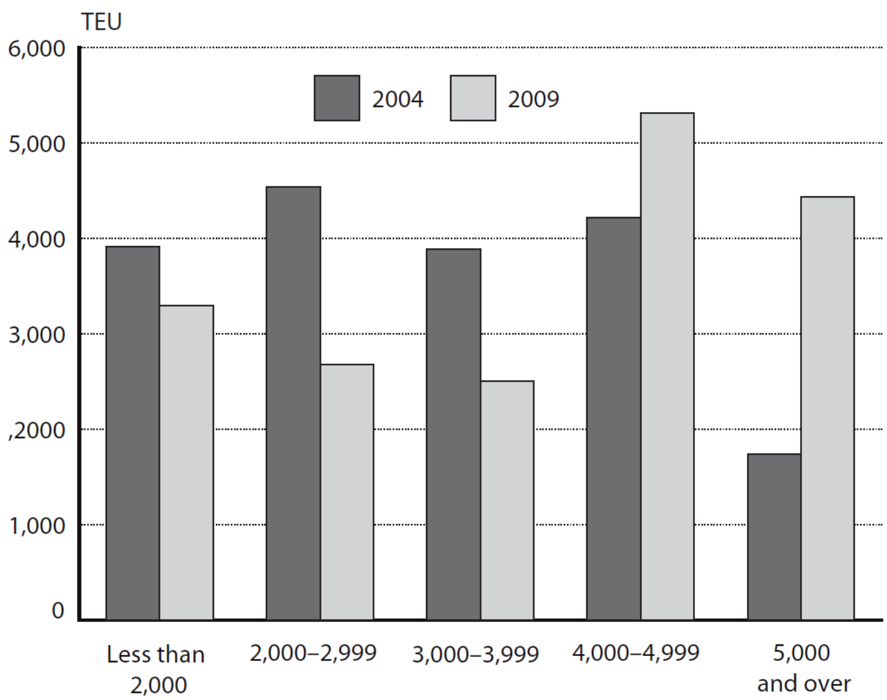

Figure 4 Container Calls at U.S. Ports by Vessel Size: 2004 and 2009
(Source: US DOT, America's Container Ports: Linking Markets at Home and Abroad, 2011)

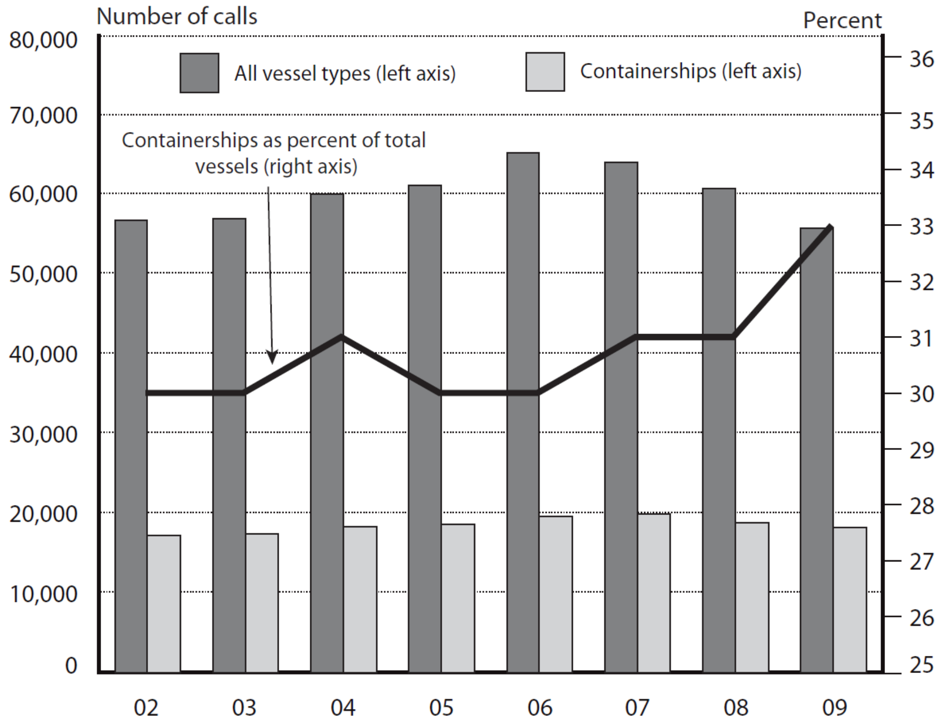

Figure 5 Vessel Calls at U.S. Seaports: 2002-2009
(Source: US DOT, America's Container Ports: Linking Markets at Home and Abroad, 2011)

2.5 Imported Container Distributions in the U.S.

Once container cargos are imported into the U.S., containers are distributed to their local destinations after transshipment into rail or truck at port. A report from the Federal Maritime Commission in 2012 analyzed distributions of containers imported via the U.S. ports along the Pacific coast and Canadian ports on Pacific coasts which are summarized in Table 8. Due to confidentiality issues, the analysis is based on regions, not on specific port 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. Additionally, container flows from Vancouver and Prince Rupert in Canada are also included, but the flows to other states are not revealed for the data confidentiality issue.

This data is very helpful for understanding container flow in the U.S. after being imported at ports. Among the containers imported in the U.S., between 2007 and 2010 almost 60% are destined for the Midwest region in all types: weight, value, volume. The Midwest region states includes Illinois, Iowa, Indiana, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Tennessee, and Wisconsin.

Table 8 Imported Container Cargo Distributions from the Pacific Coast to Midwest and to All Other States in the U.S.

Origin	Year	2007		2008		2009		2010	
	Destination	Midwest	All Other	Midwest	All Other	Midwest	All Other	Midwest	All Other

LA/LB	Metric Tons	13.53	10.86	12.02	10.02	8.66	7.55	9.45	8.61
	Revenue	1,018.40	833.64	965.63	856.67	800.33	681.77	963.06	836.75
	Est. TEU	1.85	1.46	1.62	1.33	1.19	1.05	1.30	1.20
Other West	Metric Tons	4.67	0.56	4.43	1.20	3.29	0.88	4.32	0.95
	Revenue	376.92	52.06	381.46	127.74	324.55	83.58	442.68	101.23
	Est. TEU	0.64	0.08	0.60	0.16	0.44	0.12	0.56	0.13
Vancouver and Prince Rupert	Metric Tons	0.67	N/A	1.27	N/A	1.11	N/A	1.70	N/A
	Revenue	55.57		126.92		104.93		174.93	
	Est. TEU	0.09		0.17		0.16		0.24	

* N/As for Vancouver and Prince Rupert are suppressed due to confidentiality

** Midwest includes Illinois, Iowa, Indiana, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Tennessee, and Wisconsin

As an example from Table 8, estimated TEU data is plotted in Figure 6. From 2007 to 2010, container volume distributions are compared by the destination region, Midwest or All Other States, and each bar is subdivided by port origin in the U.S. and Canada. Overall volumes of container shipments are observed as decreasing from 2007 to 2009 and have somewhat rebounding from 2010. Since the global economic recession occurred during this period in U.S. trading history, the same trend can be observable. One remarkable point is that the distribution difference of the containers imported via Los Angeles and Long Beach is not much different for the destination regions. Instead, other ports on the Pacific coast showed difference for the container distribution to the destination regions. Because container distributions from Canadian ports are only revealed for Midwest regions, it is hard to conclude the difference.

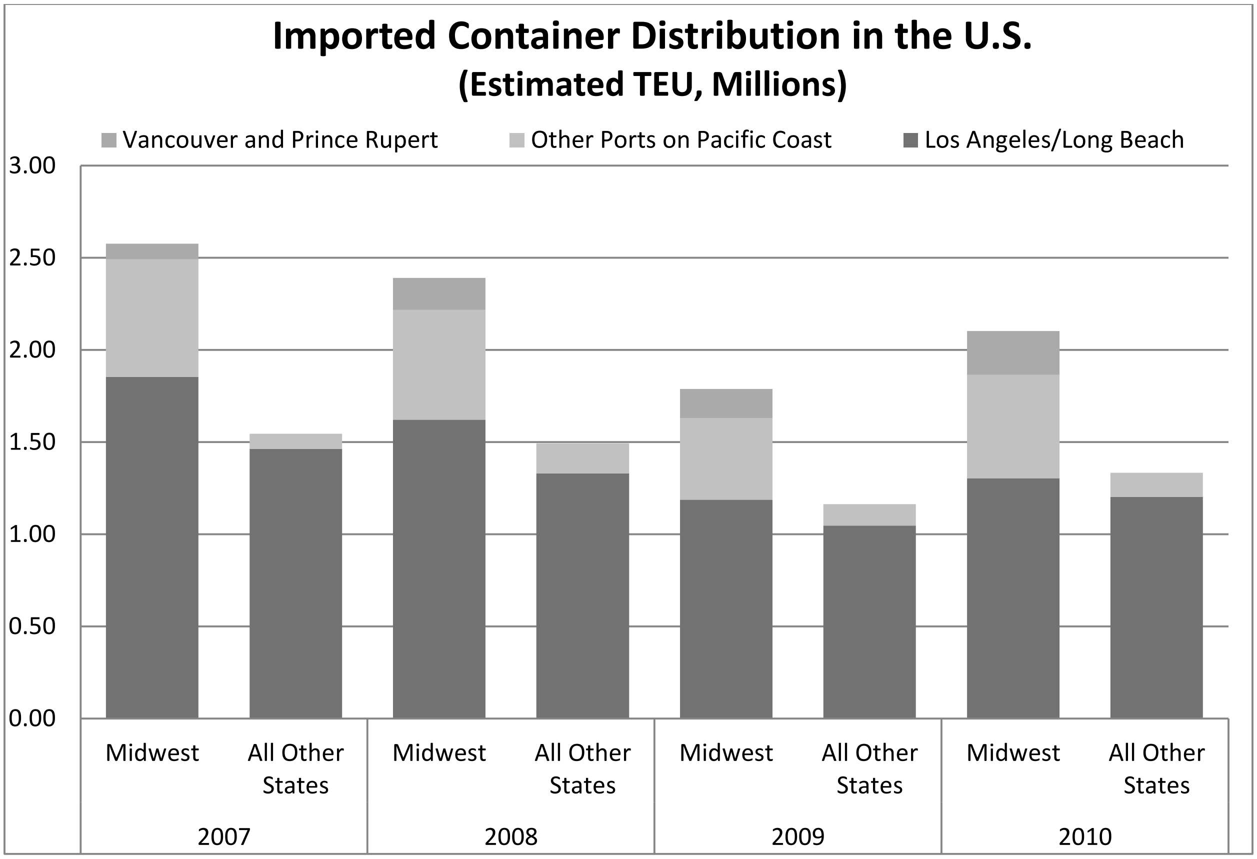

Figure 6 Imported Container Distribution in the U.S. (Estimated TEU, Millions)

Container distributions from the U.S. ports on the Gulf and East coasts are analyzed using the Public Use Waybill Sample (PUWS) carload data from 2006 to 2011 available from the Surface Transportation Board (STB). Among the PUWS data, samples recording imported and intermodal shipments with prior or subsequent waterborne movement are selected. Then the origin and termination Bureau of Economic Analysis (BEA) Economic Areas are classified to identify the origin as ports on the Gulf and East coasts and the destination as the Midwest region states. The Midwest region states are divided into two regions, Chicago-North and Memphis-South. 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. Due to confidentiality issues, specific location and transit revenue information are not revealed publicly and contracted waybill data is also excluded in the PUWS carload data.

Table 9 Imported Container Cargo Distributions from the Gulf and East Coasts to Midwest and to All Other States in the U.S.

Origin	Year	2006			2007			2008		
	Destination	Chicago-North	Memphis-South	All Other	Chicago-North	Memphis-South	All Other	Chicago-North	Memphis-South	All Other

East Coast	Metric Tons	452.8	0.12	295.72	143.48	0.12	237	429.24	0	269.8
	Revenue	44,039.52	6.28	10,031.32	12,668.68	6.28	7,000	30,449.28	0	12,252.28
Gulf Coast	Metric Tons	607.88	8.68	753.64	280.36	0	271.12	183.84	0	352.52
	Revenue	38,944.64	612.2	47,411.08	16,709.12	0	19,335.2	10,897.96	0	24,335.84

Origin	Year	2009			2010			2011		
	Destination	Chicago-North	Memphis-South	All Other	Chicago-North	Memphis-South	All Other	Chicago-North	Memphis-South	All Other
East Coast	Metric Tons	127.674	0	164.16	156.16	0	206.32	285.36	0	197.24
	Revenue	9,949.16	0	5,367.2	12,965.72	0	4,734.72	26,120.84	0	4,553.36
Gulf Coast	Metric Tons	15.686	0	33.24	17.72	0	28.8	24.24	0	71.12
	Revenue	816.28	0	3,090.36	1,662.88	0	2,501	1,948.92	0	5,655.64

* Metric Tons: Thousands
** Revenue: US Dollars, Thousands

Based on the selected PUWS carload data from the Gulf and East coasts to the Midwest regions, estimated weights and revenues of annual cargos are summarized in Table 9 and plotted in Figure 7 and Figure 8. From 2006 to 2011, container distributions are compared by the destination regions, East or Gulf Coast and Chicago-North, Memphis-South, or All Other States, and each bar is subdivided by port origin in the Gulf and East coasts of the U.S. Overall numbers of container shipments in metric tons and values are observed as decreasing from 2006 to 2009 and slightly rebounded from 2010 as observed in the Pacific coast case with similar reasons. An observable point is that the decreasing rate of container weights and revenues. The rate along the Gulf and East coasts showed much rapid than the rate along the Pacific coast between 2006 and 2007. For the container cargo distribution trend from each coast, it is hard to find constant distribution trend to the Midwest regions. A significant point is that the value's distribution to the Midwest regions is larger than the one to all other states in the U.S. This means much valuable cargos based on the same weight are distributed to the Midwest regions than to all other states when it is considered with the cargo distributions by metric tons. The distributional comparison between Chicago-North and Memphis-South in the Midwest region is not available at this point because no cargo movement is recorded to Memphis-South region after 2007. This may be resulted from confidential restriction to the use of waybill information.

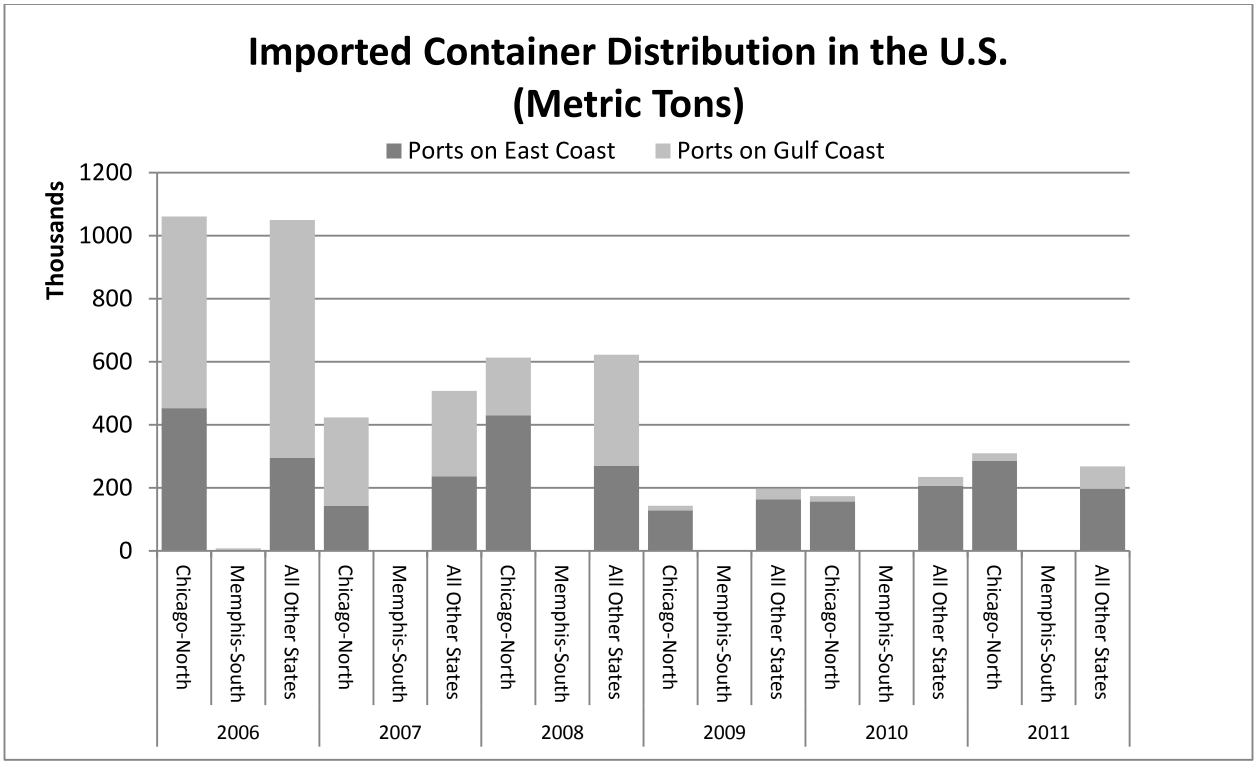

Figure 7 Imported Container Distribution in the U.S. (Estimated Metric Tons)

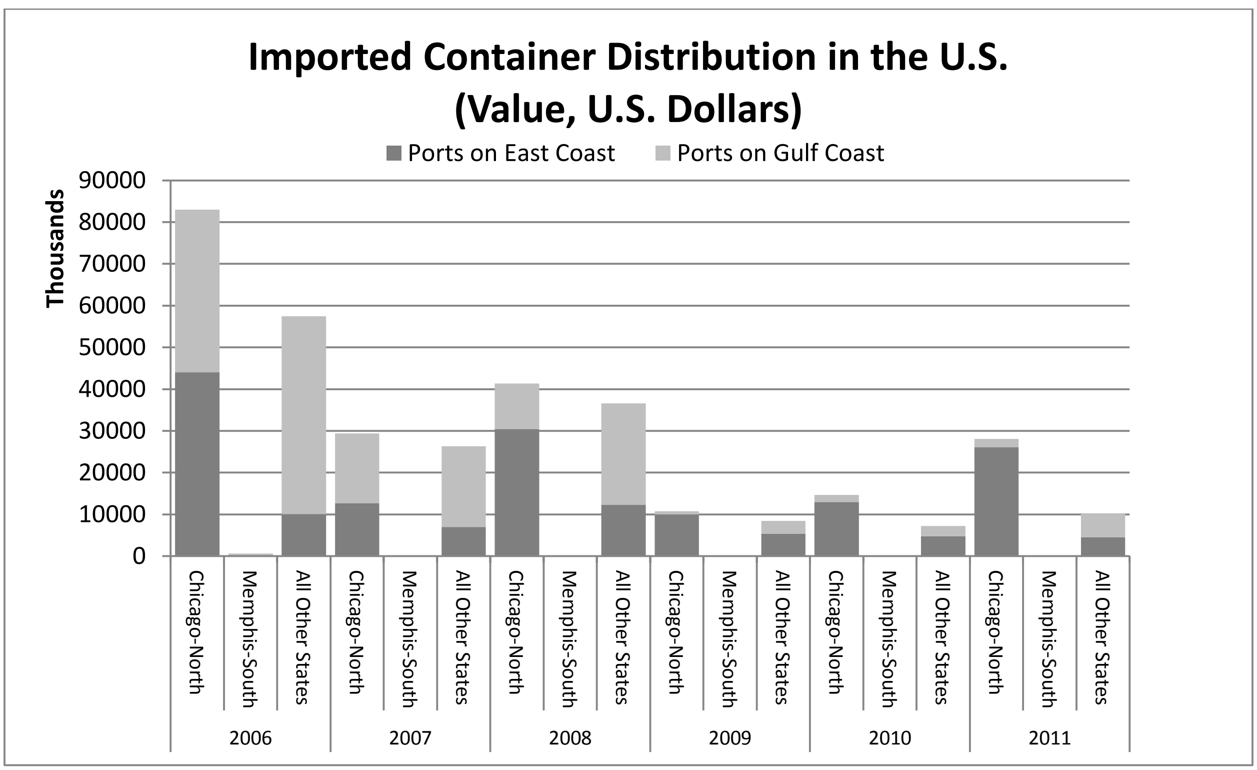

Figure 8 Imported Container Distribution in the U.S. (Estimated US Dollars)

3.0 Alternative routes to Midwest and Southern US

The Panama Canal Expansion will be introduced because the locks' increased capacity and size are supposed to impact the import container distribution into the U.S. In addition to the routes from the U.S. ports along the Pacific, Gulf, and East coasts to the Midwest and Southern US, there are two new port gateways recently established: Prince Rupert in Canada and Lázaro Cárdenas in Mexico (Rodrigue, 2010). In this document, Prince Rupert is highlighted since containerized shipments through the port of Lázaro Cárdenas in Mexico was assumed to show modest increase in volume and the port in Mexico is mainly connected up to Texas and Kansas regions. Also, the Suez Canal was found to take around 2% for share of the Northeast Asia – U.S. East Coast route with considerations of longer shipping time, higher canal toll rate, and the lingering issue of piracy along the coasts of Somalia and Yemen. In this report, therefore, two alternative routes, through the Panama Canal and through the port of Prince Rupert, will be discussed for import container flow to the U.S.

3.1 Initiation of the Panama Canal Expansion

The Panama Canal was opened in 1914 after 34 years of construction cost of $639 million (Canaga Retna, S. M., 2010). Due to the increased worldwide use of ocean container shipments, the capacity of the canal has been reached, and the waiting time to use the canal has reached 10 days during peak season (Johnson, B., 2008). As a result, in 2006, a decision was made by the government of Panama to expand the Canal an estimated cost of $5.25 billion. It is projected that in 2014, the Panama Canal's expansion project will be complete and the increased capacity will provide service for the vessels to save sailing time between Pacific and Atlantic oceans.

When the Panama Canal initiated its service in 1914, its maximum lock size was enough to handle the vessels. However, as ship sizes increased, a size known as "Pana-Max" was established, to indicate the maximum sized ship that may fit in the canal. As the containerized trade became more popular due to ever increasing global market trade, the size of the vessels increased further to meet the economies of scale. Bigger vessels can handle more containers at a time and this would consequently decrease the shipping cost. However, since the canal has not expanded its capacity and lock size, such larger vessels must call at the ports in the Pacific Coast because the post Pana-Max vessels cannot fit through the Canal, resulting in congestion in those ports.

Current conditions of the Panama Canal allow 35 vessels to pass in a day. Once a new and larger third set of lock is constructed, it will allow additional 15 vessels per day to pass through the canal. Since the new lock size is 1,200×160×50 (ft) - enlarged from 965×106×39.5 (ft), vessels of size greater than the lock size of the canal, called Post-Panamax, can pass through the canal (Canal De Panama, 2011). The comparison diagram of the canal's lock systems is described in Figure 9 and Figure 10 indicates general routes from Asia to ports on the Gulf/East Coast.

With the assumption that the canal's expansion is completed in 2014, there are few studies investigated its impact on containerized shipment into the US. Johnson (2008) reported that more than a dozen East and Gulf Coast ports are enhancing capacities and related infrastructures, because the expected container volume through the canal is expected to double by 2015 (Spivak, 2011). Meanwhile, East and Gulf Coast ports have obtained financial support from the federal government for port enhancement. For example, the Port of Newark has enhanced its facilities with a $650 million investment.

However, there have also been skeptical opinions for the port enhancement plans that are in progress in almost all ports along the East and Gulf Coasts. The executive director of the Port of Long Beach, who already deals with huge vessels which cannot go through the Panama Canal, argues that there will not be a huge change for the users from ports in California to the Atlantic ports. William D. Ankner, a former official of the Port Authority of New York and New Jersey and a former secretary of transportation for Louisiana, stated that there will only be a few beneficiaries from the Panama Canal's expansion (Johns, 2012)

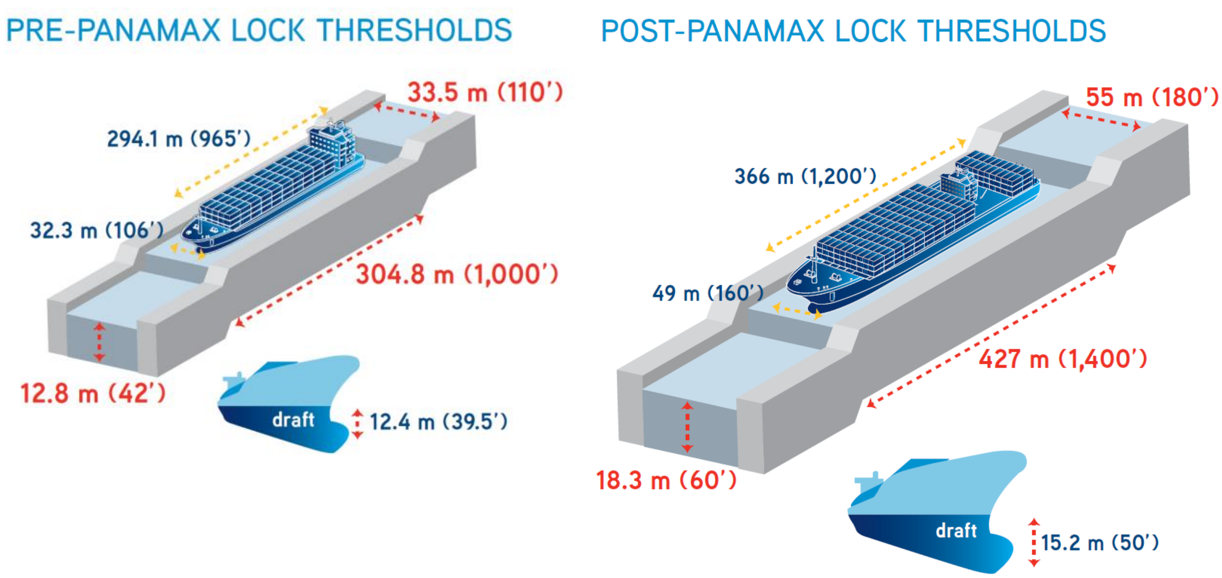

Figure 9 Pre- and Post-Expansion Vessels Transiting the Panama Canal
(Source: North American Port Analysis, Collier International, 2012)

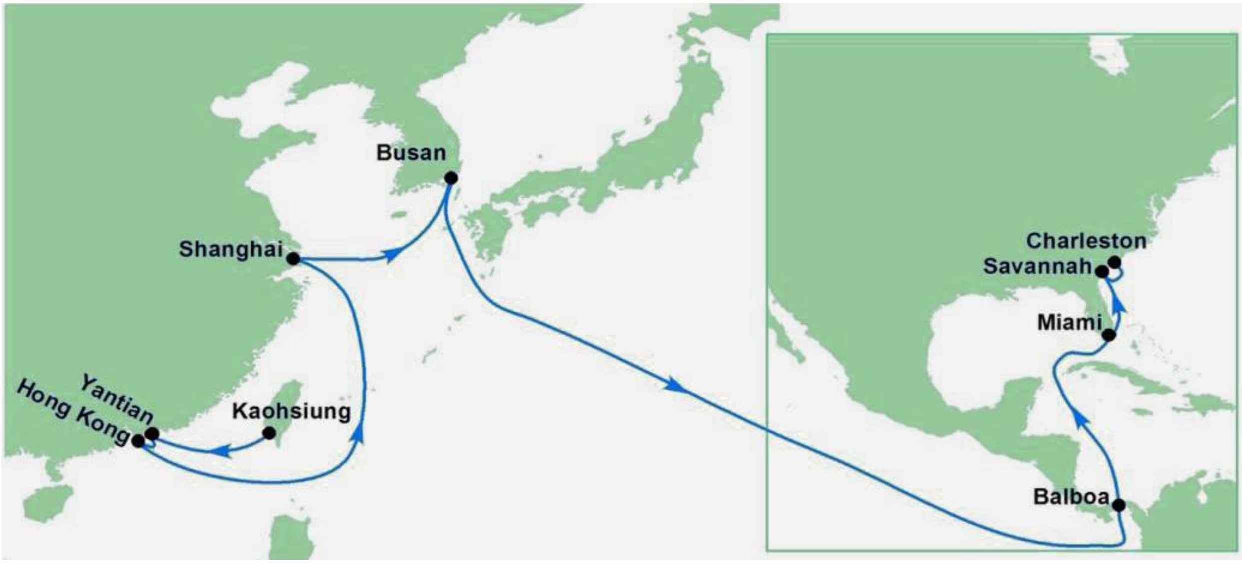

Figure 10 Possible Direct Route from Asia to East Coast through the Panama Canal (CanagaRetna, 2012)

The Army Corps of Engineers (2012) suggested that the redistribution of freight movement will not be a zero-sum game. That is, even though some freight changes its destination from the Pacific coast to the Atlantic Coast, there will be a total increase for incoming freight volume and it will be benefit from ports in both coasts.

Recently, Brandon (2012) analyzed shipments from Shanghai, China to LA/Long Beach, CA and to New York, NJ with the Geospatial Intermodal Freight Transportation model (GIFT) and the Ship Transportation Energy and Emissions Model (STEEM) models. All-water sailing from China to New York, New Jersey (NJ) takes more than 10 days longer than intermodal (sail to L.A./Long Beach, CA and rail to New York, NJ). That means higher energy consumption and CO_2 emission resulted from the All-water case. However, such a practice was still cheaper, resulting in about $900/20'ft and $1,000/40'ft less cost than the intermodal option. In their study, a survey was also conducted of the port authorities along East and Gulf Coasts with nearly a 50% response rate which argued that the canal's expansion will result in positive outcomes for their facilities.

3.2 The Port of Prince Rupert in Canada

When containers sail from Asia, the Panama Canal is not the only option to reach to the destinations in the Midwest, East, and South the U.S. The port of Prince Rupert in Canada has received investments to compete with ports in California and commenced service in 2007 with the advantages of a dedicated transmodal container terminal, shorter transpacific path, lower cost, and less congestion for container shipments into North America utilizing Canadian National RR (CN) connections as indicated in Figure 11.

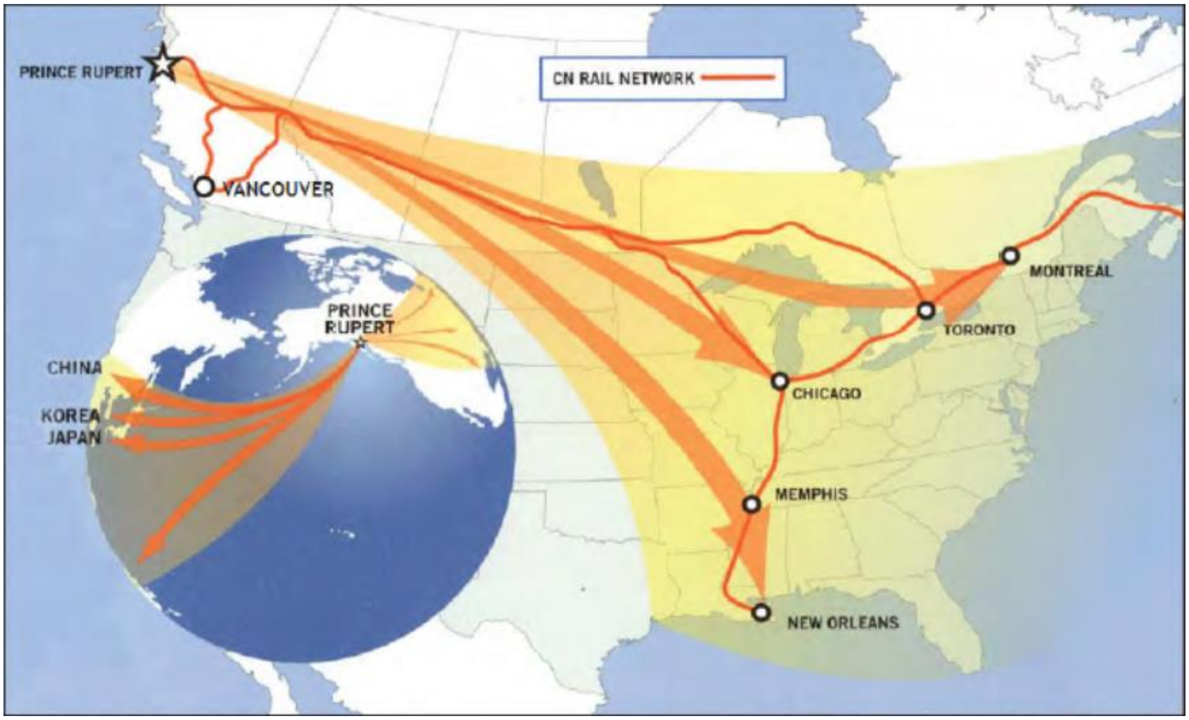

Figure 11 Location of Prince Rupert and connection with Asia and North America (Prince Rupert, 2012)

Since the capacity of the U.S. ports on the Pacific coast and of the U.S. rail systems have reached maximum, the choice of Prince Rupert has become a practical option. In 2007, the US Army Corp of Engineers investigated North American Intermodal container movement and concluded that the ports will reach their limit of capacity and disruption is expected.

Ports in Canada have been focused on containerized shipments from Asia, having expanded their facilities and having planned for further enhancements to reach their destinations in the U.S. Allison Padova Economic Division (2006) reported that the capacity of the port of Prince Rupert was to be increased by 750,000 TEU by 2007 and it is planned to be increased in capacity by 2 million TEU. When the capacity of 7.5 million TEU in Long Beach is considered, this number from Prince Rupert cannot be neglected as an alternative. The port of Prince Rupert has made a rail partnership with CN rail and promoted a High-speed gateway for Asia-North America intermodal shipment. These are all critical, as Asian trade is projected 300% increase in container volumes by 2020 and capacity is expected to increase by 5 million TEU in 2020.

Recently, Lei Fan et al (2010) quantified the impact of variables of shipping cost, ship size, port, water depth and route constraints using a linear optimization formulation for cost minimization analysis including the route future through expanded Panama Canal. They found that rail capacity is more restrictive, especially to Memphis. For shipments to Chicago and Memphis, Prince Rupert is much competitive than the Panama Canal route.

4.0 Route Considerations

Major routes connecting Asia and the Midwest/Southern US are introduced and alternative routes via an expanded Panama Canal and from Canadian ports are discussed. In this chapter, six factors affecting route choice will be discussed: shipping cost, dwelling time, channel depth/crane size, customs clearance, and union disputes.

4.1 Shipping Cost

For the estimation of shipping cost from Asia to the Midwest, it is required to have cost information including ocean freight rate, terminal charges, rail rates, bunker rates, and fuel charges. However this type of information is considered confidential by shipping line and rail service carriers and the rates are supposed to differ between contractors. Therefore, in this part, reports which estimated shipping costs are introduced.

The Federal Maritime Commission (2012) estimated shipping cost from Shanghai to Chicago and Memphis but used the shipping cost via Prince Rupert as base cost and compared it with other routes, via LA/LB, Seattle/Tacoma, and Vancouver. For the shipping cost to Chicago, the route via LA/LB cost $160 for 20ft containers and $200 for 40ft containers more than the route via Prince Rupert. Closer to Prince Rupert, less difference from the base cost of Prince Rupert was observed. When the destination is Memphis, the L.A./L.B. route showed lowest shipping cost for 20ft containers and 40ft containers. For 40ft HQ containers, Prince Rupert route showed lowest cost. The estimated shipping cost table is provided in Table 10.

Brandon (2012) compared shipping costs for transshipment containers from Shanghai to New York via LA/LB and New York. The All-Water route to New York costs about $900 for 20ft containers and $1,000 for 40ft containers more than the route via LA/LB. No additional route via a Canadian port is included in this report. The estimated shipping cost table is provided in Table 11.

Rodrigue (2010) estimated shipping costs of 40ft containers from Shanghai to five ports in the North America. Vancouver featured the lowest sailing cost of $2,300 and Montreal indicated highest cost of $4,040. Unfortunately, rail costs in the U.S. are not included in this report and it is hard to compare the shipping costs among the alternative routes. Detailed routes and cost information is described in Figure 12 and estimated shipping cost table is provided in Table 12.

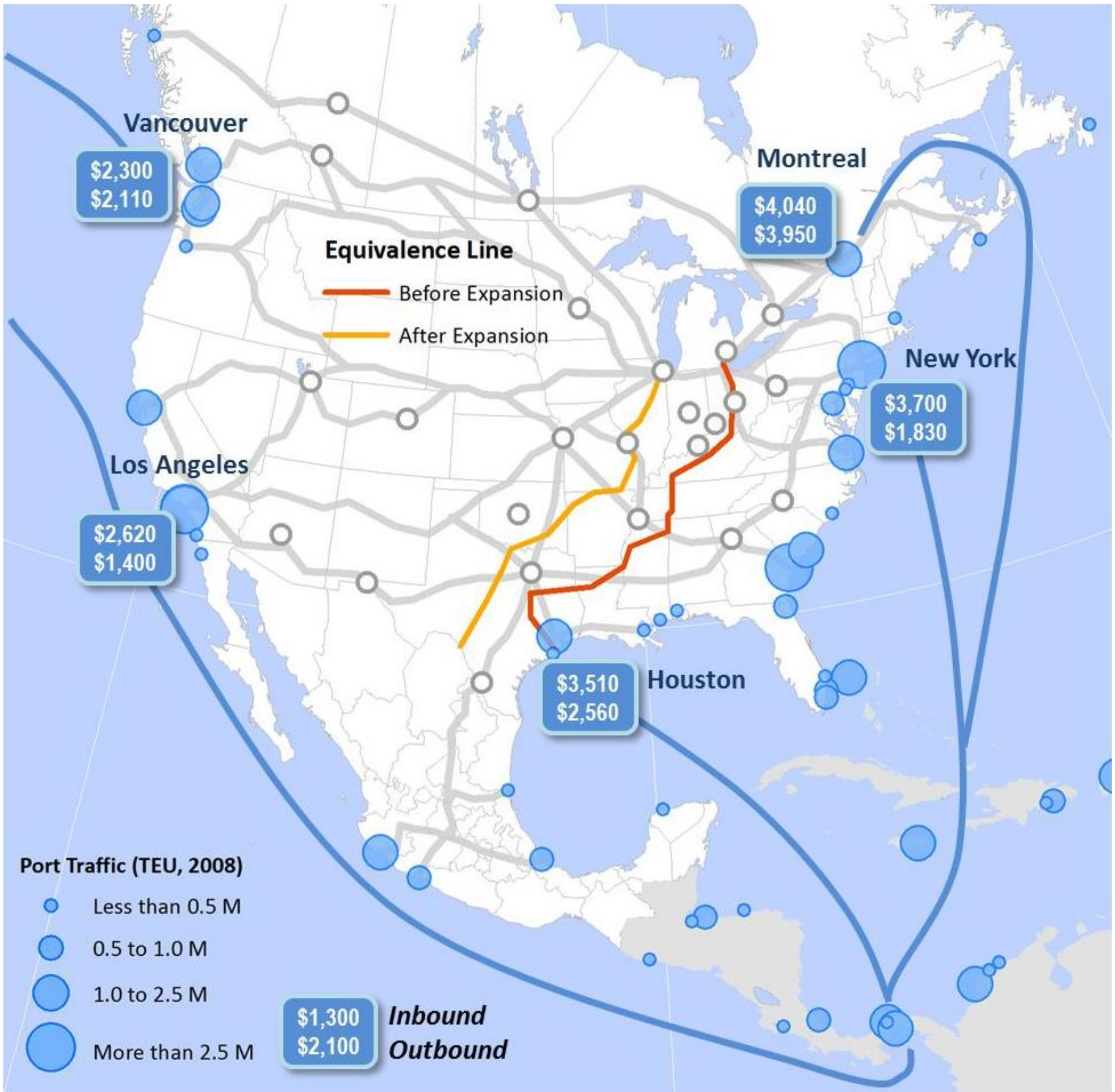

Figure 12 Shipping Rate of 40' Container between Shanghai and North America Ports (Rodrigue, 2010)

Table 10 Estimated Shipping Cost from Shanghai to Chicago and Memphis (Federal Maritime Commission, 2012)

Origin/Destination		To Chicago			To Memphis		
From Shanghai	Transfer Point	20'	40'	40'HQ	20'	40'	40'HQ
	LA/LB	$160	$200	$275	Base	Base	$150
	Seattle/Tacoma	$120	$150	$225	$40	$50	$200
	Vancouver	$92	$115	$100	$20	$25	$25
	Prince Rupert	Base	Base	Base	$60	Base	Base

Table 11 Estimated Ocean and Intermodal Shipping Cost from Shanghai to New York (Brandon, 2012)

Routes (From Shanghai)	Cost (US Dollar)	
Ocean (To the U.S. Coast)	20'	40'
East Coast	$3,101	$3,621
West Coast	$2,220	$2,620
Inland (Inside the U.S.)	Cost/TEU (20')	
NY via LA/LB (Water-Rail)	$3,658	
NY via LA/LB (Water-Truck)	$4,611	
NY (All-Water)	$3,224	

Table 12 Estimated Shipping Cost from Shanghai to US and Canadian Ports (Rodrigue, 2010)

Origin/Destination	To Vancouver	To LA/LB	To Houston	To NY	To Montreal
From Shanghai	$2,300	$2,620	$3,510	$3,700	$4,040

4.2 Dwelling Time

The structure of dwelling time for containers from Asia to the Midwest can be divided into two parts: ocean and rail. Once container vessels depart from the origin ports in Asia, it takes at least scheduled time to arrive at destination ports in the U.S. Then the containers are transshipped to the rail system and are shipped to the Midwest. There are several reports about the estimations of dwelling time for containers from Asia to Midwest, a sample of which are listed here.

A report from Federal Maritime Commission (2012) estimated sailing times from Shanghai to Prince Rupert as 10 days and to California as 12 days. From Prince Rupert to the Chicago region, 8 days are estimated for rail transit time. From California to Chicago region, 6 days are estimated for rail. Therefore, in this report, there was no sizeable difference between shipments via the port of Prince Rupert and ports in California in term of dwelling time. Summarized dwelling time is described in Table 13. Containers via ports on the Gulf/East Coasts are not included in this report (Figure 13).

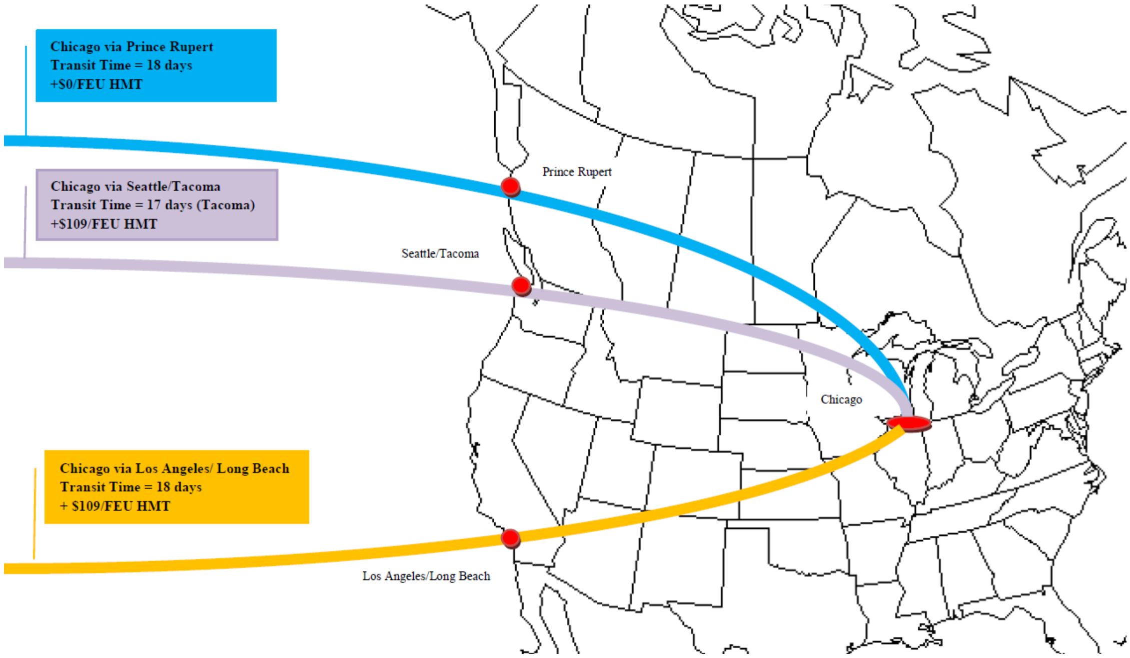

Figure 13 Transit Times between Shanghai to Chicago by Ports (1)

The US Army Corps of Engineers (2012) predicted sailing times from Asia to Prince Rupert as 10 days, to California as 14 days, and to New York as 22 days. The rail times to Midwest are estimated as 4 days from Prince Rupert or California and as 3 days from New York. When the connections are combined, the total dwelling times become 14 days via Prince Rupert, 18 days via California, and 25 days via New York. Detailed flows are described in Figure 14 and Table 14.

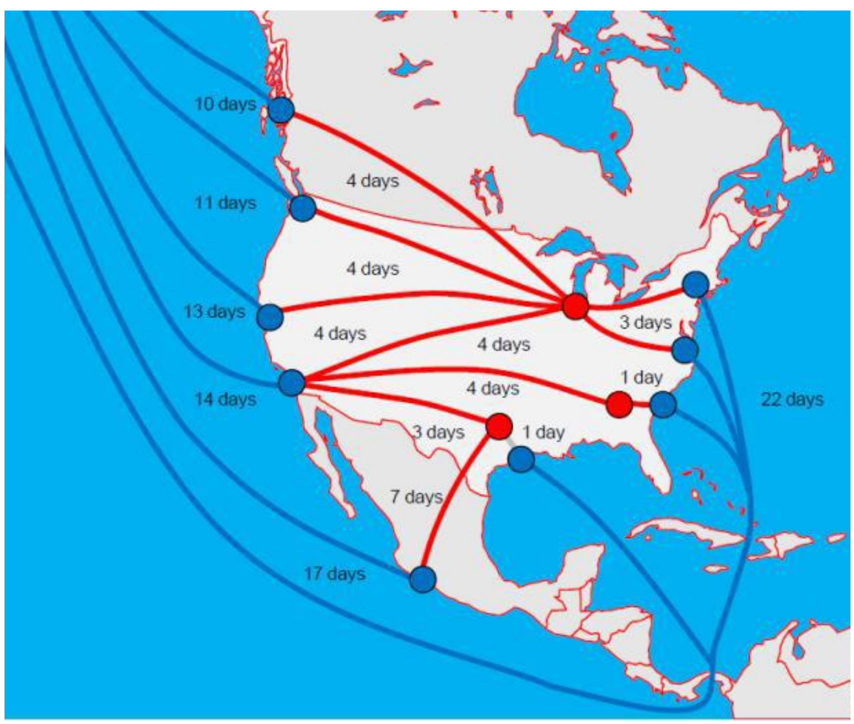

Figure 14 Transit times between Shanghai and Chicago by Ports (2)

Rodrigue (2010) estimated more detailed shipment times connecting Asia and the Midwest as shown in Figure 15. Estimated sailing times are 12 days to Prince Rupert, 13 days to California, and 25 days to New York. For the rail times, 4 days from Prince Rupert, 5 days from California, and 3 days are estimated to the Midwest Region. Summing up these dwelling times, it takes 16 days via Prince Rupert, 18 days via California, and 28 days via New York as a dwelling time from Asia to Midwest as described in Table 15.

Table 13 Dwelling Time of Container Shipments from Shanghai to Chicago and Memphis (Federal Maritime Commission, 2012)

Origin/ Destination	To Chicago				To Memphis	
Transfer Point	Prince Rupert	Vancouver	Tacoma	LA/LB	Prince Rupert	LA/LB
From Shanghai	18 days	23 days	17 days	18 days	18~20 days	17~22 days

Table 14 Dwelling Time of Container Shipments from Shanghai to Chicago (US Army Corps of Engineers, 2012)

Origin/ Destination	To Chicago					
Transfer Point	Prince Rupert	Vancouver	Oakland	LA/LB	Norfolk	New York
From Shanghai	14 days	15 days	17 days	18 days	25 days	25 days

Table 15 Dwelling Time of Container Shipments from Shanghai to Chicago (Rodrigue, 2010)

Origin/Destination	To Chicago				
Transfer Point	Prince Rupert	Vancouver/Seattle/Tacoma	Oakland	LA/LB	NY
From Shanghai	16 days	18 days	18 days	19 days	29 days

4.3 Sailing Frequency

The Federal Maritime Commission (2012) concluded that the port of Prince Rupert is currently the most competitive port with those on the West Coast of the U.S. The large ports of Los Angeles and Long Beach are experiencing congestion whereas the less congested port of Prince Rupert is increasing its operational capacity. Also, the Canadian port of Prince Rupert is located closer to Asia than ports on the West Coast of the U.S.

However, when it is considered that the dominant containerized freight destination is the Midwest city of Chicago, the difference in total transit time from origin to the Midwest is not significant. Added to that, the frequency of vessel departure from Asia to the Canadian port is far less than that from Asia to ports in the U.S. The frequencies of vessel departure from three ports in Asia are depicted by Figure 16, Figure 17, and Figure 18. Sailing time and weekly departure frequency from Hong Kong, Yantian, Shanghai, and Busan are visualized. For example, from Shanghai, two vessels depart for the port of Prince Rupert, but there are 23 sailings to LA/LB and 14 to Seattle/Tacoma. Moreover, there are some 'express services' between Asia and U.S. ports which makes U.S. ports more competitive.

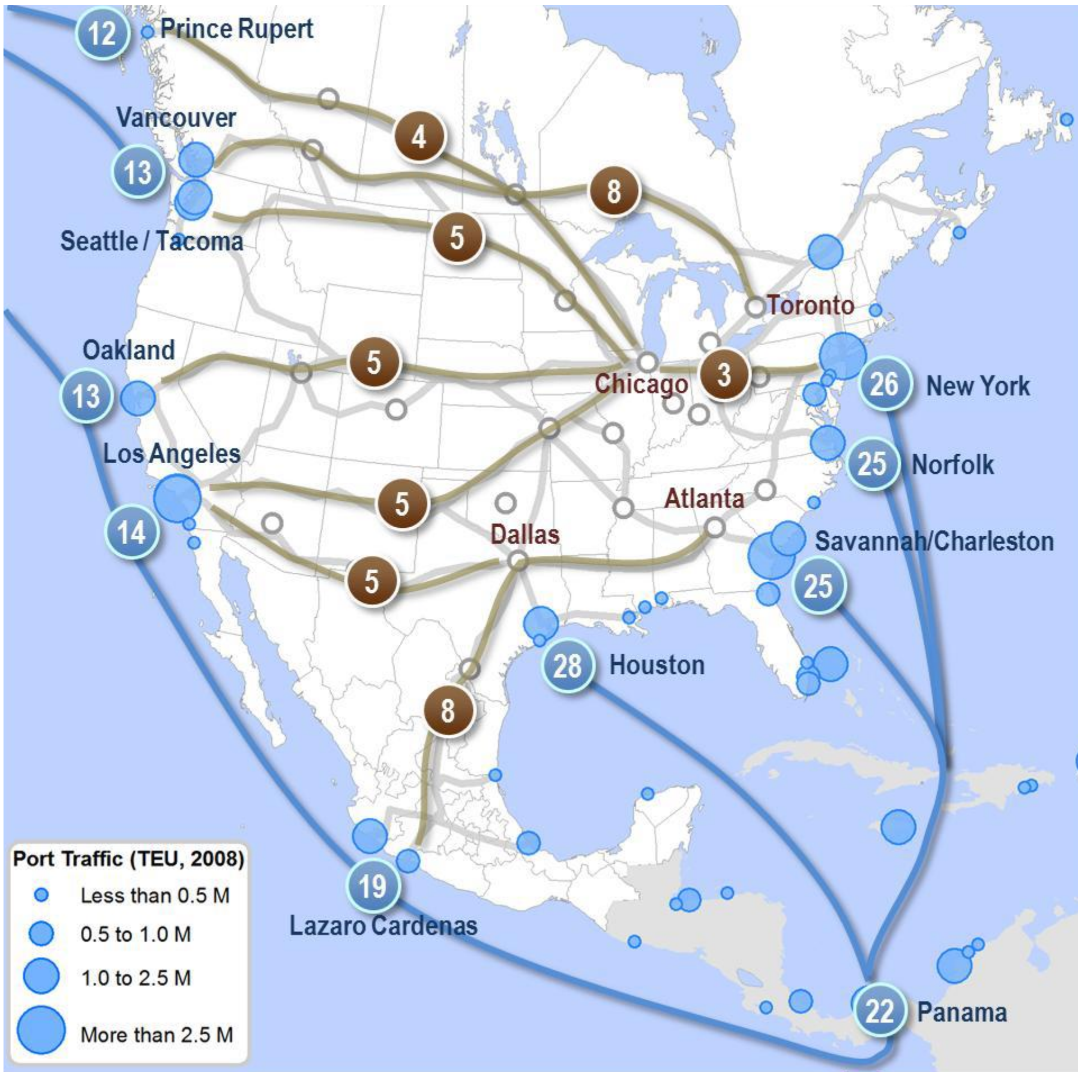

Figure 15 Transit times between Shanghai and Chicago by Ports (3)

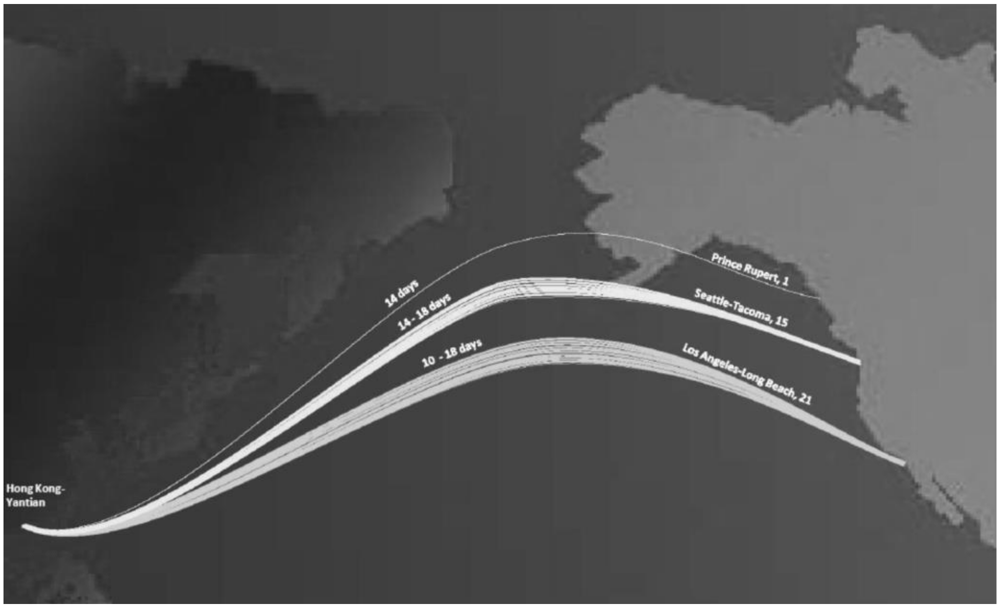

Figure 16 Comparison of Weekly Service Frequency and Ocean Transit Times from Hong Kong & Yantian to Prince Rupert, Seattle-Tacoma and Los Angeles-Long Beach (Federal Maritime Commission, 2012)

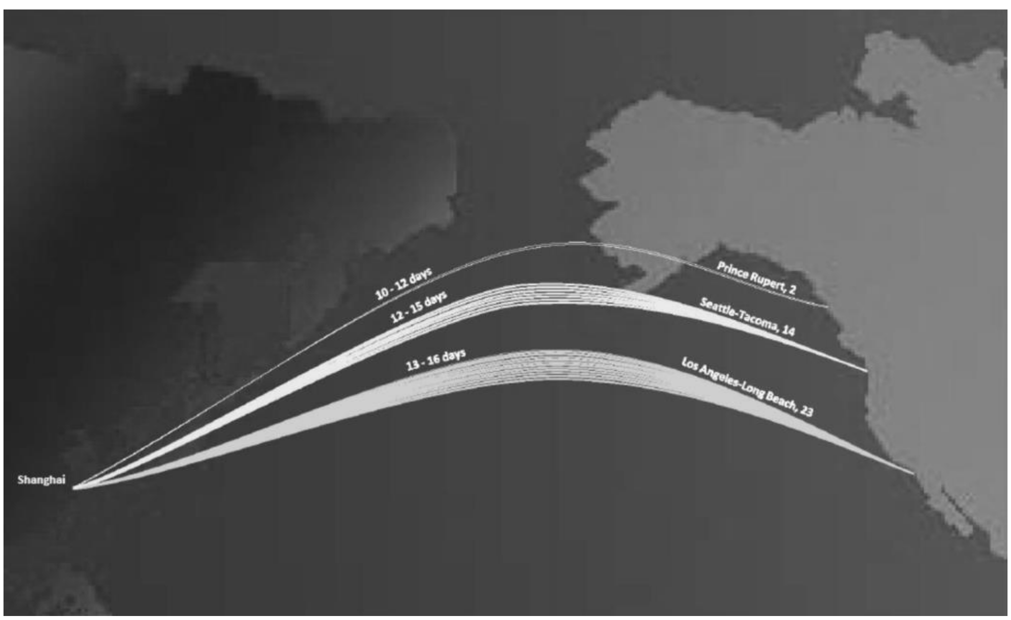

Figure 17 Comparison of Weekly Service Frequency and Ocean Transit Times from Shanghai to Prince Rupert, Seattle-Tacoma and Los Angeles-Long Beach (Federal Maritime Commission, 2012)

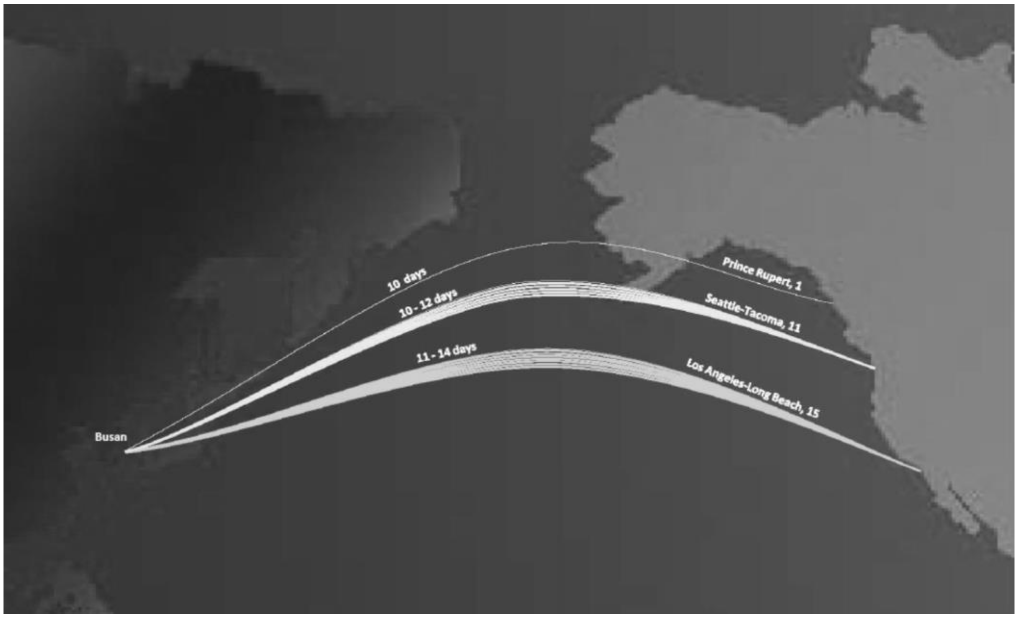

Figure 18 Comparison of Weekly Service Frequency and Ocean Transit Times from Busan to Prince Rupert, Seattle-Tacoma and Los Angeles-Long Beach (Federal Maritime Commission, 2012)

4.4 Channel Depth & Crane Size

As discussed previously, vessel sizes have been increasing and the hull and width of vessel are also deeper and wider than previous generations. As depicted in Figure 19, the newest generation of vessel requires 50ft of sea level to call at port. The design of the hull is U-shaped and this could make the required sea level swallower than V-shape hulled vessels. For the width of the vessel, post-panamax requires cranes which can load a ship 18 containers wide and super post-panamax requires those that can load a ship 22 containers wide. Therefore, when the port is trying to handle post-panamax or super post-panamax vessels, channels of 50 foot depth, crane capability of 18 to 22 container widths, and docks engineered to handle the larger cranes. (US Army Corps of Engineers, 2012)

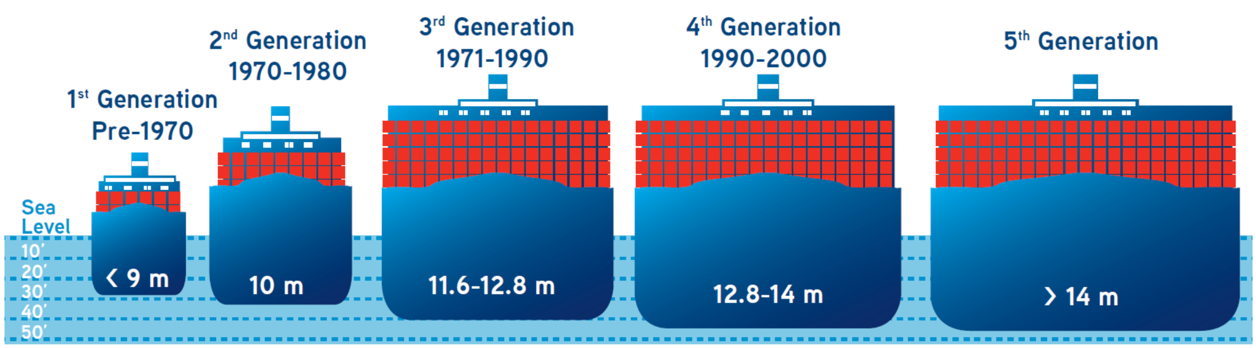

Figure 19 Vessel Size and Sea Level (Conway, 2012)

Based on the three listed criteria, the top 10 ports are compared in Table 16. Ports on the Pacific, Gulf, and East Coasts are listed with each port's channel depth and readiness. It is observed that all five ports in Pacific coast are already ready for the post-panamax vessel calls, but there is only one post-panamax ready port on the Gulf and East coasts. The port of New York is working on raising the Bayonne Bridge, which will be completed in 2015. The port of Houston is currently dredging its channel and will complete in 2013. (Conway, 2012)

Table 16 Port Channel Depth and Readiness

Coast	Port	Channel Depth (ft.)	Readiness
West	Los Angeles, CA	53	Yes
	Long Beach, CA	53	Yes
	Oakland, CA	50	Yes
	Seattle, WA	50	Yes
	Tacoma, WA	51	Yes
Gulf & East	New York, NJ	50	Bayonne Bridge, 2015
	Savannah, GA	42	No
	Norfolk, VA	50	Yes
	Houston, TX	45	Dredging, 2013
	Charleston, SC	45	No

4.5 Customs Clearance

The customs clearance process is strictly followed by the directions from U.S. Customs and Border Protection (CBP). If payments of duty and tax and filing entry documents to CBP are completed, cargos will be cleared to be released to the consignee (recipient). Also additional process of Importer Security Filing (ISF/10+2), which went to effect after January 26, 2009, should be completed 24 hours before its arrival on U.S. port.

Depending on the commodity inside the container, U.S. Food and Drug Administration (US FDA) and the Federal Communications Commission (FCC) may be contacted for the customs clearance. They ask for additional documents or for registering the producer and the seller of specific items. Also, CBP has a right to examine the cargo on importer’s expense. Since the selected cargo has to transport to private facility for CBP, the bill includes examination and transportation fees. It is stated in the U.S. Code 1467 and there is no distinction between commercial and personal cargos. When the importing containers are concentrated at port, congestion may occur and additional charges cannot be avoided. Examination process consequently takes longer and importers have to wait until they are noticed or contacted from CBP when the exam is completed. For transshipment containers coming to inland ports can be completed at the final destination. This means that the containers destined Chicago can clear its customs status at inland port in Joliet, IL and examinations usually held in Joliet.

Guan and Yang (2010), by using Heuristics algorithms, tried to find best combination for the berth allocation and security inspection at port. Since both operations are the major process occurring from the port inside, it will be desirable if the best combinations are found. They found that the inspection rate should be 9 times faster than current condition to make port operations smooth. Since tremendous financial investment and human resources are expected to match this difference, the solution is recommended that combination of ‘increasing service rate’ and ‘reasonable sampling’ will be appropriate.

4.6 Union Dispute

Recently, there was a strike at Canadian Pacific Rail in 2012. The cargos on the rail are left standing on the port of Vancouver and inland ports in Canada and the U.S. Shippers has to pay millions of dollars to change the transport mode from rail to truck in Canada, and this affected cross border traffic between the U.S. and Canada. Since there are U.S. automobile assembly companies in Canada, delivery of the auto parts from the U.S. to the plant in Canada and the assembled automobile to the U.S. has been suffered. (U.S. Federal Maritime Commission)

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 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.

4.7 Route Choice Behavior

Route choice research in freight and logistics is not relatively active than passenger travel behavior analysis, but there are several results published in domestic intermodal mode choice behavior identifying factors affecting freight mode choice including cost, commodity attributes, spatial distribution, and mode characteristics.

However, it is hard to find route choice behavior in international shipments. A route choice for international shipment is usually determined from a party where pays total or most logistics cost after a contract is made. Since this process is usually classified as a confidential in business, it is hard to identify the decision maker. Even though the decision maker is known, behavior analysis for shippers in Asian trading partner countries requires much effort to classify samples and to obtain enough response results from surveys. Then it is possible to contact buyer or consignee in the U.S., but this also requires tremendous effort to find companies trading with specific countries in all U.S. states.

5.0 Conclusion and Further Progress

The container shipments are dominant way of international maritime shipments into the United States. Among imported container shipments, almost 60% are destined for the Midwest region in weight, value and volume, and this is the largest amount which destined to one region in U.S. The container shipments to the Midwest transship from ports where vessels from Asia since there is no direct All-water route between them. After transshipment, rail or truck mode is utilized for delivering to inland port near the Midwest. The feasible ways for this process are identified in three routes. The dominant route in weight, value, and volume currently includes ports on the West Coast, and the second route includes ports on the Gulf or East Coast after passing the Panama Canal, and the last route includes the port of Prince Rupert in Canada.

Each route has advantages and disadvantages. The route utilizing ports on the West Coast is currently dominant gateway for container shipments from Asia. Enough capacity and spacious container yards for storage and deeper channel depth for vessels of post-panamax are currently provided and infrastructures for transshipment are already facilitated to connect to the Midwest regions. And, network and capacity expansion on the San Pedro Bay and the port of Portland are expected to complete by 2015 and this will surely attract more container flow to the Midwest Region through the West Coast ports. Relatively shorter sailing times than the routes to the Gulf and East Coast are advantages as well. However, the experienced congestion and union disputes from the West Coast ports make shippers and importers worry for delayed shipping schedule and additional charges.

The expanded Panama Canal's lock system will benefit from the routes to ports on the Gulf and East Coasts. Expansion of the canal will allow larger vessels than the panamax size to use the canal and more containers can transport to ports on the Gulf and East Coast with shorter dwelling times. In accordance with port and transshipment facility enhancements of ports on the Gulf and East Coast, container shipments from Asia can be arrived in the Midwest regions with increased volume and shortened schedule. Thus the port authorities on the Gulf and East Coasts insist that facility enhancements will lead securing vessel calls and employment opportunities. However, the federal financial supports for facility enhancement are concerned from professionals. The enhancements process will not be completed before initiation of the expanded canal system and then vessel calls will remain at ports on the West Coast. The points that channel depths on the Gulf and East Coasts are not adequate for vessels of post-panamax size, longer sailing time, and relatively expensive shipping cost are critical as well.

The port of Prince Rupert is recently analyzed as the most competitive port for container transshipments from Asia to the Midwest regions with reasons. The sailing route from Asia to the port of Prince Rupert is the shortest path than the routes to other ports on U.S. coasts. The port capacity is enough to handle the containers from Asia and the port authority is planning to increase its capacity as much as the port of Los Angeles in California. With the characteristics of dedicated container transshipment port, the CN rail systems are fully utilized for the connection between the port and the Midwest regions at competitive rate. However, it is reported that frequency of vessel sailings from Asia to Prince Rupert is very low comparing to frequency from Asia to the West Coast U.S. ports. About 10~20 times more vessels are dwelling between ports in Asia and ports on the West Coast of U.S. than the port of Prince Rupert. Also, recent union disputes by the CN rail is a critical disadvantage for the port's attraction.

In this document, three routes for container imports of the U.S. are reviewed according to international capacity expansions in terms of container volume and distributions, port capacities, shipping cost, dwelling time, sailing frequency, channel depth and union disputes. With advantages and disadvantages of each port, it is hard to conclude which route will be the most popular for trading between Asia and the Midwest regions. Following tasks will prepare information for analysis of container shipments redistribution in the U.S. in depth. First, redistribution of freights into U.S. will be analyzed based on the reviewed factors affecting route choices of container shipments from Asia. In addition, freight distribution scenarios and the network impact modeling will be conducted with GIS network analysis. Consequent economic impact analysis and web-based analysis tool will help to find the optimal freight village locations in U.S. at the final stage.

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CHAPTER 3: TRANSPORTATION INFRASTRUCTURE DATABASE DEVELOPMENT

1.0 Introduction

The task 2 aims to collect and develop network database for the assignment of predicted freight flow affected by the Panama Canal expansion and Prince Rupert port expansion. The network database is the one of the most important elements in transportation demand model, and the network represents flow of people or goods between origins and destinations. In particular, the network database covering the U.S. territory is required in this project, as well as various attributes such as link speed, capacity, number of lanes, and traffic counts are necessary.

Therefore, the task collects reliable network databases provided by reputable agencies, and evaluate the suitability of the databases. Then, the most appropriate database is selected through this task. The selected network is developed properly for this research then the developed network will be used in the assignment step with various scenarios.

2.0 Network Database Preparation

Network development may be one of the most important steps performed independently in the entire travel demand model. In addition, a network represents the flow of people or goods between origins and destinations (Meyer & Miller, 2001). Therefore, a network database should be prepared in an appropriate manner for this research.

The research requires a network database with the ability to cover the whole U.S. region. There are three types of network databases covering the U.S. territory: Highway Performance Monitoring system database, National Highway Planning Network database, and Freight Analysis Framework database. In this task, we review these network databases, check their pros and cons, and choose the proper network to use when considering the quality of the network.

3.0 Highway Performance Monitoring System (HPMS)

The HPMS is a wholly national level public road information system containing length, pavement condition, operating characteristics, functional class of public road, and other various data (see Figure 1). The purpose of the HPMS is to provide data for the decision making process with FHWA, state and/or federal Department of Transportation (DOT), and Congress. The HPMS contains various data such as operational characteristics, road conditions, and annual statistics (FHWA, Highway Performance Monitoring System, 2013).

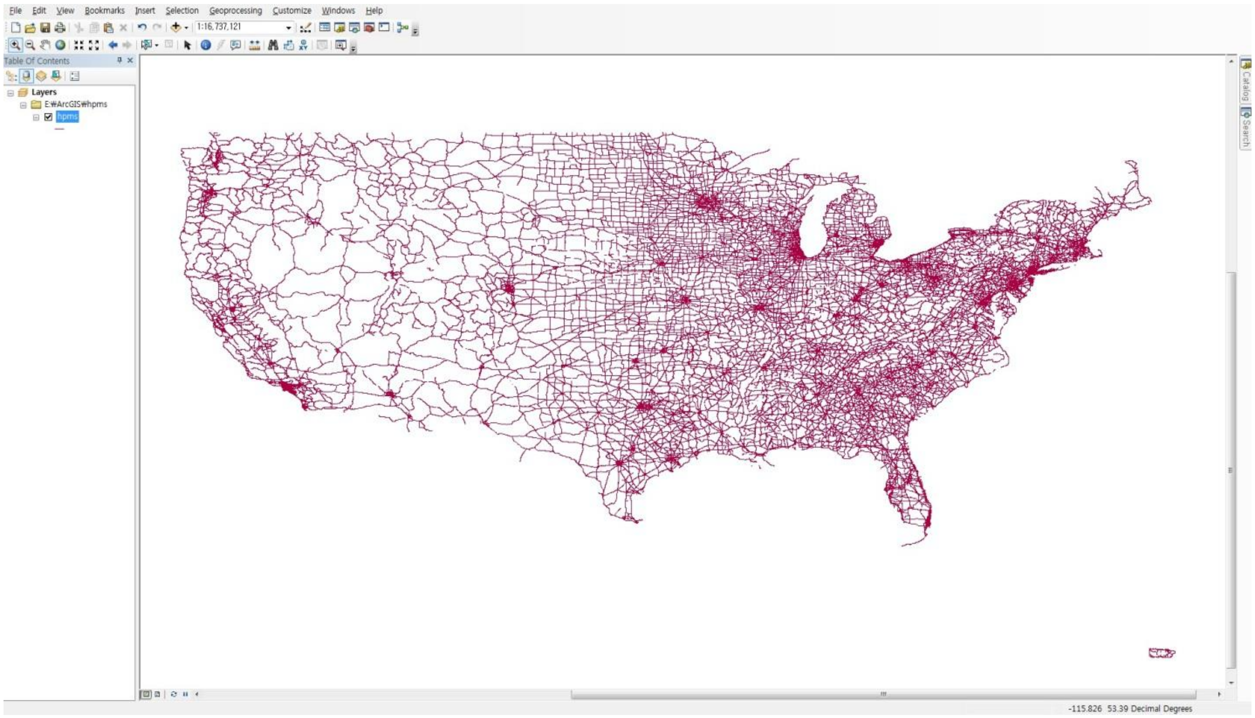


Figure 20 Highway Performance Monitoring System Network

4.0 The National Highway Planning Network (NHPN)

The National Highway Planning Network (NHPN) is a geospatial network database which consists of polylines and their attributes representing link features in the entire U.S provided by the Federal Highway Administration (FHWA) (see Figure 2). The NHPN contains information linked to High Performance Monitoring System (HPMS). Using a linear referencing system, NHPN contains HPMS information, such as, functional class, Average Annual Daily Traffic counts (AADT), and number of through lanes. NHPN also has been used as a base network database for Freight Analysis Framework (FHWA, Planning Process, 2013).

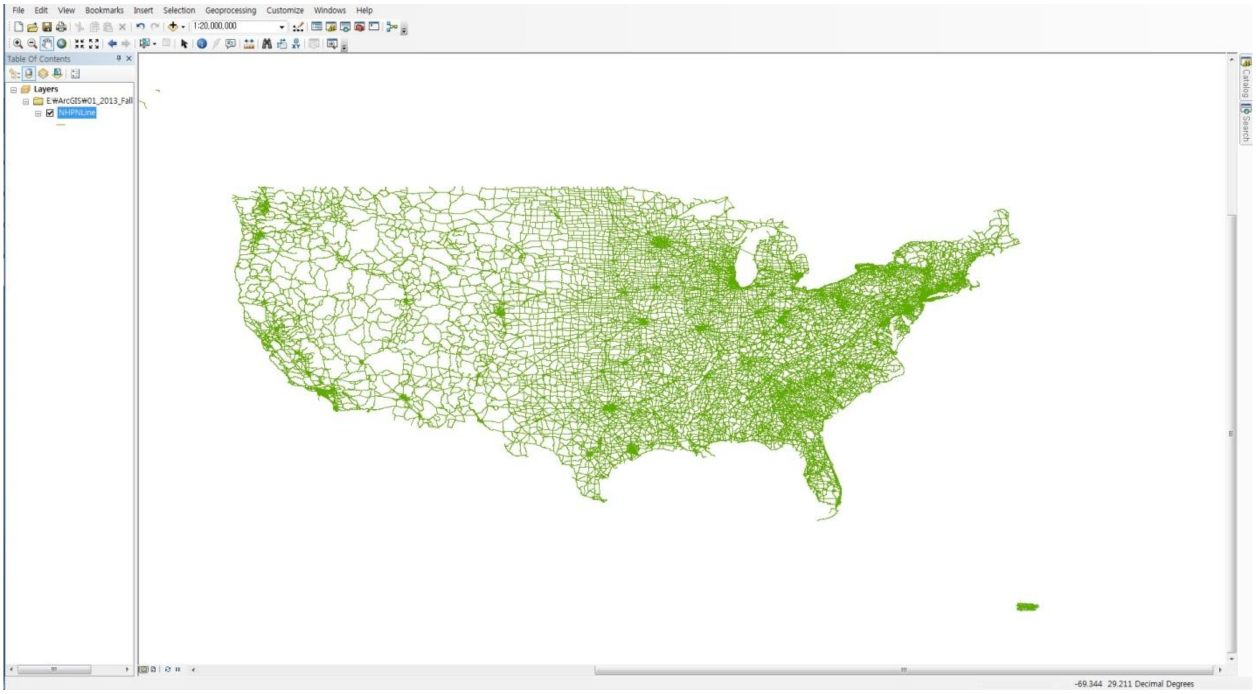


Figure 21 National Highway Planning Network

5.0 The Freight Analysis Framework version 3 (FAF3)

FAF3 network database consists of GIS based shapefiles that represent the centerline of the highway network in the U.S. The network database was developed from the NHPN and adjusted to be used for FAF3 goals. The network consists of 170,998 links representing national highways and their total length is approximately 447,800 mile (See Figure 3) (FHWA, Freight Analysis Framework 3 User Guide, 2013). The FAF3 network includes the 2008 Highway Performance Monitoring System (HPMS) database to ensure base year information (Battelle, 2011). Using information from HPMS the FAF3 network database performs freight truck assignment and calibration.

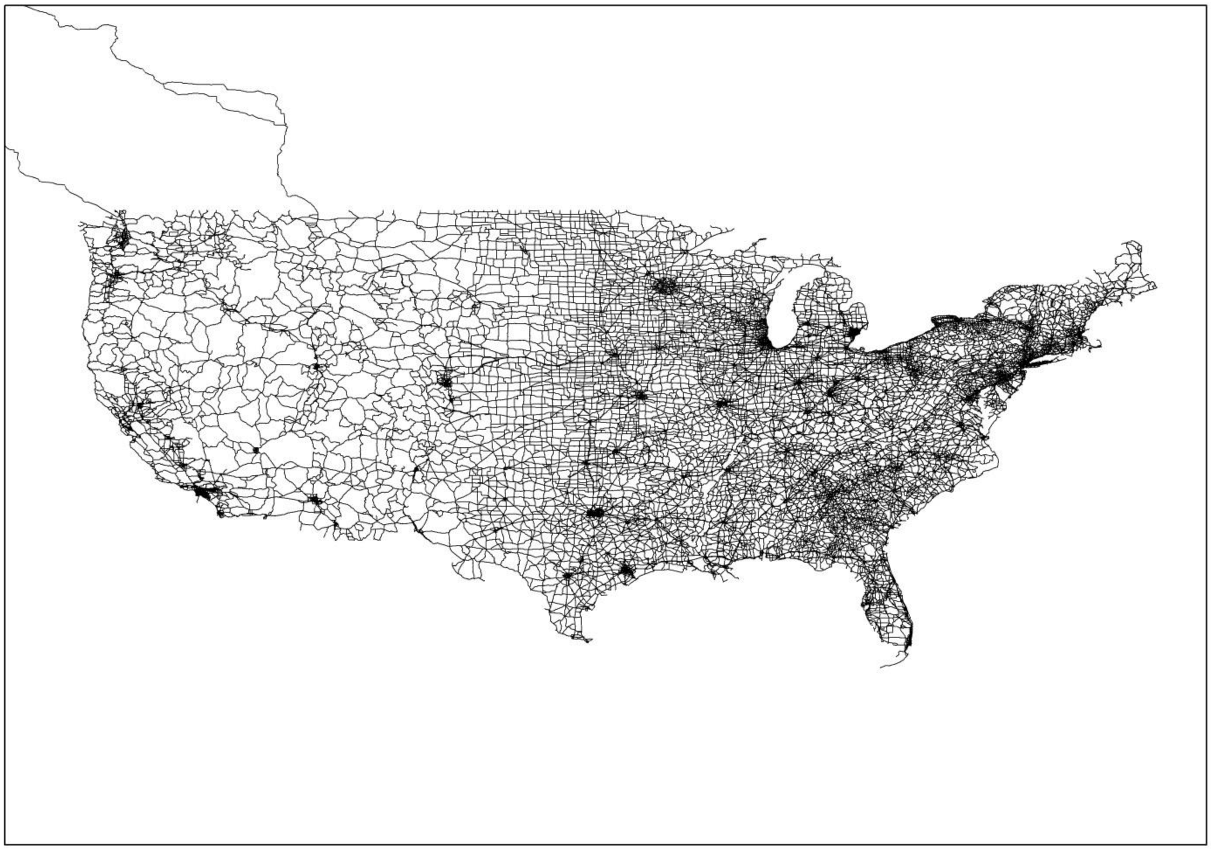


Figure 22 FAF3 network

6.0 Network Database Choice

The three network databases are compared to determine which is best suited for the project (see Table 1). Reliable data is of greatest importance to the project so, we check reliability preferentially. All the databases are provided by FHWA as the same type of file as a GIS shapefile. They also cover the whole U.S territory. Therefore, other attributes are considered to choose the proper network for assignment process. Generally, links have various characteristics with the key characteristics being the network assignment process and/or network analysis, length of link, link cost, and link capacity (Bell & Ilda, 1997). Also, since we cannot collect traffic counts on the whole roadway system, AADT information is necessary to perform this project. We do not consider the entire U.S. network only the interstate network is considered as a major subject in this research.

HPMS and NHPN contain number of through lanes that can be used to calculate link capacity. FAF3 network includes computed capacity instead of number of through lanes. HPMS and NHPN have 2011 AADT but FAF3 has 2007 AADT and calibrated truck volume. All of the databases contain functional class of the network. Travel time is one of the most important factors to affect travel tendency. The travel time depends on vehicle speed, therefore, can be computed by using the assigned speed (Bell & Ilda, 1997). FAF3 attributes contain computed speed but HPMS and NHPN do not have any speed information. Though their links are categorized in each state by Federal Information Processing Standards (FIPS) and state FIPS codes are available in an attribute field. So, it is possible to add speed on each link using the state's FIPS codes.

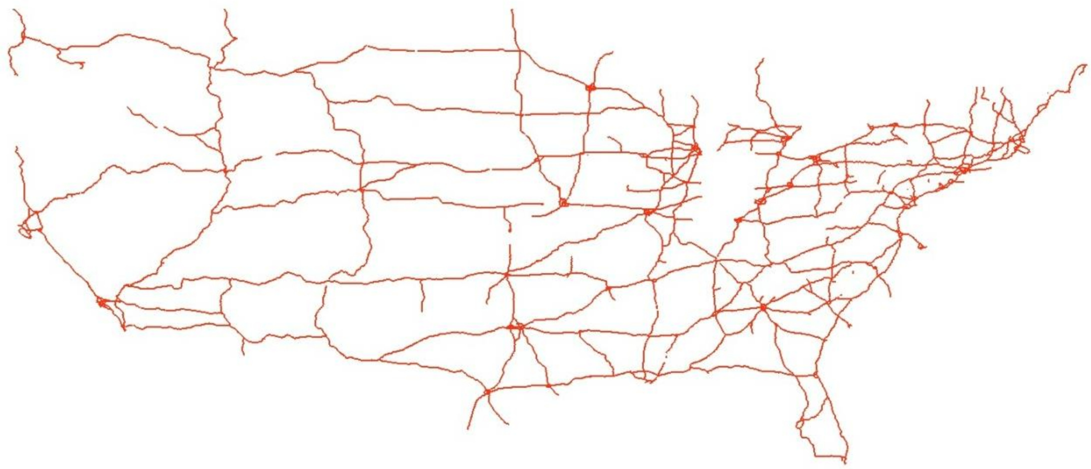
Table 17 Comparing Characteristics of Database

	HPMS	NHPN	FAF3
Provider	FHWA	FHWA	FHWA
Format	GIS shapefile	GIS shapefile	GIS shapefile
Coverage	Whole U.S.	Whole U.S.	Whole U.S.
Attributes			
Capacity	No. of lanes	No. of lanes	Computed Capacity
AADT	Yes	Yes	Yes
Year of AADT	2011	2011	2007
Functional Class	Yes	Yes	Yes
Speed	No	No	Computed Speed

The first phase of analysis is to detect any significant weaknesses between the databases. HPMS has a critical problem in that the database does not contain interstate networks in Ohio and Oregon (see Figure 4). Thus, HPMS is excluded from this research.

NHPN and FAF3 both have pros and cons. NHPN has recent information on AADT but it is not optimized for freight flow analysis. On the other hand, FAF3 is optimized for freight flow analysis. The network has been calibrated for freight flow and contains calibrated truck volumes and a 2040 forecasted AADT and truck volume. However, it has older AADT compared with NHPN. Considering all of the elements NHPN was chosen as best network database for the project.

HPMS interstate network



NHPN interstate network

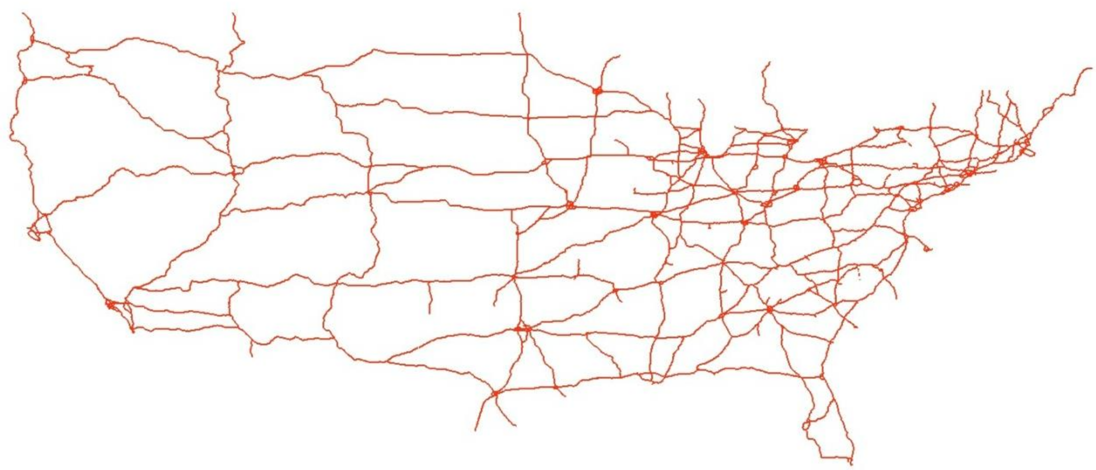


Figure 23 Comparing HPMS and NHPN interstate network

Build Interstate Network

NHPN network database consists of various functional classes of roadway (see Figure 2). In this project we focus on only the interstate to analyze freight movement. Therefore, it is necessary to extract interstate network data from NHPN. Using ArcGIS, network data which are rural and urban interstate are extracted (see Figure 5). NHPN categorizes its network functional classes and rural interstates as code 1 and urban interstate as code 11. Also, NHPN gives code 12 to urban expressways. But, most of the urban expressway networks are short, scattered, and disconnected with other interstates. Consequently, the urban expressway network is excluded in this research.

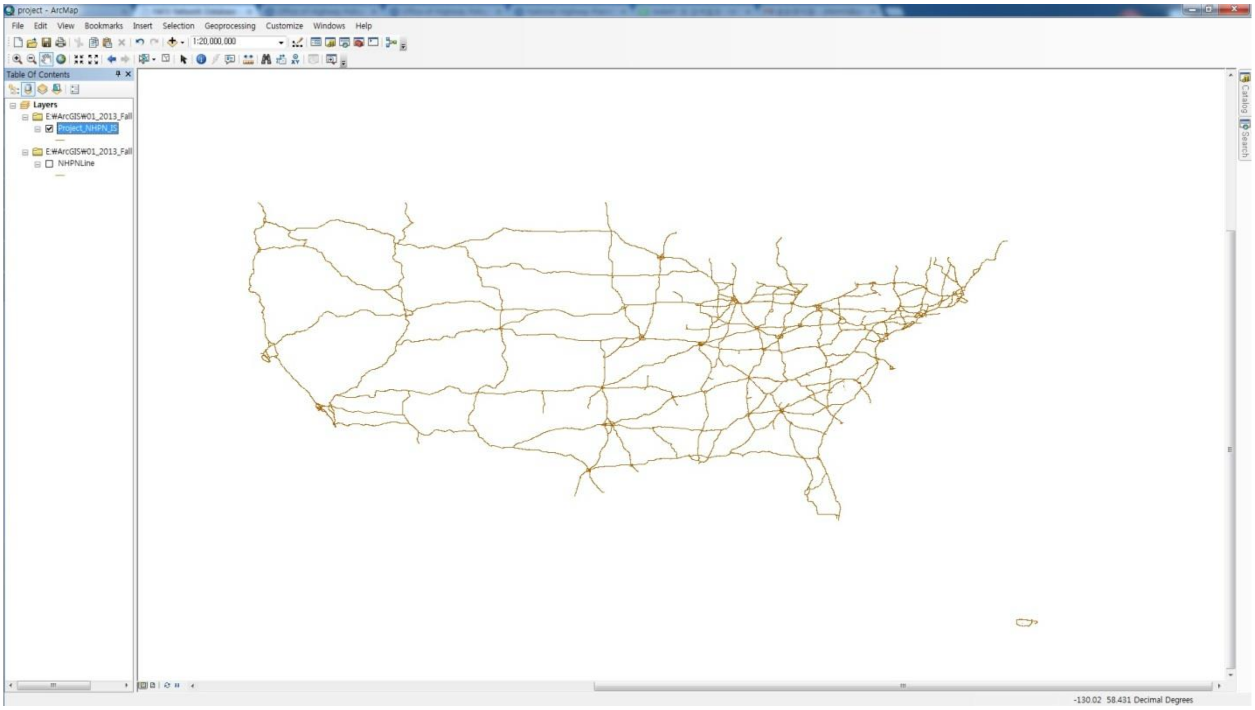


Figure 24 Extracted interstate networks by ArcGIS

We can convert this interstate network shapefile to a network data file for an assignment analysis by using CUBE which is a software product for transportation planning. In other words, it can convert from shapefile to network data file. It is important to note that at the beginning of the conversion process two additional fields “A node” and “B node” need to be generated. The following figure (see Figure 6) shows the converting tool in CUBE.

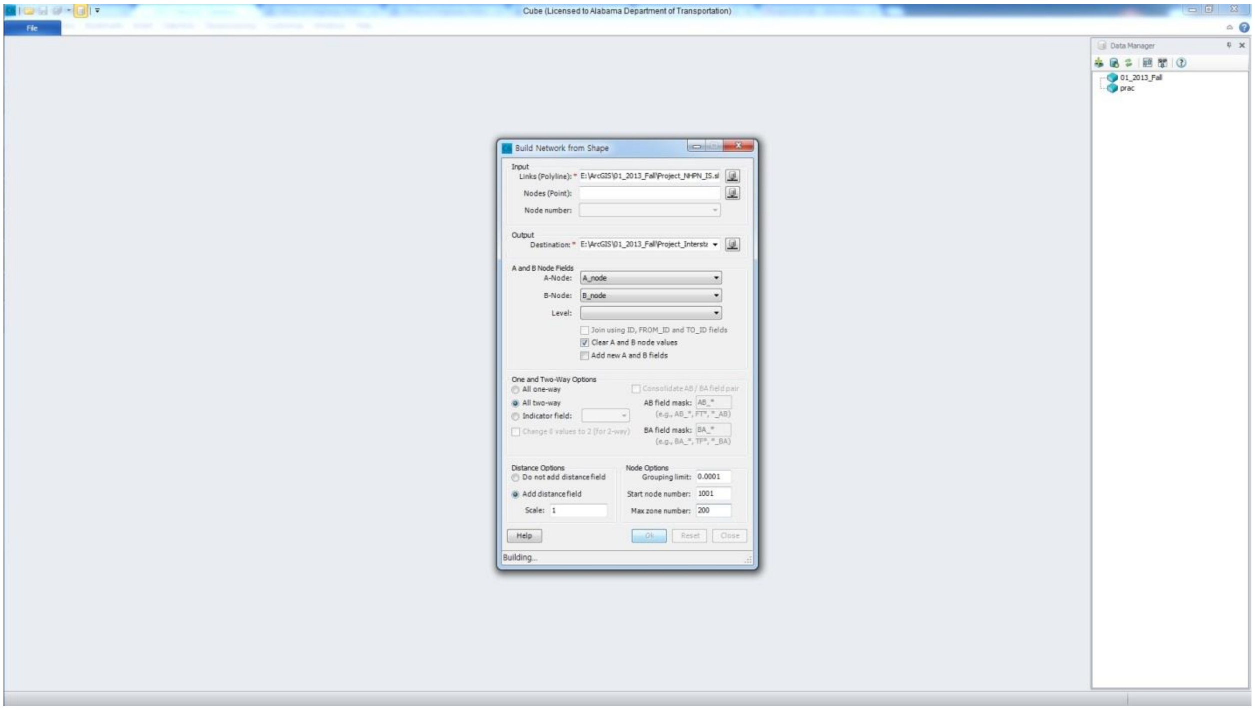


Figure 25 Converting step on CUBE software

When the converting process is finished CUBE produces a "title.net" file including network attributes such as "A node", "B node" and other attributes from the shapefile (see Figure 7).

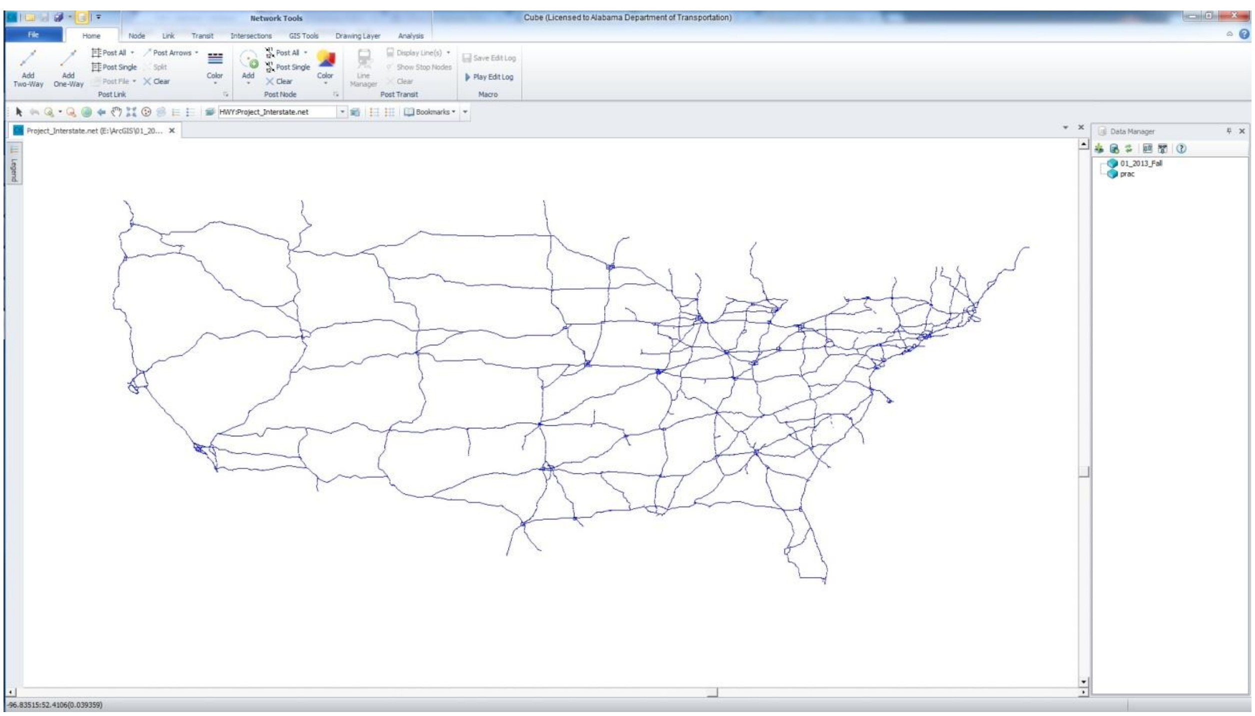


Figure 26 The generated network file on CUBE

This network consists of nodes and straight lines so, it could have slight differences in shape when comparing it to the GIS shapefile. Thus, the best fit of the network shape will be built through this step. There is a function named “True Shape Display” in CUBE which adjusts the generated network file shape to original shape.

The network building step is finished and error checking the network file should now begin. This examination step includes checking unused nodes, dangling links, and missing key attributes on each link. As mentioned earlier, HPMS has many disconnected links due to human errors that occurred supposedly while building the network. NHPN also has some disconnected links like HPMS. There were no unused nodes but more than nine thousand dangling links were detected (see Figure 8).

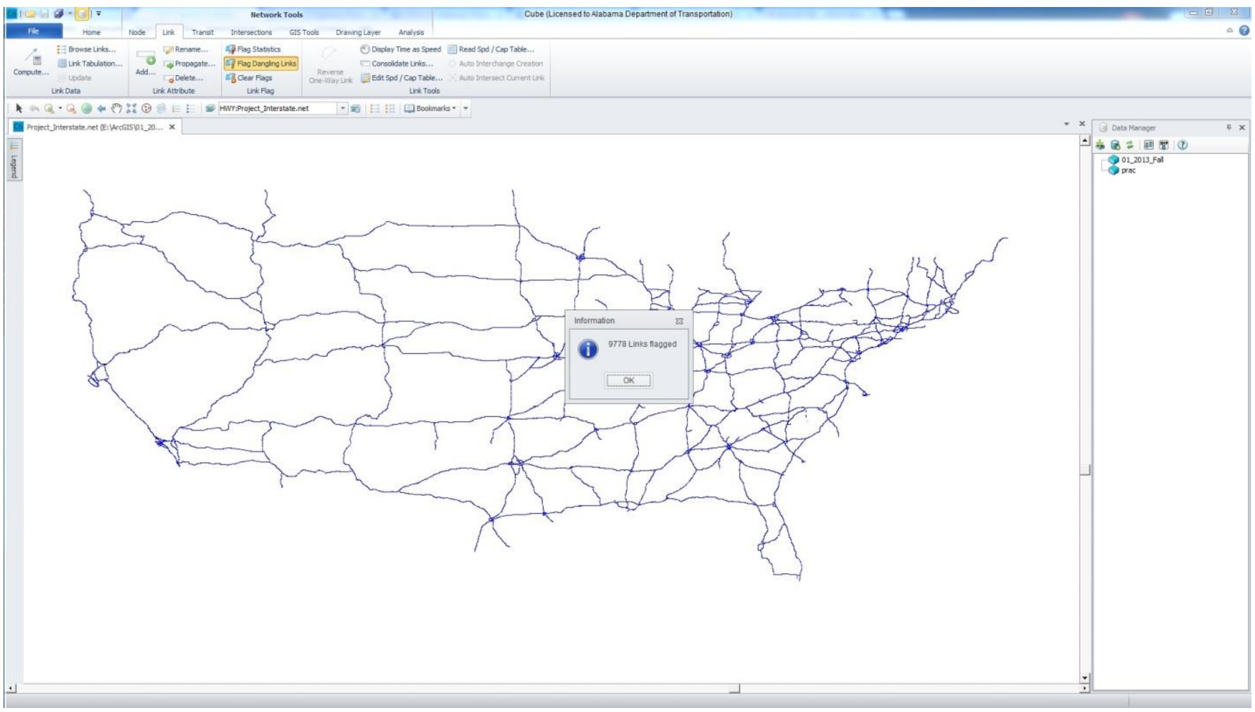


Figure 27 Result of detecting dangling links

Figure 9 shows the location of dangling links which were detected at end of the interstate links. The error can be solved by connecting zone centroid connectors and some of them can even be ignored. Figure 10 shows some major routes that were disconnected. The disconnected links like this kind are fixed by adding links or joining links. The revised links do not have any attributes so, it is necessary to add link attributes manually. Which consist of functional class code, number of through lanes, and speed limits. AADT information is not entered because the AADT in this database is from HPMS. It is not possible for the project to use uncertain information.

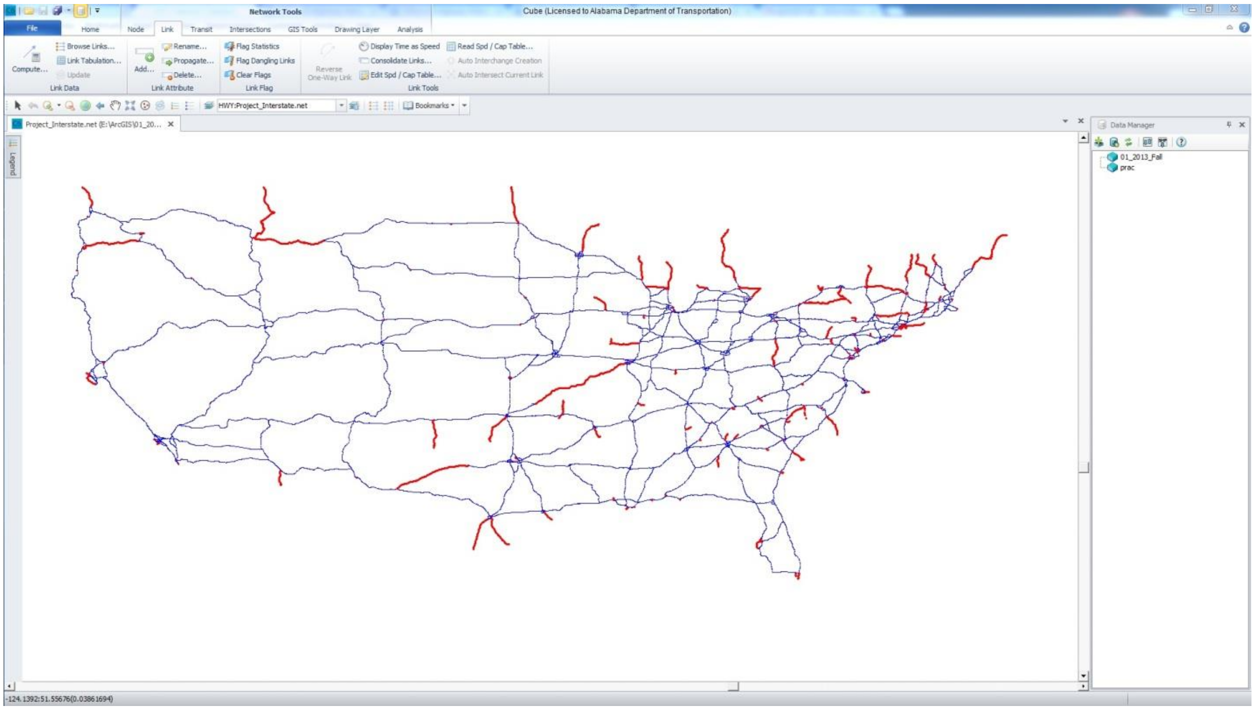


Figure 28 Result of detecting dangling links as symbol

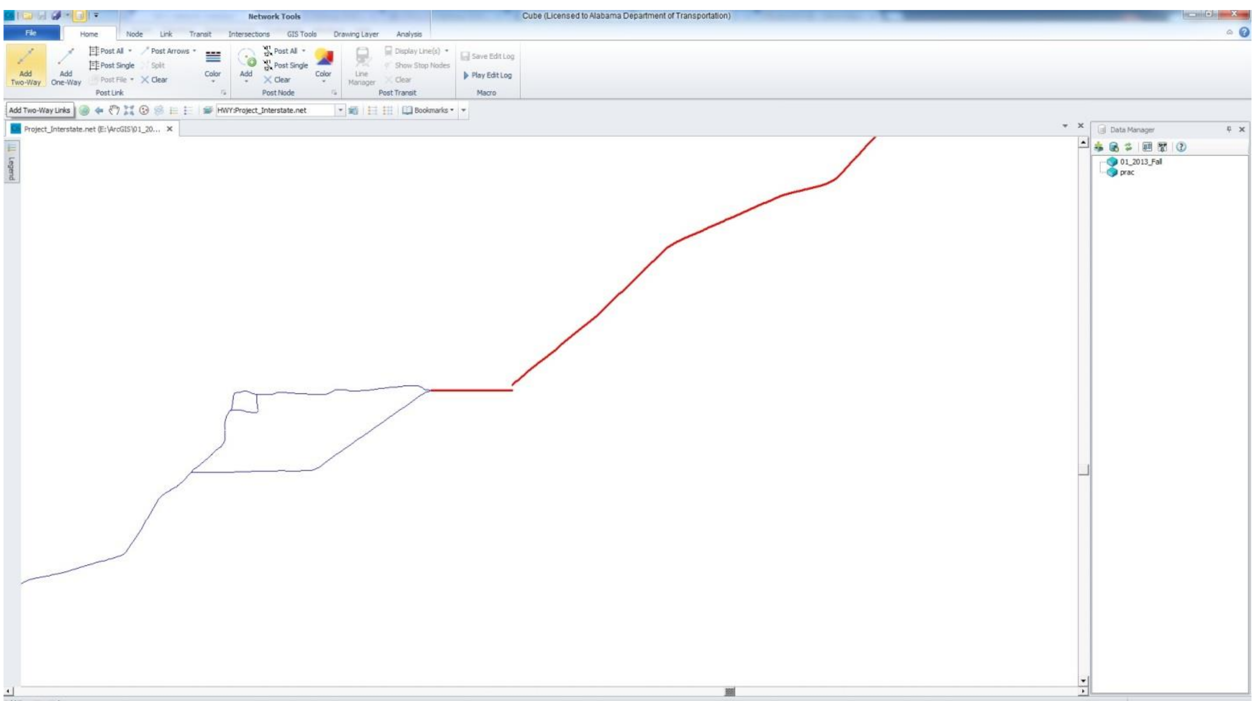


Figure 29 Example of disconnected links

The next step to check errors is to find missing attributes in network links. Key attributes for the assignment methodology are length of link, speed, capacity, and AADT. Length of link is automatically calculated by CUBE software and AADT data is linked from HPMS. Therefore, the next step is to check the capacity attribute in each link. FAF3 network database includes calculated link capacity data but NHPN has number of through lanes instead of capacity data. CUBE can compute capacity using number of through lanes so, we check missing field on number of through lanes on each link. Total six hundred thirty links are observed that have zero value in number of through lanes field (see Figure 11). Using layer property the links contain zero value of number of lanes are identified and expressed as red bold lines. The modification step for the error is to add the real number of through lanes manually. The real numbers are identified by using Google map and HPMS database.

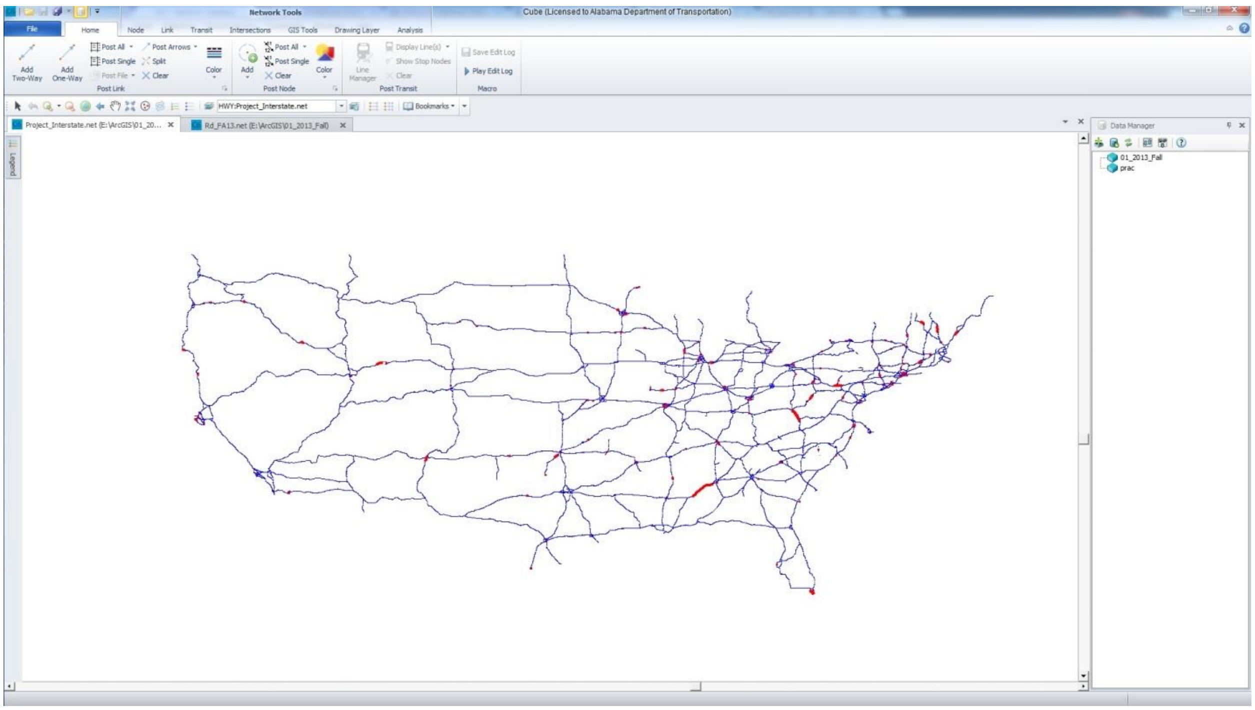


Figure 30 Result of checking number of through lanes

The final step is to input the speed attribute into link field. The link speed database will be used in the freight assignment step on the task 4. Assigning the freight volume, link travel time will be used in equilibrium method for the assignment step. The link travel time can be calculated by using link distance and link speed attributes. Therefore, it is necessary to prepare link speed database.

Currently HPMS database does not include speed information on each link. NHPN also does not have speed information. FAF3 database has travel speed in each link but linear referencing system of FAF3 is different with NHPN. For this reason it is not possible to link the speed information from FAF3 to NHPN. Thus, we have to add the information manually. The network consists of more than thirty thousand links and it is not possible to input speed data one by one. However, NHPN categorizes the links in each state by FIPS codes. We can enter the information for each state and by functional classes at once.

The speed limit information was referred by a website that provides speed limits by states and functional classes (GHSA, 2013) (see Table 2).

The way to enter the speed information is to use the “Compute” function. First of all, a new link attribute field is generated for the information that will be entered. Secondly, the attributes value as a function link condition is added (see Figure 12). For example, if we want to add 70 mile/hour as a speed limit on rural interstate in Alabama, enter the function as “speed_lim=70” and enter the condition “STFIPS=1 & FCLASS=1.” STFIPS represents state FIPS codes and FCLASS represents functional class of the road. “FCLASS=1” is a conditional argument to find links which are rural interstate and STFIPS=1 is also a conditional argument to find links located in Alabama. “speed_lim=70” means that 70 is entered in the attributes field named “speed_lim.”

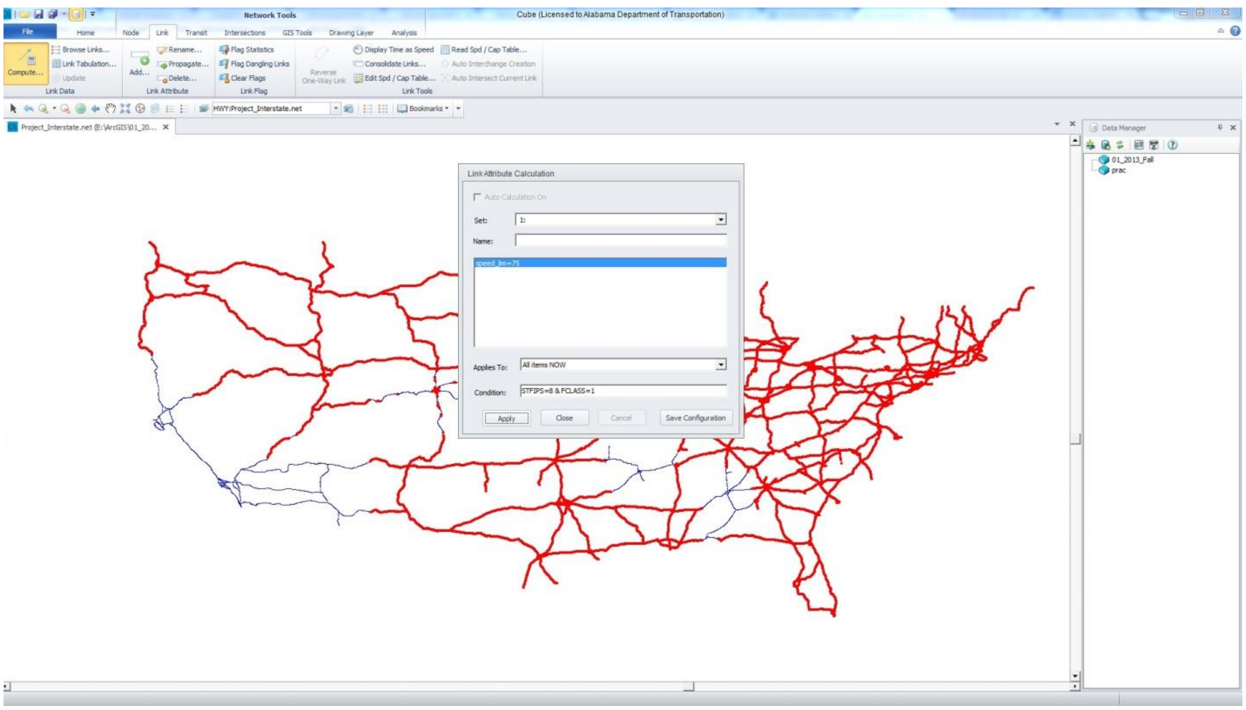


Figure 31 Step to input speed information in the network

Table 18 State FIPS codes and speed limits

STFIP	STATE	Rural	Urban	STFIP	STATE	Rural	Urban
1	Alabama	70	65	30	Montana	75	65
2	Alaska	55	55	31	Nebraska	75	65
4	Arizona	75	65	32	Nevada	75	65
5	Arkansas	70	55	33	New Hampshire	65	65
6	California	70	65	34	New Jersey	65	55
8	Colorado	75	65	35	New Mexico	75	65
9	Connecticut	65	55	36	New York	65	55
10	Delaware	55	55	37	N. Carolina	70	70
11	D.C	55	55	38	North Dakota	75	75
12	Florida	70	65	39	Ohio	70	65

13	Georgia	70	55	40	Oklahoma	75	70
15	Hawaii	60	60	41	Oregon	65	55
16	Idaho	75	65	42	Pennsylvania	65	55
17	Illinois	70	55	44	Rhode Island	65	55
18	Indiana	70	55	45	S. Carolina	70	70
19	Iowa	70	55	46	South Dakota	75	75
20	Kansas	75	70	47	Tennessee	70	70
21	Kentucky	65	65	48	Texas	75	75
22	Louisiana	75	70	49	Utah	75	65
23	Maine	75	75	50	Vermont	65	55
24	Maryland	65	65	51	Virginia	70	70
25	Massachusetts	65	65	53	Washington	70	60
26	Michigan	70	70	54	West Virginia	70	60
27	Minnesota	70	60	55	Wisconsin	65	65
28	Mississippi	70	70	56	Wyoming	75	75
29	Missouri	70	60				

Build Railroad Network

There are two railroad network databases in a shapefile format that can be used for this project. The first is provided by the U.S. Census Bureau known as TIGER file. The other is provided by nationatlas.gov. Both agencies provide all of the railroads networks consisting of polylines and attributes. However, the TIGER file is not as well organized as nationalatlas.gov. For example, railroad company names are not well described in TIGER file. The same company`s name is expressed in different formats such as “B N S F RR”, “B N S F Rlwy”, “B N and Santa Fe RR”, “B N and Sf Rlwy”, “Bn_Sf RR”, “Bn Sf RR” representing Burlington Northern Sana Fe railway company. The case can cause errors when extracting data. Therefore, we decide to use the shapefile provided by nationalatlas.gov.

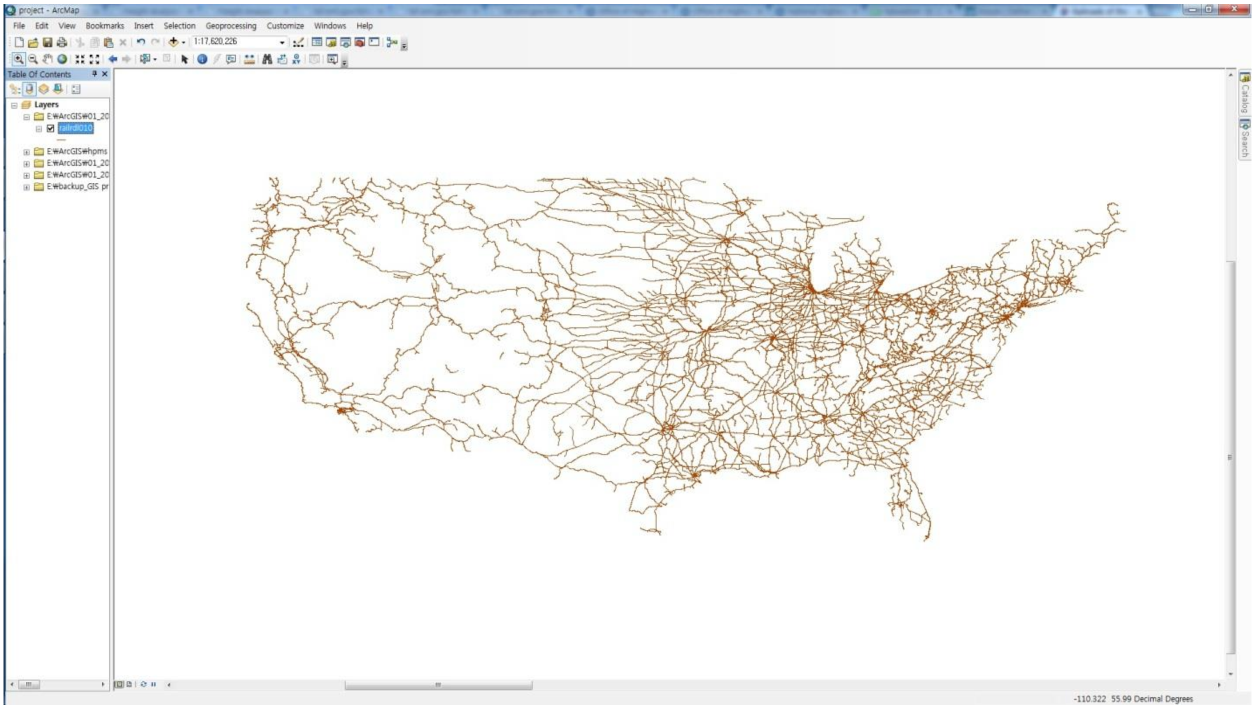


Figure 32 Railroad Network Provided by nationalatlas.gov

The network database consists of all of the railroads such as linehaul and Amtrak. We focus on linehaul railroad, especially, class I level. So, class I railroad network is extracted from the shapefile. According to the class I railroad statistics, classification is as follows;

- BNSF Railway (BNSF)
- CSX Transportation (CSX)
- Grand Trunk Corporation
- Kansas City Southern Railway (KCS)
- Norfolk Southern Combined Railroad Subsidiaries (NS)
- Soo Line Corporation
- Union Pacific Railroad (UP) (AAR, 2012)

Grand Trunk Corporation and Soo Line Corporation are not added on indices in the database. According to the article on the website of nationalatlas.gov, Grand Trunk Corporation consists of U.S operations of Canadian National (CN). Also, Soo Line is wholly owned subsidiary of Canadian Pacific (CP) (nationalatlas.gov, 2013). So the class I railroads are classified by BNSF, CSX, KCS, NS, CN, CP, and UP.

The converting step from shapefile to network file in CUBE is entirely the same with the interstate case. The initial network shapes are looked as roughly connected links (see Figure 14). So, adjusting shape is performed. The differences between the initial network with original shapefiles are easily detected (see Figure 15). Using true shape display function the shape is adjusted to the original shape (see Figure 16).

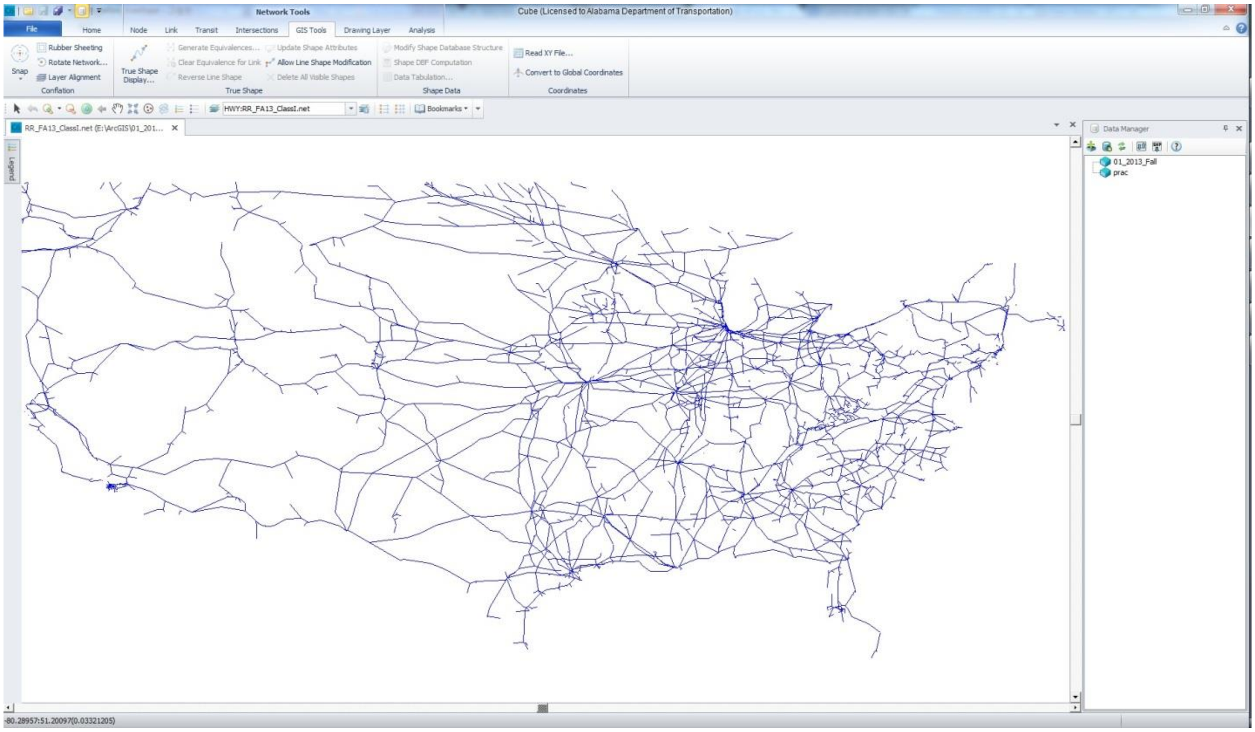


Figure 33 Initial produced class I railroad network on CUBE

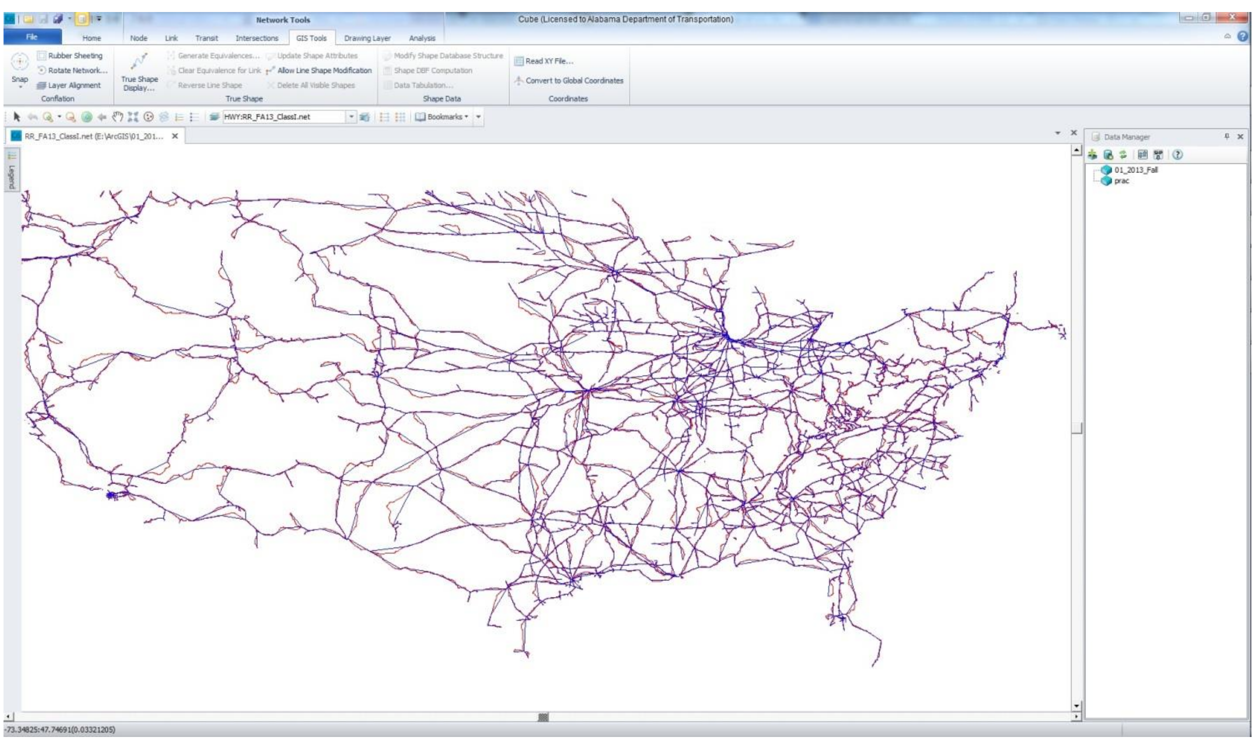


Figure 34 Comparing network shape initial and original shape file

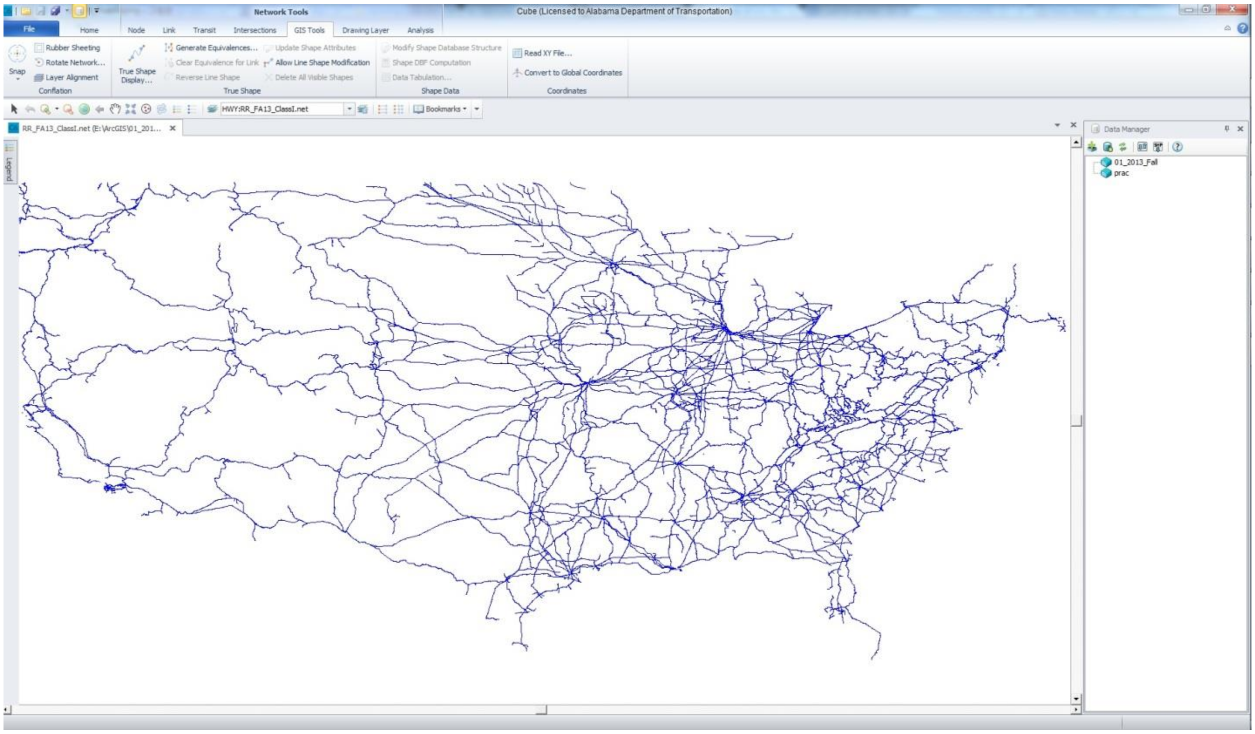


Figure 35. After adjusting true shaping step

As mentioned above, the link speed database is necessary to assign freight volume. The speed information that represents the link speed is the speed limits same as the truck mode. Thus, railroad speed limit information is manually added on the link attribute field.

According to the Track Safety Standards Compliance Manual (track safety manual), the railroad operating speed limits are affected by class of track, type of train as freight or passenger, geometry condition, or signal apparatus. However, track class information on each segment is not provided. Therefore, assumption is made that the speed limit of the railroad network is 60 mph.

Table 19 Operating Speed Limits

Classes of track	The maximum speed limits for freight train (mph)	The maximum speed limits for passenger train (mph)
1	10	15
2	25	30
3	40	60
4	60	80
5	80	90

(FRA, 2002)

Conclusion

The suitability of the network database is evaluated in this task. Though the all of the collected databases have pros and cons, the most appropriate database is chosen to be utilized in transportation demand model. As a result of the evaluation, The National Highway Planning Network is proved as the most suitable database, and railroad network database provided by nationalatlas.gov is confirmed for railway assignment step. Both of databases are converted as proper format to be used in CUBE, and some errors included in the databases are modified. Moreover, additional attributes required for the demand model are collected and added on the databases to be used in the task 4.

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CHAPTER 4: FREIGHT DISTRIBUTION SCENARIO ANALYSIS

1.0 Introduction

Container shipments into the U.S. have been increased. Even though sharply declined trade volumes had experienced after the recent economic recession, overall container shipments into the U.S. after 2009 has been caught up with the trade volumes before the recession. (U.S. DOT, 2011)

As found in the previous literature review part, almost 60% of total imported container weights into the U.S. was exported from six Asian trading partner countries (China, Japan, Korea, Singapore, Taiwan, and Hong Kong), and 13 U.S. and one Canadian ports received 97% of the 60% of total import container cargos in 2011.(Sang, 2014) Among the subjected 14 ports, six ports on the Pacific Coast handled 71% of the containers from six Asian countries and other eight ports on the Gulf and East Coast handled 29%.

With the characteristics of ocean shipments, especially container shipments proceeding to the Gulf and East Coasts from the Asian countries have to overcome the geographical issue passing the Panama Canal and this effort is followed by additional shipping cost and capacity constraint.

To increase the economies of scale and the capacity, the Panama Canal has constructed its expansions and scheduled its expanded service initiation in 2015.(Canal De Panama, 2011) Once its capacity is expanded, larger vessels and more cargos can travel through the Panama Canal compared to the current condition, and it is believed that container cargo distribution into U.S. ports on the Gulf and East Coasts will be affected positively.

In addition to this, increased container cargo flows have been observed at the Port of Prince Rupert in Canada.(Port of Prince Rupert, 2012) This Canadian port utilized the shorter ocean shipping time and lower cost than the ones at the U.S. ports on the Pacific Coast and the rail connections to the U.S. regions. By 2020, this port will increase its capacity by 2.5 times than current one and it is expected to receive more vessel calls from Asian trading partners connecting to the U.S. Midwest regions.

Under these circumstances of expected global trade increase, the Panama Canal's expansion, and the capacity increase at the Port of Prince Rupert, it is very important to estimate the import distribution of container shipments into the U.S. Midwest regions since this can maximize the performance of existing and future investments for infrastructure planning.

Therefore, in this report, import distributions of container shipments from the six Asian partner countries to the U.S. Midwest regions considering expansions of international capacity will be examined under different conditions.

2.0 Literature Review

In addition to the references discussed in the previous part, The Tioga Group, Inc. (2007 and 2008) and Wilson and Benson (2008) also analyzed port capacity and global trade in terms of containerized shipments.

For the analysis of route selection and optimization, active research and results have been discussed recently. Leachman (2008) concluded that the container vessels calling on the West Coast ports are very sensitive to congestion and willing to change the destination port to less congested location. However, once congestion is relieved with infrastructure improvements and lead time is secured, San Pedro Bay is expected to remain its vessel calls from Asia. Levine et al. (2009) estimated origin-destination matrix of US import container freight with a linear program using a gravity model based on Transportation Analysis Zones (TAZ) which unit zone is larger than Bureau of Economic Analysis (BEA) unit area. Shintani et al. (2007) used a genetic algorithm-based heuristic to solve the Knapsack problem in terms of calling sequences at ports.

Lei Fan et al. (2010) constructed an optimization model considering vessel size, container shipper route, port, and shipping corridor, and concluded that Prince Rupert is a competitive alternative route for shipments to the Midwest Region while the Panama Canal's expansion were identified with little impact of container flow.

Jula and Leachman (2011) estimated the effects of container fees at the San Pedro Bay ports with Analytical model for Long- and Short-run supply chain model. They also introduced a queuing model to estimate container flow time considering volume, infrastructure, staffing level, and operating schedule focusing on Asian shipments coming into the U.S. rail intermodal terminals through the West Coast ports. (2012)

Wilson et al. (2011) evaluated congestion with delay cost functions with a spatial optimization model for grain shipments on the Mississippi River. Lei Fan et al. (2012) developed intermodal flow network model to analyze logistic system congestion since most ports observed congestion and capacity expansion is assumed to reduce congestion cost and waiting time. Most recently, Steven and Corsi (2012) analyzed port attractiveness for containerized shipments from individual shipment data, port characteristics, and actual freight charges and concluded that larger shippers are more interested in factors affecting delivery speed than charges.

However, little research has analyzed import container freight with optimal route and attributes affecting route choices to the Midwest Region.

3.0 Purpose and Organization

The purpose of this report is to analyze the imported container cargo 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.

4.0 Method

4.1 Optimization

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 on each route with constraints.

A diagram of the current network in this report is summarized and figured as below followed by descriptions of formulation and constraints.

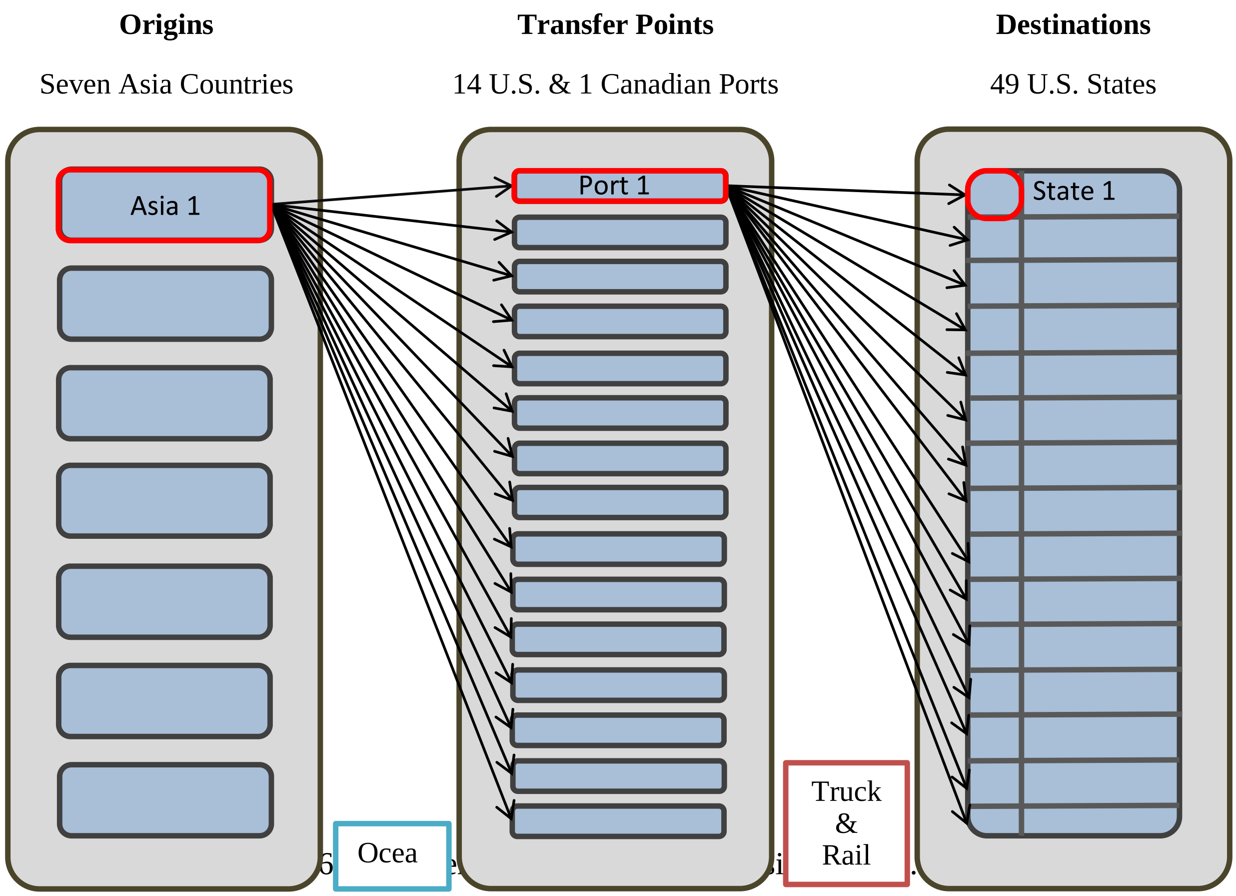

Figure 1. Container Flow Network from Asia to the U.S. States

4.2 Mathematic Formulation and Constraints

1) Objective Function:

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

2) Constraints:

(Equation 1)

$$\sum_{i} export_i \times x_{ij} \ \leq \ capacity_j$$

(Equation 2)

$$\sum_{j>5} \sum_{i} export_i \times x_{ij} \leq PanamaCanalCap$$

(Equation 3)

$$att_k = \sum_j \sum_i export_i \times x_{ij} \times y_{jk}$$

(Equation 4)

$$\sum_i x_{ij} = 1.0$$

(Equation 5)

$$\sum_k y_{jk} = 1$$

(Equation 6)

$$totalCost_j = \sum_i export_i \times x_{ij} \times oceanCost_{ij} + \sum_k \sum_i export_i \times x_{ij} \times y_{jk} \times inlandCost_{jk}$$

(Equation 7)

$$\lambda_j = \frac{(Upper_j - totalCost_j)}{(Upper_j - Lower_j)}$$

(Equation 8)

$$\lambda_j \leq 1$$

3) Variables:

- λ_j : The auxiliary variable, which is the overall satisfactory level of compromise for *j*th objective
- $export_i$: Exported amount from *i*th origin location.
- x_{ij} : Distribution probability between *i*th origin and *j*th port.
- $capacity_j$: Capacity at j.
- y_{jk} : Distribution probability between *j*th port and *k*th state.
- att_k : Attracted amount at the *k*th U.S. state.
- $totalCost_j$: Total cost at *j*th objective.
- $Upper_j$: Upper bound for *j*th objective.
- $Lower_j$: Lower bound for *j*th objective.
- PanamaCanalCap : Capacity of the Panama Canal.
- $oceanCost_{ij}$: Ocean shipping cost between *i*th origin and *j*th port.
- $inlandCost_{jk}$: Inland shipping cost between *j*th port and *k*th U.S. state.

4) Constraints Description

The model distributes container freight flow through the least cost routes to satisfy at the U.S. states as the final destination with subject to a series of constraints. Constraint (1) specifies that the distributed amount from an origin country to a port should not exceed capacity of a port. Constraint (2) is a conditional statement for containers using the Panama Canal to be less than the Canal's capacity. Constraint (3) matches the container flow amount to be the same between origin Asian countries and destination U.S. states. Constraints (4) and (5) ensure the total of distribution probabilities becomes one between origin countries and ports and between ports and states respectively. Constraint (6) estimates total cost at *j*th port including costs between *i*th origin and *j*th port and costs between *j*th port and *k*th state. Constraint (7) compromises the overall satisfactory level between upper and lower bound at *j*th objective. There are two reasons why the port location is subjected to optimize the flow network: the first one is that the purpose of this project is to estimate the container freight distribution from Asian countries and 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 trend. Lastly, Constraint (8) assures the satisfactory level at constraint (7) residing between the limits.

5.0 Data

5.1 Container Flow from Origins to Destinations

1) Origin Countries

Among the six primary Asian trading partner countries with the U.S. listed in US DOT report (Jan 2011), the five countries are selected: China, Japan, Korea, Taiwan, and Hong Kong (Singapore is excluded). Two more countries of Mongolia and Macao are additionally included. These seven countries are categorized as 'East Asian' group by the United Nations which is referred as one foreign origin region in the Freight Analysis Framework (FAF) dataset. The most recent data for these countries was retrieved from the World Institute for Strategic Economic Research Trade (WISERTrade) database which provides extensive worldwide trade data including the amounts of U.S. import and export by individual port (2013). The selection criterion is the containerized cargo weights during 2012 and it is listed in Table 20.

Table 20 Imported Container Amount from Seven Asian Trading Partners

Description	ANNUAL 2010	ANNUAL 2011	ANNUAL 2012
TOTAL ALL PARTNER COUNTRIES	129,436.15	136,680.35	143,510.94
TOTAL 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)

By matching the list of countries of WISERTrade with FAF data, it is possible to analyze modal split since FAF provides the mode choice record. When the mode choice probabilities from FAF data are multiplied by the total container flow between a port and a state, container freight distribution by mode can be estimated. Even though the mode choice probabilities from FAF dataset are not based on actual container movement but based on the Commodity Flow Survey (CFS) results, this is believed as appropriate public resource for freight mode choice up to date with considerations of freight movement trend and its forecast as recommended by the Bureau of Transportation Statistics (2007).

2) Destination States

All the U.S. states are considered as destinations in this research, since the data of container volume flow from the Asian countries to each state in the U.S. is available from WISERTrade and FAF database. 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.

3) Container Flow Data

As discussed above, container flow data from the seven Asian countries to the 49 U.S. states are retrieved from the WISERTrade database.

5.2 Capacity of the U.S. and Canadian Ports

1) Port Selection

In 2012, imported container cargo weights into U.S. are 143.51 million tons and the rank of the ports can be listed in Table 21. Selected ports are highlighted in gray. In addition to the selected thirteen U.S. ports in this list, the port of Gulfport, MS is subjected to consider in this report since it resides in this research corridor states, Mississippi. Also, the Port of Prince Rupert in Canada is included in this report since effect of its capacity expansion is a subject of this project.

Table 21 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)

2) Capacity of the U.S. and Canadian ports

Container port has various available data and information for its capacity estimation. Recently, the TIOGA Group, Inc. has investigated container port capacity and its utilization metrics (2010). Based on the five capacity dimensions of container yard (CY), berth length, depth of the port, operating hours, and stacking height, report proposed three types of measurements to estimate port's capacity: land use, crane use, and berth use. They found that the U.S. ports have substantial unused capacity inherent in their terminal infrastructure 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 observable that the estimated port capacity by CY/cranes/berth exceeds actual TEU in 2008.

Table 22 Example of Port Capacity Estimation

Container Yard	LALB	Oakland	Portland	Seattle	Tacoma	West Coast Ports
2008 TEU	14,337,801	1,347,975	245,459	1,376,496	1,347,975	18,655,706
Gross Acres	2,757	786	193	531	525	4,792
CY Acres	1370	455	73	294.75	299	2,492
CY/Gross Ratio	50%	58%	38%	56%	57%	52%
Annual CY Capacity - TEU	16,341,696	4,086,880	862,400	2,949,800	2,250,080	26,490,856
Annual TEU/Gross Acre	5,201	1,715	1,272	2,592	4,286	3,893
Annual TEU/CY Acre	10,466	2,963	3,362	4,670	7,525	7,487
Est. CY TEU Slots	243,180	72,980	12,320	42,140	40,180	410,800
Avg. CY Slots/ Acre - Density	178	160	169	143	134	165
Avg. Annual TEU/CY Slot (Turns)	59	18	20	33	34	45
CY Utilization	88%	33%	36%	58%	60%	70%
Container Cranes	**LALB**	**Oakland**	**Portland**	**Seattle**	**Tacoma**	**West Coast Ports**
Cranes	133	32	8	24	25	222
Cranes per Berth	2.7	1.5	4.0	2.2	2.8	2.4
Annual Crane Capacity - TEU	33,130,563	7,817,162	2,016,000	5,697,053	6,576,824	55,237,602
Annual TEU/Crane	107,803	42,124	30,682	57,354	53,919	84,035
Annual Moves/Crane	60,587	24,141	17,046	33,826	28,694	7,502
Annual Vessel Calls/Crane	21	57	19	27	27	27
Crane Utilization	43%	17%	12%	24%	20%	34%
Berths and Vessels	**LALB**	**Oakland**	**Portland**	**Seattle**	**Tacoma**	**West Coast Ports**
Berths	49	22	2	11	9	93
Berth Feet	57,053	19,150	1,946	12,810	10,260	101,219
Annual Vessel Calls	2,795	1,831	127	652	671	6,076
Annual Vessel Calls per Berth	57	83	51	59	75	65
Berth Utilization - Vessel Call Basis	27%	40%	25%	35%	36%	31%
Annual TEU per Berth	292,608	61,272	122,730	125,136	149,775	200,599
Annual TEU/Foot of Berth	251	70	126	107	131	184
Average Vessel Capacity - TEU	4,534	4,578	4,358	4,510	4,322	4,518
Est. Max. Vessel Capacity - TEU	13,000	7,470	3,420	7,470	7,997	na
Avg. vs. Max. Vessel Capacity	35%	61%	127%	60%	54%	na
Average TEU per Vessel	5,130	736	1,949	2,111	2,009	3,070
Avg. Vessel Ute. - % Discharge/Load	113%	16%	45%	47%	46%	68%
Berth Capacity - Avg. Vessel Basis	52,282,959	3,368,833	810,576	3,952,148	3,760,669	64,175,186
Berth Utilization - Avg. Vessel Basis	27%	40%	30%	35%	36%	29%
Avg. Discharge/Load per Max. Vessel	14,708	1,201	1,529	3,497	3,717	na
Berth Capacity - Max. Vessel Basis	149,907,029	5,497,117	636,062	6,546,180	6,958,498	na
Berth Utilization - Max. Vessel Basis	10%	25%	39%	21%	19%	na

* Example table for container port capacity estimation by The Tioga Group, Inc., July 8, 2010
* Units: TEU

In this report, therefore, the capacity of each port is adopted from the result of the TIOGA Group's report. Since there are three different capacity estimations are suggested, the least capacity volume for each port is considered and listed in below Table 23**.** Also, unit scale is converted from TEU to Tonnage because the adopted volumes are estimated with TEU scale and the WISERTrade database provides 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. Rather it is estimated as one third for the averaged usage amount per TEU by Mitchell (2011). This conversion unit value of 7 Ton/TEU will be applied for the shipping and rail cost estimation in the next part.

The capacity estimation of the Port of Prince Rupert in Canada is based on the TEU amount specified from the official webpage of the port. Current TEU amount is introduced as 500,000

TEU and expected amount in 2020 with capacity expansion is advertised as 2 million TEU. Then the volume amount becomes 3.5 million tons and 14 million tons respectively.

Table 23 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 (%)
	TOTAL Capacity	325,899.26	61,599.11	18.90 %
1	LA/LB, CA	114,391.87	31,477.80	27.52%
2	Oakland, CA	23,581.83	4,137.98	17.55%
3	Seattle, WA	20,648.60	2,690.71	13.03%
4	Tacoma, WA	15,750.56	3,536.60	22.45%
5	Prince Rupert, BC	3,500.00	3,164.67	90.42%
6	NY/NJ, NJ	61,406.80	6,963.46	11.34%
7	Norfolk, VA	19,044.40	1,640.58	8.61%
8	Charleston, SC	9,686.80	1,151.83	11.89%
9	Savannah, GA	20,664.08	3,937.73	19.06%
10	Houston, TX	21,889.28	1,587.53	7.25%
11	Mobile, AL	6,287.68	347.91	5.53%
12	Miami, FL	9,047.36	962.31	10.64%
13	Gulfport, MS	34,292.16	0.098	0.0003%

* Unit: Thousand Tons of Container (Metric)
** Unit of 'Estimated Capacity by TIOGA report' is converted from Table 5 multiplying by 7 Ton/TEU.
*** Least Capacity Estimated Amount

When the estimated port capacity is compared to the actual import amount from the seven Asian countries, it is observable that almost all ports are currently using its capacity at 30% or lower. The only exception is the port of Prince Rupert and this can be explained from its geological location and partner countries. Since this port provides lower cost and shorter shipping time for the containerized shipments from Asia, it can be valid when the seven Asian trading partners are considered for. On the other hand, Gulfport, MS showed very low usage ratio for the Asian import container flow, because the capacity of this port is relatively very high in the Gulf Coast and the majority trading partners of this port are Central or South American countries reaching the usage ratio of these trade flow up to 3%.

5.3 Capacity of the Panama Canal

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

Table 24.

Table 24 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

* The Panama Canal Authority Report.
* Unit: Thousand Tons of Container (Metric)

5.4 Container Ocean and Rail Cost

Ocean and rail cost 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 as confidential.

1) Ocean cost

First of all, distance tables from each country to each port are retrieved from the webpage of Portworld (www.portworld.com/map) which provide nautical mile distance from origin ports in Asia to the U.S. ports (2013). The obtained distance matrix is listed in Table 25. Also, shipping times in days are described in Table 26 showing minimum all-water shipping time for each origin port to destination port pair based on actual schedule from six maritime container shipping liners including Evergreen, COSCO, K-Line, Hanjin, NYK, and Hyundai.

Table 25 Nautical Mile Distance from Asian Countries to the U.S. Ports

Descriptions	LA/LB, CA	Oakland, CA	Seattle, WA	Tacoma, WA	Prince Rupert, BC	NY/NJ, NJ	Norfolk, VA	Charleston, SC	Savannah, GA	Houston, TX	Mobile, AL	Miami, FL	Gulfport, MS
China	5,693	5,378	5,042	5,042	5,032	10,553	10,348	10,138	10,123	10,089	9,946	9,741	9,969
Japan	5,140	4,833	4,544	4,544	4,535	9,983	9,778	9,568	9,553	9,519	9,376	9,171	9,369
Korea	5,249	4,933	4,597	4,597	4,588	10,108	9,903	9,693	9,678	9,644	9,501	9,296	9,472
Taiwan	6,014	5,707	5,383	5,383	5,374	10,857	10,652	10,442	10,427	10,393	10,250	10,045	110,347
Hong Kong	6,370	6,054	5,277	5,277	5,713	11,219	11,014	10,804	10,789	10,755	10,612	10,407	10,594

* Source: PortWorld, 2013
* Unit: Nautical Miles

Table 26 Scheduled Shipping Time in Days

Description	LA/LB, CA	Oakland, CA	Seattle, WA	Tacoma, WA	Prince Rupert, BC	NY/NJ, NJ	Norfolk, VA	Charleston, SC	Savannah, GA	Houston, TX	Mobile, AL	Miami, FL	Gulfport, MS
Shanghai, China	12	12	12	11	11	25	25	31	24	30	33	30	35
Tokyo/ Yokohama, Japan	10	15	9	9	19	26	33	24	23	27	28	21	28
Busan, Korea	11	15	11	9	11	23	23	25	22	23	24	25	24
Kaohsiung, Taiwan	13	17	20	18	15	23	30	30	29	36	36	27	38
Hong Kong, China	14	15	15	15	16	26	29	30	28	28	39	28	41

Unit cost of ocean shipment estimated by Mitchell (2011) was implied in this cost estimation. Detailed unit costs per mile are described in Table 27.

Table 27 Container Ocean Shipping Unit Cost

Route	Container Size	Average Cost	Cost per Mile
China to the U.S. East Coast	20'	$3,101	$0.26
	40'	$3,621	$0.30
China to the U.S. West Coast	20'	$2,220	$0.35
	40'	$2,620	$0.41

* Source: Charles W.W. Mitchell, III, Impact of the expansion of the Panama Canal (2011)

The distance in Table 25 is multiplied by the cost corresponding to its destination ports and estimated ocean cost is calculated and listed in Table 28.

Table 28 Container Ocean Shipping Cost from Asia Countries to the U.S. Ports

Descriptions	LA/LB, CA	Oakland, CA	Seattle, WA	Tacoma, WA	Prince Rupert, BC	NY/NJ, NJ	Norfolk, VA	Charleston, SC	Savannah, GA	Houston, TX	Mobile, AL	Miami, FL	Gulfport, MS
China	$92.25	$87.14	$81.70	$81.70	$81.54	$171.00	$167.68	$164.27	$164.03	$163.48	$161.16	$157.84	$161.54
Japan	$83.29	$78.31	$73.63	$73.63	$73.48	$161.76	$158.44	$155.04	$154.79	$154.24	$151.93	$148.60	$151.82
Korea	$85.05	$79.93	$74.49	$74.49	$74.34	$163.79	$160.47	$157.06	$156.82	$156.27	$153.95	$150.63	$153.48
Taiwan	$97.45	$92.47	$87.22	$87.22	$87.08	$175.92	$172.60	$169.20	$168.96	$168.41	$166.09	$162.77	$167.66
Hong Kong	$103.22	$98.10	$85.51	$85.51	$92.57	$181.79	$178.47	$175.06	$174.82	$174.27	$171.95	$168.63	$171.66

* Unit: Dollars per Ton
** Values are calculated from multiplication of distance value in Table 6 and unit cost in Table 7.

2) Inland cost

Since rail and truck are the most dominant modes for imported container flow in the U.S. as described in FAF database, both modes are considered in this analysis and rail and highway distance matrix of the U.S. is retrieved from the Oak Ridge National Laboratory database (2013). From the "Intercounty Distance Matrix", distance between counties where locating major U.S. ports and container freight stations are 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). Connection from the port of Prince Rupert to the U.S. states is assumed only with rail network and highway connection is excluded.

The unit cost value ($/mile/TEU) is adopted from the WebGIFT(Geospatial Intermodal Freight Transportation) freight model which is provided by 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).

For the inland shipping cost in our model, these values are multiplied by the distance and the mode choice probabilities calculated from FAF database.

6.0 Model Implementations

6.1 Current Situation

The estimated container freight flow from the seven Asia trading partners to the selected U.S. ports is listed as in table 29 with actual flow retrieved from WISERTrade database. The model estimation is also provided in the third column and these estimated numbers are calibrated by adjusting upper and lower bound in Constraint (7) until each estimated flow at all ports are validated almost at 90% ratio with actual flow and determined to apply results from this model to analysis of three scenarios. For the distributional comparison between the ports to the U.S. States, Table 30 shows the inland flow from ports to states but it was not available to find a source to compare the model result with.

Table 29 Actual and Estimated Container Freight Flow from Asia to the U.S. Ports

	Actual Flow in 2012	Estimated Flow for 2012	Portion
LA/LB, CA	31,477.80	31,532.55	0.99
Oakland, CA	4,137.98	4,309.15	0.96
Seattle, WA	2,690.71	2,548.75	1.05
Tacoma, WA	3,536.60	3,089.69	1.14
Prince Rupert, BC	3,164.67	2,875.83	1.10
NY/NJ, NJ	6,963.46	7,049.58	0.98
Norfolk, VA	1,640.58	1,669.34	0.98
Charleston, SC	1,151.83	1,109.99	1.03
Savannah, GA	3,937.73	3,890.00	1.01
Houston, TX	1,587.53	1,512.37	1.04
Mobile, AL	347.91	369.3596	0.94
Miami, FL	962.31	981.99	0.97
Gulfport, MS	1.41	1.32	1.06
Total	61,599.11	60,939.91	1.01

* Actual Flow in 2012 retrieved from WISERTrade database
* Unit: Thousand Tons of Container (Metric)

Table 30 Estimated Container Freight Flow from the U.S. Ports to states

No.	Ports	Total	Chicago-North	Memphis-South	Port States	Others
1	LA/LB, CA	31,532.55	4,722.71	2,621.98	13,167.82	11,020.02
2	Oakland, CA	4,309.14	441.86	227.96	3,338.96	300.36
3	Seattle, WA	2,548.74	238.85	232.04	573.60	1,504.23
4	Tacoma, WA	3,089.69	272.63	453.14	527.25	1,836.65
5	Prince Rupert, BC	2,875.82	1,654.05	424.36	0.00	797.40
6	NY/NJ	7,049.57	461.97	2,006.88	2,929.17	1,651.53
7	Norfolk, VA	1,669.34	0.00	0.00	760.79	908.55
8	Charleston, SC	1,109.99	205.53	139.87	207.50	557.07
9	Savannah, GA	3,889.99	136.17	147.16	1,516.36	2,090.28
10	Houston, TX	1,512.36	35.33	167.62	1,276.97	32.43
11	Mobile, AL	369.36	0.00	0.00	239.70	129.65
12	Miami, FL	981.99	5.11	70.10	632.47	274.29
13	Gulfport, MS	1.31	0.00	0.00	0.25	1.06
	Total	60,939.91	8,174.27	6,491.15	25,170.89	21,103.58

* Unit: Thousand Tons of Container (Metric)

6.2 Midwest Regions Scenarios of Container Flow from Six Asian Trading Partners to the U.S.

By using built optimization model for import container distribution, three scenarios are expected and each scenario is analyzed with current capacity and capacity expansions of the Panama Canal and the Port of Prince Rupert respectively. The expanded Panama Canal is scheduled to initiate its service in 2015 and the Port of Prince Rupert will complete its capacity expansion project by 2020. For closer comparison, the Panama Canal's expanded case is analyzed with 2019 and the Canadian port expansion is considered with 2020 data. Also, all other variables are assumed to be increased with 3% rate annually based on several reports and news addressing the increase rate around 3% (HIS, 2009; Tioga Group, Inc., 2007 and 2008).

1) Scenario I: Through the West Coast Ports

Table 31 Container Flow from the West Coast to Midwest Regions (2012)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	31,532.552	4,722.719	2,621.987	13,167.824	11,020.020
Oakland, CA	4,309.147	441.860	227.960	3,338.960	300.368
Seattle, WA	2,548.748	238.859	232.045	573.607	1,504.237
Tacoma, WA	3,089.690	272.635	453.147	527.256	1,836.652
Prince Rupert, BC	2,875.825	1,654.057	424.366	0.000	797.402
Total	44,355.962	7,330.131	3,959.505	17,607.647	15,458.679

* Unit: Thousand Tons of Container (Metric)

a. Panama Canal Expansion (2019)

Table 32 Container Flow from the West Coast to Midwest Regions (2019)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	30,846.774	4,615.616	2,966.203	7,550.612	15,714.343
Oakland, CA	2,705.323	260.228	426.772	62.733	1,955.591
Seattle, WA	8,178.124	828.396	4.921	6,872.635	472.172
Tacoma, WA	2,400.808	160.817	73.285	775.435	1,391.271
Prince Rupert, BC	4,854.703	145.126	233.378	0.000	4,476.198
Total	48,985.732	6,010.184	3,704.558	15,261.415	24,009.575

* Unit: Thousand Tons of Container (Metric)

b. Prince Rupert Expansion (2020)

Table 33 Container Flow from the West Coast to Midwest Regions (2020)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	31,278.155	5,744.887	3,737.826	7,462.819	14,332.623
Oakland, CA	2,388.639	210.737	349.057	406.246	1,422.599
Seattle, WA	6,366.896	83.289	393.213	281.879	5,608.515
Tacoma, WA	1,967.387	59.749	49.350	34.157	1,824.131
Prince Rupert, BC	5,315.635	711.192	325.718	620.315	3,658.410

Total	47,316.712	6,809.853	4,855.165	8,805.416	26,846.278

* Unit: Thousand Tons of Container (Metric)

The first scenario analyzed two cases of capacity expansions at the Panama Canal and the Port of Prince Rupert with the current container flow of 2012 for the West Coast ports. Current flow is described in Table 31 and Los Angeles (LA) and Long Beach (LB) ports showed the biggest receiving ports from the seven Asian countries. In each table, 'Total' indicates the total imported amount at the port, 'Chicago-North' and 'Memphis-South' indicate the amount flows from the port to the Chicago-North and Memphis-South states, 'Port States' indicates the flow amount distributed to the states where the selected ports locate (the Canadian state is excluded in Scenario 1), and 'Others' shows the flow amount to other states except the Midwest Regions and the states where the selected ports included.

When the Panama Canal expansion is expected in Table 32, overall container flow through the West Coast decreased assigning less shipment to the Midwest Regions. Even though the LA/LB port resulted receiving more container cargos in 2020, all other ports on the West Coast experienced reduced container cargo arrivals. When the Port of Prince Rupert capacity increase is assumed in Table 33, more shipments are observed concentrating on the Canadian port for all destination states including the Midwest regions while the total imported amount at the West Coast ports are declined as well as the case of 2019.

c. Mode Split

Distribution from each port to the U.S. state is estimated by multiplying the estimated amount with the mode choice probabilities based on FAF data. FAF data provides three different kinds of mode of truck, rail, and intermodal ('intermodal' means shipments by multiple modes including containerized shipments). As can be observed from Table 34 to Table 36, truck was dominant mode for all container flow from the West Coast ports. Modal split tables from selected ports to all states are added in Appendix I.

Table 34 Estimated Container Freight Mode Choice from the West Coast Ports to the U.S. States in 2012

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	Truck	21,150.487	2,640.923	2,161.369	11,890.960	4,457.235
	Rail	291.951	87.470	33.899	36.712	133.870
	Intermodal	8,459.673	1,406.194	2,997.061	607.674	3,448.744
Oakland, CA	Truck	3,454.923	125.425	26.890	3,007.060	295.548
	Rail	162.067	9.789	0.101	69.389	82.787
	Intermodal	438.785	111.559	57.250	116.395	153.581
Seattle, WA	Truck	1,269.505	109.497	32.404	0.000	1,127.604
	Rail	127.766	20.249	1.019	0.000	106.498
	Intermodal	1,107.392	57.792	39.296	0.000	1,010.304
Tacoma, WA	Truck	2,673.356	410.531	266.152	260.245	1,736.428
	Rail	195.147	0.000	0.000	193.738	1.409

	Intermodal	73.998	14.697	0.049	38.406	20.846
Prince Rupert, BC	Truck	0.000	0.000	0.000	0.000	0.000
	Rail	3,164.669	153.061	259.587	0.000	2,752.021
	Intermodal	0.000	1,761.090	326.108	44.717	0
Total	Truck	28,548.272	3,286.377	2,486.814	15,158.265	7,616.815
	Rail	3,941.601	270.570	294.606	299.839	3,076.586
	Intermodal	10,079.849	3,351.332	3,419.764	807.193	4,633.475

Table 35 Estimated Container Freight Mode Choice from the West Coast Ports to the U.S. States in 2019

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	Truck	20,047.438	2,846.879	1,507.693	7,023.604	8,669.262
	Rail	724.114	184.588	25.637	32.462	481.427
	Intermodal	10,075.222	1,584.149	1,432.873	494.546	6,563.653
Oakland, CA	Truck	2,040.222	674.207	148.509	58.474	1,159.031
	Rail	133.390	22.502	2.668	0.662	107.558
	Intermodal	1,410.701	334.732	240.017	3.597	832.356
Seattle, WA	Truck	5,988.340	6.961	5.978	5,659.672	315.729
	Rail	308.982	0.180	3.864	302.556	2.383
	Intermodal	1,011.887	2.233	30.657	910.407	68.590
Tacoma, WA	Truck	2,762.128	935.903	59.405	423.532	1,343.289
	Rail	312.906	0.000	0.000	293.658	19.248
	Intermodal	187.454	29.730	0.104	58.245	99.374
Prince Rupert, BC	Truck	0.000	0.000	0.000	0.000	0.000
	Rail	4,452.849	13.097	170.833	0.000	4,268.919
	Intermodal	0.000	0.000	0.000	0.000	0.000
Total	Truck	30,838.128	4,463.950	1,721.584	13,165.282	11,487.312
	Rail	5,932.241	220.366	203.002	629.338	4,879.535
	Intermodal	12,685.263	1,950.844	1,703.651	1,466.795	7,563.973

* Unit: Thousand Tons of Container (Metric)

Table 36 Estimated Container Freight Mode Choice from the West Coast Ports to the U.S. States in 2020

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
LA/LB, CA	Truck	20,656.311	3,619.202	2,034.002	7,005.285	7,997.822
	Rail	626.219	274.685	34.920	27.364	289.250
	Intermodal	9,995.625	1,851.000	1,668.904	430.170	6,045.551
Oakland, CA	Truck	3,407.076	1,626.745	288.768	382.118	1,109.445
	Rail	120.800	18.199	6.864	8.264	87.473
	Intermodal	2,496.475	976.063	791.361	15.864	713.187
Seattle, WA	Truck	3,429.808	25.396	154.363	231.522	3,018.526
	Rail	58.105	1.221	5.638	12.192	39.055

	Intermodal	2,522.874	15.713	160.777	38.165	2,308.220
Tacoma, WA	Truck	2,318.867	95.449	148.676	18.053	2,056.688
	Rail	13.786	0.000	0.000	13.440	0.346
	Intermodal	33.014	12.789	0.137	2.664	17.423
Prince Rupert, BC	Truck	0.000	0.000	0.000	0.000	0.000
	Rail	4,920.119	0.155	451.792	1,461.761	3,006.411
	Intermodal	0.000	0.000	0.000	0.000	0.000
Total	Truck	29,812.062	5,366.792	2,625.809	7,636.978	14,182.482
	Rail	5,739.028	294.260	499.214	1,523.020	3,422.534
	Intermodal	15,047.987	2,855.564	2,621.179	486.863	9,084.381

* Unit: Thousand Tons of Container (Metric)

2) Scenario II: Through the Gulf Coast Ports

Table 37 Container Flow from the Gulf Coast to Midwest Regions (2012)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	1,512.369	35.339	167.621	1,276.971	32.439
Mobile, AL	369.360	0.000	0.000	239.709	129.651
Miami, FL	981.993	5.112	70.104	632.478	274.298
Gulfport, MS	1.319	0.000	0.000	0.253	1.066
Total	2,865.040	40.451	237.725	2,149.410	437.455

* Unit: Thousand Tons of Container (Metric)

a. Panama Canal Expansion (2019)

Table 38 Container Flow from the Gulf Coast to Midwest Regions (2019)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	7,044.404	934.350	1,972.541	0.000	4,137.513
Mobile, AL	2,441.995	0.000	151.338	1,182.922	1,107.735
Miami, FL	702.913	30.543	0.000	672.370	0.000
Gulfport, MS	25.192	0.000	0.000	0.000	25.192
Total	10,214.504	964.893	2,123.879	1,855.291	5,270.441

b. Prince Rupert Expansion (2020)

Table 39 Container Flow from the Gulf Coast to Midwest Regions (2020)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	8,392.476	0.000	0.000	3,878.778	4,513.698
Mobile, AL	3,216.331	2.193	1,139.461	486.365	1,588.311
Miami, FL	1,407.024	469.432	227.398	77.828	632.367
Gulfport, MS	36.467	0.000	0.000	13.603	22.864
Total	13,052.297	471.624	1,366.859	4,456.574	6,757.240

The Scenario 2 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. With current condition as described in Table 37, few shipments distributed from the Gulf Coast ports to the Midwest Regions.

When the Panama Canal Expansion is expected in Table 38, however, the total flow into the Gulf Coast increased more than three times than the current flow. Obvious increased flow to the Midwest regions is also observed as well as the flow to other states. When the Port of Prince Rupert capacity increase is assumed in Table 39, overall shipments coming into the Gulf Coast did not decreased but increased by more than 20% than the shipments in 2019. Even though almost half of the flow amount to the Midwest regions in 2019 are decreased, flow to the Gulf Coast vicinity and other states is increased.

For the unassigned flow from Houston to both Midwest regions, this would not be a possible case in actual trade market however, it is understandable in this analysis with assumptions applied to our container flow optimization model. Since considered variables and constraints are mainly focused on capacity at ports and cost for shipping, container flow through the U.S. ports and rail/highway networks are optimized with minimum cost, and also it seems that the increased capacity amount is filled by shifted flows which were destined to the Gulf Coast ports by 2019 and this can be supported by observing increased volume on the West Coast ports and by considering lower shipping cost through the West Coast.

Meanwhile, it is observable that the container flow to ‘Port States’ at the Gulf Coast ports is increased at large from 2019 to 2020 showing the flow from 1,855.291 to 4,456.574. Also, it is noticeable that other ports, especially port of Mobile, on the Gulf Coast showed increased flow amounts to the Midwest regions during the same period.

And, it is understandable when the flow is observed altogether by coasts. Flow from the Gulf Coast Ports to the Midwest Regions was estimated to change from 3,087.772 in 2019 to 1,838,483 in 2020. And the West Coast Ports to the Midwest Regions was estimated to change from 9,714.742 in 2019 to 11,665.018 in 2020.

The port of Houston, TX is a large and important port for international container trade along the Gulf Coast. So, it is not appropriate that the flows from this port to Midwest regions are not assigned any container freight. However, our estimation of container flow optimization is primarily based on port capacity and shipping cost and corresponding changes were observed at the West and Gulf Coast ports. Even though it is not as much as detailed, flows from each coast to states is believed to be easily interpretable with total flow numbers at coasts.

c. Mode Split

Modal split for the container freight distribution from the Gulf Coast ports to the Midwest regions showed similar pattern with the modal distribution at the West Coast ports. Dominant mode is observed as truck.

Table 40 Estimated Container Freight Mode Choice from the Gulf Coast Ports to the U.S. States in 2012

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	Truck	375.075	0.000	375.075	0.000	0.000
	Rail	128.293	0.000	128.293	0.000	0.000
	Intermodal	99.069	0.000	99.069	0.000	0.000
Mobile, AL	Truck	126.508	0.000	0.000	126.508	0.000
	Rail	0.174	0.000	0.000	0.174	0.000
	Intermodal	0.594	0.000	0.000	0.594	0.000
Miami, FL	Truck	1,076.419	2.063	0.000	666.443	407.912
	Rail	23.600	0.004	0.000	2.857	20.739
	Intermodal	425.811	0.533	0.000	75.674	349.603
Gulfport, MS	Truck	0.253	0.000	0.000	0.253	0.000
	Rail	0.000	0.000	0.000	0.000	0.000
	Intermodal	0.000	0.000	0.000	0.000	0.000
Total	Truck	1,578.001	2.063	375.075	792.951	407.912
	Rail	152.068	0.004	128.293	3.032	20.739
	Intermodal	525.474	0.533	99.069	76.268	349.603

* Unit: Thousand Tons of Container (Metric)

Table 41 Estimated Container Freight Mode Choice from the Gulf Coast Ports to the U.S. States in 2019

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	Truck	4,562.442	597.138	1,172.084	0.000	2,793.220
	Rail	1,641.026	233.136	575.784	0.000	832.105
	Intermodal	728.731	55.528	210.262	0.000	462.941
Mobile, AL	Truck	1,447.753	28.813	179.978	795.319	443.644
	Rail	377.537	0.789	0.000	376.012	0.737
	Intermodal	641.036	4.648	1.139	11.591	623.659
Miami, FL	Truck	688.963	0.000	0.000	655.512	33.452
	Rail	3.038	0.000	0.000	3.038	0.000
	Intermodal	63.743	0.000	0.000	13.821	49.923
Gulfport, MS	Truck	0.000	0.000	0.000	0.000	0.000
	Rail	0.000	0.000	0.000	0.000	0.000
	Intermodal	0.000	0.000	0.000	0.000	0.000
Total	Truck	6,699.159	625.951	1,352.061	1,450.830	3,270.316
	Rail	2,021.601	233.925	575.784	379.050	832.842
	Intermodal	1,433.510	60.176	211.400	25.411	1,136.523

* Unit: Thousand Tons of Container (Metric)

Table 42 Estimated Container Freight Mode Choice from the Gulf Coast Ports to the U.S. States in 2020

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
Houston, TX	Truck	6,637.687	64.158	16.719	3,467.985	3,088.825
	Rail	1,277.853	0.374	1.666	278.555	997.258
	Intermodal	565.869	0.854	0.078	132.238	432.699
Mobile, AL	Truck	1,827.039	0.000	1,139.461	322.500	365.078
	Rail	276.530	0.000	0.000	159.832	116.698
	Intermodal	568.696	0.000	0.000	4.033	564.662
Miami, FL	Truck	953.734	298.210	170.059	75.876	409.589
	Rail	74.969	20.428	0.123	0.352	54.067
	Intermodal	449.962	149.700	43.310	1.600	255.353
Gulfport, MS	Truck	13.603	0.000	0.000	13.603	0.000
	Rail	0.000	0.000	0.000	0.000	0.000
	Intermodal	0.000	0.000	0.000	0.000	0.000
Total	Truck	9,418.460	362.367	1,326.240	3,866.361	3,863.492
	Rail	1,629.353	20.802	1.789	438.739	1,168.023
	Intermodal	1,584.527	150.554	43.387	137.872	1,252.714

* Unit: Thousand Tons of Container (Metric)

3) Scenario III: Through the East Coast Ports

Table 43 Container Flow from the East Coast to Midwest Regions (2012)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	7,049.577	461.976	2,006.886	2,929.179	1,651.537
Norfolk, VA	1,669.342	0.000	0.000	760.790	908.552
Charleston, SC	1,109.990	205.539	139.872	207.503	557.076
Savannah, GA	3,889.998	136.175	147.169	1,516.365	2,090.288
Total	13,718.907	803.690	2,293.927	5,413.837	5,207.454

* Unit: Thousand Tons of Container (Metric)

a. Panama Canal Expansion (2019)

Table 44 Container Flow from the East Coast to Midwest Regions (2019)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	7,808.704	510.266	1,716.615	1,347.457	4,234.365
Norfolk, VA	3,332.118	290.775	214.321	662.962	2,164.059
Charleston, SC	1,917.387	332.146	243.709	395.087	946.444
Savannah, GA	4,938.409	6.294	15.367	0.000	4,916.748
Total	17,996.619	1,139.482	2,190.013	2,405.507	12,261.617

* Unit: Thousand Tons of Container (Metric)

b. Prince Rupert Expansion (2020)

Table 45 Container Flow from the East Coast to Midwest Regions (2020)

Ports	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	8,256.755	595.700	404.902	2,209.097	5,047.056
Norfolk, VA	3,239.374	577.702	412.319	428.850	1,820.504
Charleston, SC	2,003.056	99.645	83.986	215.845	1,603.579
Savannah, GA	5,644.566	828.246	1,291.398	0.000	3,524.922
Total	19,143.751	2,101.292	2,192.605	2,853.792	11,996.061

* Unit: Thousand Tons of Container (Metric)

The Scenario 3 compared 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 listed in Table 43.

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 in that extent as shown in Table 44. This is assumed that the increased capacity of the canal affects more flows to the Gulf Coast ports but not to the East Coast ports. Also, when the Port of Prince Rupert capacity increase is expected in Table 45, assigned volumes to the Midwest regions and other states are not decreased but increased with significant changes.

c. Mode Split

Modal split for the container freight distribution from the East Coast ports to the Midwest regions showed similar pattern with other coasts. Truck mode was dominant and rail showed less than 10% proportion compare to truck mode.

Table 46 Estimated Container Freight Mode Choice from the East Coast Ports to the U.S. States in 2012

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	Truck	5,998.328	1,761.090	326.108	750.837	3,160.293
	Rail	30.956	1.996	27.933	0.129	0.898
	Intermodal	983.239	254.693	116.700	80.791	531.055
Norfolk, VA	Truck	1,769.929	0.000	0.000	0.000	1,769.929
	Rail	0.000	0.000	0.000	0.000	0.000
	Intermodal	135.130	0.000	0.000	0.000	135.130
Charleston, SC	Truck	544.286	42.844	140.256	90.018	271.168
	Rail	64.774	0.674	13.943	7.548	42.610
	Intermodal	258.983	9.674	77.383	71.924	100.002
Savannah, GA	Truck	3,000.887	95.710	329.030	272.553	2,303.594
	Rail	263.590	67.983	3.580	3.624	188.402
	Intermodal	609.047	3.082	36.107	81.567	488.291
Total	Truck	11,313.430	1,899.644	795.395	1,113.408	7,504.984
	Rail	359.320	70.653	45.456	11.301	231.910
	Intermodal	1,986.399	267.449	230.190	234.282	1,254.478

* Unit: Thousand Tons of Container (Metric)

Table 47 Estimated Container Freight Mode Choice from the East Coast Ports to the U.S. States in 2019

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	Truck	4,807.218	229.648	597.054	1,090.693	2,889.824
	Rail	30.186	0.342	6.436	1.514	21.894
	Intermodal	1,738.318	96.236	255.866	309.565	1,076.651
Norfolk, VA	Truck	4,056.793	374.799	889.293	698.538	2,094.162
	Rail	23.575	22.213	0.000	0.280	1.082
	Intermodal	583.690	64.564	151.884	43.466	323.777
Charleston, SC	Truck	1,273.193	260.696	135.962	305.175	571.361
	Rail	77.796	14.345	2.130	37.844	23.477
	Intermodal	523.912	63.839	86.184	199.317	174.571
Savannah, GA	Truck	4,039.271	4.917	47.399	0.000	3,986.956
	Rail	556.201	4.544	0.000	0.000	551.657
	Intermodal	410.450	0.473	2.438	0.000	407.539
Total	Truck	14,176.475	870.059	1,669.708	2,094.405	9,542.303
	Rail	687.759	41.444	8.566	39.638	598.111
	Intermodal	3,256.370	225.111	496.372	552.348	1,982.538

* Unit: Thousand Tons of Container (Metric)

Table 48 Estimated Container Freight Mode Choice from the East Coast Ports to the U.S. States in 2020

Ports	Mode	Total	Chicago-North	Memphis-South	Port States	Others
NY/NJ	Truck	6,061.063	285.051	247.833	2,361.183	3,166.996
	Rail	67.436	2.300	1.943	11.008	52.184
	Intermodal	1,917.051	234.042	91.409	226.113	1,365.488
Norfolk, VA	Truck	2,575.915	384.222	263.756	542.112	1,385.825
	Rail	9.927	8.335	0.040	0.499	1.052
	Intermodal	761.372	215.322	165.120	31.733	349.197
Charleston, SC	Truck	1,407.033	100.464	62.834	144.414	1,099.320
	Rail	76.740	10.351	0.752	12.937	52.700
	Intermodal	575.433	34.005	34.027	75.405	431.997
Savannah, GA	Truck	4,467.474	606.332	1,010.779	0.000	2,850.364
	Rail	509.650	38.319	93.568	0.000	377.763
	Intermodal	640.571	133.417	202.081	0.000	305.072
Total	Truck	14,511.484	1,376.068	1,585.201	3,047.709	8,502.506
	Rail	663.753	59.306	96.304	24.445	483.698
	Intermodal	3,894.427	616.786	492.637	333.251	2,451.753

* Unit: Thousand Tons of Container (Metric)

7.0 Results and Henceforth Tasks

Two capacity increase cases of the Panama Canal and the Port of 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 from the Panama Canal is assumed for the trading condition in 2019, many shipments were observed changing their routes to the ports on the Gulf/East Coast. At the West Coast ports, inbound shipment volume decreased for the Midwest regions. Also shipment to other states did not show significant increase even though 7-year time period is considered for capacity changes. On the other hand, the Gulf Coast ports experienced increased container flow with huge amount for both the Midwest Regions and other states. At the East Coast ports, overall shipment volume increased and volume for the Midwest regions was 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 of shipment volume for the Midwest regions is not assumed. At the West Coast ports, LA/LB ports showed dominant flow increase to the Midwest Regions and other states rather 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, flow to the Midwest Regions is decreased and this is assumed to route changes to the West Coast ports. At the East Coast ports, shipments to the Midwest Regions increased with amount, also overall shipments and shipments to other states were increased. This can be explained that the Canadian port is geographically too far from the East Coast and its capacity increase affected for the flow to the Midwest Regions but less for other states.

With overall, it can be concluded that capacity increase of the Panama Canal resulted container flow increase at the Gulf/East Coast for the Midwest regions. And capacity increase of the Port of Prince Rupert showed significant changes for the Midwest Region shipments.

Cost and capacity are primary factors in this analysis for optimizing imported container flow in to the U.S. Although a lot of efforts were made to minimize assumptions in analysis process, there are still some left for further enhancements. First is about cost assumptions including congestion effects at each port, rail capacity, and route choice behavior from shipper or consignee side. Second is growth rate of imports. Annual growth rate of 3% are unitarily applied for the seven Asian trading partner countries and all the U.S. states and this may fluctuate by global market situation. Also assumed that these partners will be remaining at top until 2020 and inclusion of India or Thailand would be supplemental list. Lastly, toll rates at the Panama Canal were not fully engaged with container flow through the canal and specific toll amount would be a qualifier to be suggested for precise estimation.

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CHAPTER 5: TRANSPORTATION NETWORK IMPACT MODELING

1.0 Introduction

The objective of this task is to perform the assignment of freight volume by truck and railroad using the network database developed in the previous task. Origin-Destination trip tables (O/D tables) are conducted and mode choice probability is also estimated in the previous task 3. In this task, FAF3 zone system is adopted and international ports are added as additional zones for the assignment. Also, the O/D tables are modified to meet FAF3 zone system and to be divided into truck O/D table and railroad O/D table. Using the network, zone system, and O/D tables, the freight assignment task is conducted in this task.

2.0 Construction of FAF3 Zones

For this project the FAF3 zone system is adopted for assigning freight volume. FAF3 consists of a total of 123 CFS regions and 8 international trade zones (see Figure 1). This project focuses on the continental U.S so, 120 zones out of 123 zones except Alaska and Hawaii are applied. Apart from the FAF3 zones an additional 13 zones are added to represent international trade ports (see Table 1). The O/D matrix prepared in the previous chapter consists of 13 additional zones representing international trade ports for origin and 48 states U.S excluding Alaska and Hawaii. The District of Columbia is considered as a zone. Therefore, the 13 international trade ports are represented as origins and 49 states are represented as destinations divided to 120 FAF3 zones. See Figure 2, the origins are indicated as a triangle and the destinations are depicted as a rectangle.

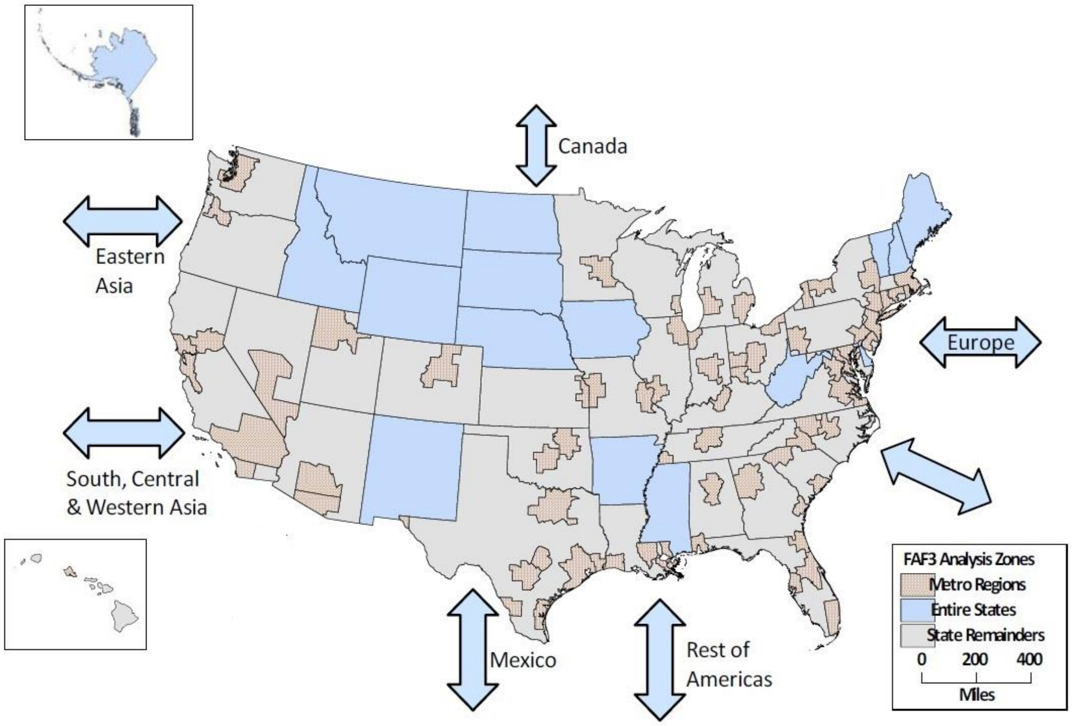


Figure 37 Geographic Location for FAF3 Data (Southworth, Davidson, Hwang, & Peterson, 2010)

Table 49 The List of Additional Zones for Representing International Ports

Zone No.	Port
151	LA/LB, CA
152	Oakland, CA
153	Seattle, WA
154	Tacoma, WA
155	Prince Rupert
156	NY/NJ, NJ
157	Norfolk, VA
158	Charleston, SC
159	Savannah, GA
160	Houston, TX
161	Mobile, AL
162	Miami, FL
163	Gulfport, MS

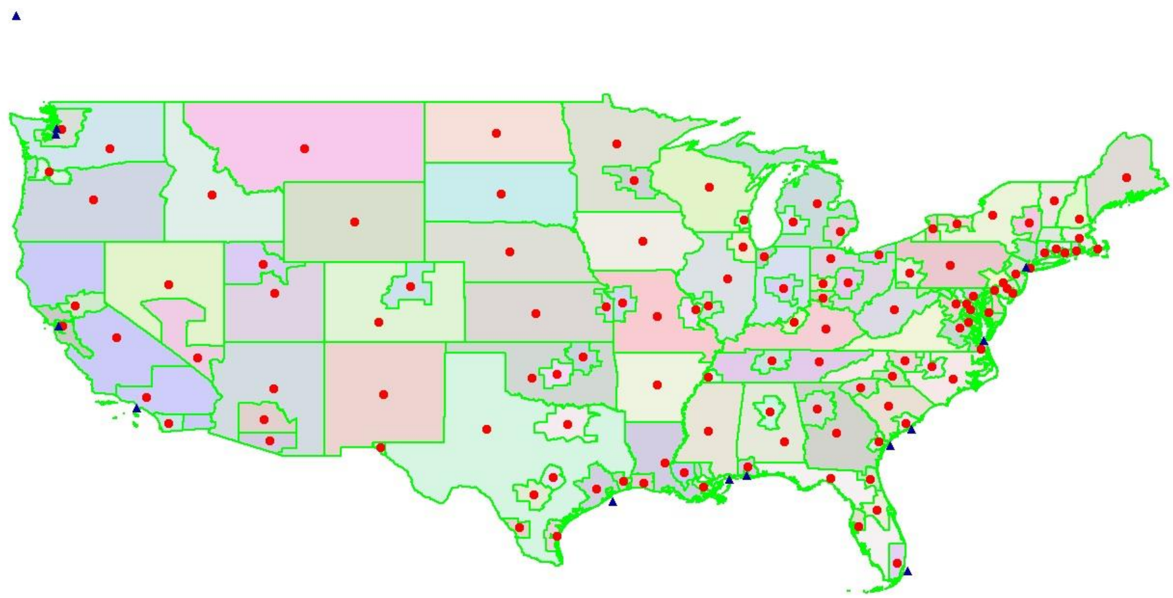


Figure 38 The Representation of Origins and Destinations

3.0 Origin/Destination Table

The first step is to prepare a proper Origin/Destination matrix (O/D matrix) for freight assignment. In previous chapters networks and O/D pairs were built for the assignment phase. The O/D matrix estimated in a previous chapter provides freight flows from 13 international ports to all of the states in U.S. (see Table 2-4). The O/D matrix consists of total freight tonnage by all modes between origin and destination. So, it is necessary to divide the total freight O/D matrix to freight by each mode O/D matrix. The mode ratio is shown as table 5. Also, we assume that all of the freight from Prince Rupert, Canada would use railway only. Each mode O/D matrix is rebuilt by using the mode ratio matrix.

Table 50 2012 Original O/D Matrix Built in a Previous Chapter (Total kilo tons by all mode)

D \ O	LA/LB	Oakland	Seattle	Tacoma	P.Rupert	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfport
Total	31532.55	4309.15	2548.75	3089.69	2875.83	7049.58	1669.34	1109.99	3890.00	1512.37	369.36	981.99	1.32
Alabama	291.45	0.00	132.82	0.00	0.00	0.00	0.00	0.00	22.28	133.09	239.71	0.00	0.00
Arizona	210.62	34.91	0.93	7.21	0.00	0.00	0.00	0.00	23.17	0.00	0.00	0.00	0.00
Arkansas	341.10	19.27	69.81	2.32	0.00	0.00	0.00	1.10	1.55	0.00	0.00	0.00	0.00
California	12535.35	3190.76	0.00	492.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Colorado	220.87	20.07	100.47	2.32	0.00	0.00	0.00	0.70	15.10	0.00	0.00	0.00	0.00
Connecticut	0.00	0.00	18.76	6.43	0.00	27.53	0.00	16.47	56.75	0.00	0.00	0.00	0.00
Delaware	0.00	0.00	0.00	0.02	0.00	0.00	0.27	0.00	3.18	0.00	0.00	0.15	0.00

Dist Columbia	0.00	0.00	3.90	9.78	0.00	7.67	22.15	1.49	7.69	0.00	0.00	0.00	0.00
Florida	0.00	0.00	0.00	23.55	0.00	0.00	0.00	46.03	342.36	354.37	0.00	632.48	0.25
Georgia	1984.60	0.00	30.36	170.22	0.00	589.35	0.00	92.38	280.57	0.00	127.39	212.43	0.19
Idaho	25.32	1.35	4.07	2.19	0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	0.00
Illinois	1910.99	253.37	44.08	147.19	1191.56	37.05	0.00	152.00	0.00	0.00	0.00	0.00	0.00
Indiana	476.94	60.95	34.92	57.25	0.00	256.53	0.00	12.52	0.00	107.12	0.00	0.00	0.00
Iowa	167.64	9.60	15.89	7.72	0.00	52.84	0.00	12.88	0.00	0.00	0.00	0.00	0.00
Kansas	207.41	18.98	22.33	2.19	131.74	0.00	0.00	0.00	4.39	34.18	0.00	0.00	0.00
Kentucky	176.27	46.34	23.35	50.56	0.00	417.90	0.00	6.42	0.00	0.00	0.00	0.00	0.00
Louisiana	21.42	0.00	0.00	113.80	0.00	0.00	0.00	0.00	76.91	32.44	2.26	20.90	0.88
Maine	0.00	0.00	1.01	0.00	18.69	0.61	0.00	0.55	3.45	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	50.08	34.61	0.00	49.96	316.75	15.04	53.30	0.00	0.00	0.00	0.00
Massachusetts	0.00	53.35	0.00	10.09	0.00	0.00	0.00	0.00	556.03	0.00	0.00	0.00	0.00
Michigan	280.37	73.39	181.11	54.68	0.00	412.08	0.00	0.00	6.68	0.00	0.00	0.00	0.00
Minnesota	1811.47	40.60	0.00	9.78	235.90	11.66	0.00	33.02	18.23	0.00	0.00	0.00	0.00
Mississippi	366.00	48.43	0.00	5.66	0.00	52.07	0.00	7.65	0.00	0.00	0.00	1.79	0.00
Missouri	671.13	49.68	9.26	37.44	0.00	0.00	0.00	24.53	14.32	26.32	0.00	0.00	0.00
Montana	26.09	0.54	1.16	0.26	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00
Nebraska	167.96	12.89	5.57	0.00	0.00	0.00	0.00	0.00	16.47	35.34	0.00	0.08	0.00
Nevada	171.65	6.97	2.98	3.99	0.00	0.00	0.00	0.00	19.97	0.00	0.00	0.00	0.00
New ampshire	0.00	0.00	3.38	0.51	60.75	3.85	0.00	2.66	2.12	0.00	0.00	0.00	0.00
New Jersey	0.00	0.00	543.23	554.53	241.45	1276.36	203.97	34.94	452.42	0.00	0.00	0.00	0.00
New Mexico	29.99	0.84	0.00	0.51	0.00	1.03	0.00	1.26	0.00	0.00	0.00	1.27	0.00
New York	0.00	0.00	196.80	188.62	343.21	1339.35	0.00	126.75	963.71	0.00	0.00	0.00	0.00
North Carolina	862.35	0.00	179.14	69.73	0.00	240.19	0.00	75.30	77.17	0.00	0.00	0.00	0.00
North Dakota	93.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.03	0.00
Ohio	700.45	1.39	149.64	251.02	66.00	687.01	0.00	89.94	93.00	0.00	0.00	0.00	0.00
Oklahoma	340.31	8.79	9.99	7.33	0.00	0.00	0.00	16.66	21.20	0.00	0.00	0.00	0.00
Oregon	387.46	47.59	44.54	16.73	0.00	63.77	0.00	0.00	0.00	0.00	0.00	9.96	0.00
Pennsylvania	339.32	0.00	39.95	93.92	0.00	126.04	569.38	72.02	145.32	0.00	0.00	0.00	0.00
RhO/De Island	0.00	0.00	0.00	1.03	133.30	6.86	0.00	0.00	7.69	0.00	0.00	0.00	0.00
South Carolina	653.31	0.00	0.00	39.76	0.00	188.32	0.00	38.04	59.40	0.00	0.00	22.19	0.00
South Dakota	36.97	0.42	0.82	0.00	0.00	1.19	0.00	0.55	0.00	0.00	0.00	0.00	0.00
Tennessee	398.42	87.36	0.00	97.53	226.62	1010.50	0.00	0.00	35.46	0.00	0.00	70.10	0.00
Texas	4274.61	0.00	0.00	198.14	0.00	0.00	0.00	195.63	342.41	789.51	0.00	0.00	0.00
Utah	274.69	8.76	2.11	12.87	0.00	0.00	0.00	0.00	28.65	0.00	0.00	0.00	0.00
Vermont	0.00	0.00	0.00	3.73	0.00	0.39	0.00	0.00	1.33	0.00	0.00	1.52	0.00
Virginia	0.00	0.00	45.40	206.24	0.00	125.15	556.82	7.77	40.84	0.00	0.00	0.00	0.00
Washington	632.48	148.20	573.61	34.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West Virginia	0.00	2.09	0.00	0.00	0.00	64.31	0.00	5.71	0.00	0.00	0.00	3.28	0.00
Wisconsin	421.84	61.19	7.28	60.99	226.60	0.00	0.00	19.96	94.79	0.00	0.00	0.00	0.00
Wyoming	22.58	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.81	0.00

Table 51 2019 Original O/D Matrix Built in a Previous Chapter (Total kilo tons by all mode)

D \ O	LA/LB	Oakland	Seattle	Tacoma	P.Rupert	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfp
Total	30846.77	2705.32	8178.12	2400.81	4854.70	7808.70	3332.12	1917.39	4938.41	7044.40	2441.99	702.91	
Alabama	315.99	0.00	0.00	7.93	20.95	0.00	583.63	16.13	0.00	0.00	192.47	0.00	
Arizona	286.84	6.49	0.00	15.65	0.00	0.00	3.33	16.74	4.57	21.72	0.00	0.00	
Arkansas	446.60	2.24	0.00	4.74	10.20	0.00	59.99	15.65	0.00	12.20	0.00	0.00	
California	6074.26	29.61	6872.64	744.53	0.00	662.97	0.00	0.00	4789.77	1984.97	0.00	0.00	
Colorado	0.00	238.74	0.00	9.65	0.00	0.00	99.44	2.57	0.00	12.98	0.00	0.00	
Connecticut	346.98	5.70	0.00	19.68	0.00	32.73	3.36	23.90	3.87	23.76	0.00	0.00	
Delaware	0.00	0.28	0.00	1.12	0.00	2.64	0.20	0.00	0.42	0.10	0.00	0.00	
Dist Columbia	0.00	8.16	0.00	2.10	0.00	36.97	0.94	0.00	11.59	6.79	0.00	0.00	
Florida	0.00	0.00	0.00	120.52	1141.55	57.92	8.50	0.00	0.00	0.00	202.59	672.37	
Georgia	3414.78	110.89	0.00	95.25	0.00	54.31	79.32	147.25	0.00	24.42	988.50	0.00	

Idaho	35.50	2.13	0.00	0.58	0.00	0.00	3.04	1.42	0.00	0.84	0.00	0.00
Illinois	2654.75	140.27	0.00	78.39	145.13	0.00	85.84	241.07	0.00	443.44	0.00	0.00
Indiana	0.00	56.76	0.00	9.55	0.00	755.52	59.59	33.54	0.00	338.57	0.00	0.00
Iowa	245.80	7.35	0.00	1.75	0.00	0.00	10.12	20.66	0.00	51.16	0.00	0.00
Kansas	214.41	2.02	0.00	5.65	233.38	0.00	20.87	0.00	0.00	11.57	0.00	0.00
Kentucky	399.82	48.15	0.00	6.91	0.00	22.70	25.93	17.87	0.00	393.06	0.00	0.00
Louisiana	0.00	106.04	121.50	19.40	0.00	0.00	8.66	2.17	4.38	0.00	35.19	0.00
Maine	0.00	0.00	0.00	1.23	0.00	25.96	1.01	1.93	0.00	0.53	0.00	0.00
Maryland	0.00	32.91	0.00	16.45	0.00	606.21	48.36	25.89	0.00	43.28	0.00	0.00
Massachusetts	308.51	37.92	0.00	231.31	0.00	126.95	15.21	35.24	0.00	31.90	0.00	0.00
Michigan	512.48	51.98	0.00	15.53	0.00	70.89	184.72	36.63	0.00	405.55	0.00	0.00
Minnesota	780.59	9.37	828.40	14.92	0.00	0.00	0.00	0.00	0.00	34.25	0.00	0.00
Mississippi	0.00	0.90	0.00	10.80	148.43	306.58	0.00	16.86	0.00	40.15	83.37	0.00
Missouri	0.00	35.58	0.00	13.78	0.00	857.26	30.40	49.84	15.37	29.78	0.00	0.00
Montana	0.00	0.32	0.00	0.32	0.00	33.53	1.34	1.32	0.00	0.33	0.00	0.00
Nebraska	0.00	0.00	0.00	8.66	0.00	184.04	10.37	3.64	0.00	7.94	0.00	30.54
Nevada	148.30	3.73	90.41	8.66	0.00	0.00	0.00	12.54	0.00	4.19	0.00	0.00
NewHampshire	0.00	0.53	0.00	0.78	0.00	77.53	3.38	6.97	0.00	3.35	0.00	0.00
New Jersey	2892.78	545.50	0.00	120.07	0.00	0.00	407.03	183.90	0.00	213.31	0.00	0.00
New Mexico	0.00	0.02	35.53	0.17	0.00	0.00	0.00	0.75	5.31	2.27	0.00	0.00
New York	1212.89	186.70	0.00	337.30	2061.16	0.00	149.90	151.04	0.00	297.24	0.00	0.00
North Carolina	1287.20	66.25	0.00	23.52	0.00	74.17	126.63	119.82	0.00	208.67	0.00	0.00
North Dakota	0.00	0.55	0.00	0.12	0.00	113.18	1.90	0.00	6.29	5.10	0.00	0.00
Ohio	1320.49	239.03	0.00	15.64	0.00	103.84	93.34	127.05	0.00	598.02	0.00	0.00
Oklahoma	0.00	6.92	0.00	8.97	0.00	447.94	13.53	26.94	0.00	5.34	0.00	0.00
Oregon	443.64	49.10	0.00	10.21	0.00	0.00	29.93	0.00	96.83	160.72	0.00	0.00
Pennsylvania	0.00	93.02	0.00	46.73	68.09	1418.41	97.42	95.74	0.00	108.52	0.00	0.00
RhO/De Island	0.00	0.96	0.00	2.63	0.00	180.36	5.62	7.24	0.00	6.03	0.00	0.00
South Carolina	377.93	39.36	0.00	18.10	0.00	588.97	67.29	44.84	0.00	252.18	0.00	0.00
South Dakota	0.00	0.00	0.00	0.16	0.00	46.92	0.96	1.04	0.00	1.27	0.00	0.00
Tennessee	1185.50	86.02	4.92	26.92	0.00	0.00	0.00	12.62	0.00	943.45	151.34	0.00
Texas	3519.52	150.59	0.00	238.33	1025.83	0.00	361.83	211.30	0.00	0.00	787.86	0.00
Utah	154.05	12.25	224.72	11.19	0.00	0.00	0.00	21.46	0.00	5.44	0.00	0.00
Vermont	0.00	3.48	0.00	0.23	0.00	13.40	1.11	0.00	0.00	1.12	0.67	0.00
Virginia	123.03	196.21	0.00	0.00	0.00	758.49	38.74	15.31	0.00	107.72	0.00	0.00
Washington	1476.35	33.13	0.00	30.90	0.00	0.00	577.58	112.09	0.00	97.98	0.00	0.00
West Virginia	0.00	0.11	0.00	0.50	0.00	24.98	3.34	6.27	0.00	65.18	0.00	0.00
Wisconsin	667.79	58.05	0.00	43.04	0.00	95.24	6.97	49.77	0.00	36.81	0.00	0.00
Wyoming	0.00	0.00	0.00	0.25	0.00	28.11	1.44	0.40	0.00	1.21	0.00	0.00

Table 52 2020 Original O/D Matrix Built in a Previous Chapter (Total kilo tons by all mode)

D \ O	LA/LB	Oakland	Seattle	Tacoma	P.Rupert	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gu
Total	31278.15	2388.64	6366.90	1967.39	5315.64	8256.75	3239.37	2003.06	5644.57	8392.48	3216.33	1407.02	
Alabama	331.65	8.29	73.99	0.00	728.44	31.07	0.00	219.16	0.00	0.00	144.83	0.00	
Arizona	91.17	5.58	139.34	25.53	20.19	62.77	0.00	0.00	29.73	0.00	0.00	0.00	
Arkansas	329.48	1.78	125.06	0.00	21.09	19.15	3.59	22.76	0.00	0.00	13.56	0.00	
California	6677.11	379.34	276.14	34.16	563.99	1427.83	1194.46	388.90	3215.80	3657.59	0.00	0.00	
Colorado	251.33	1.78	156.19	2.22	163.75	38.61	1.93	1.33	14.22	0.00	0.00	2.72	
Connecticut	170.25	4.99	192.80	0.00	0.00	78.78	3.72	18.76	0.00	0.00	0.00	17.14	
Delaware	0.00	0.25	0.00	0.00	0.00	2.42	0.00	0.00	0.00	2.28	0.00	0.00	
Dist Columbia	5.20	7.53	23.34	15.41	0.00	10.67	0.00	3.08	0.00	0.00	0.00	4.00	
Florida	1119.42	18.19	521.26	0.00	108.12	474.89	0.00	0.00	0.00	0.00	0.00	77.83	
Georgia	3169.86	131.13	11.71	0.00	662.82	389.21	145.49	16.91	0.00	0.00	496.44	0.00	

Idaho	22.51	1.69	11.49	0.00	1.34	3.14	0.00	4.22	1.27	0.00	0.00	0.00
Illinois	2016.72	113.45	8.91	32.17	425.15	240.08	391.82	2.41	762.86	0.00	0.00	109.88
Indiana	508.95	44.16	10.06	12.23	56.13	53.67	63.90	26.89	511.15	0.00	0.00	36.06
Iowa	223.78	5.92	10.99	14.78	0.00	8.47	25.26	21.70	5.67	0.00	0.00	38.84
Kansas	282.28	1.69	148.31	0.00	46.63	22.60	0.00	0.00	10.44	0.00	0.00	3.96
Kentucky	355.21	39.00	10.40	0.00	0.00	40.80	51.44	9.01	0.00	0.00	455.23	0.00
Louisiana	0.00	87.73	90.56	0.00	0.00	106.72	0.00	15.01	0.00	0.00	12.40	0.00
Maine	20.18	0.00	0.00	5.33	0.00	4.71	1.10	0.66	0.00	0.00	0.00	0.01
Maryland	338.65	26.65	271.08	10.04	0.00	74.07	0.00	53.88	0.00	0.00	0.00	33.07
Massachusetts	0.00	6.58	0.00	0.00	0.00	819.23	0.00	0.00	0.00	0.00	0.00	0.00
Michigan	507.24	42.05	5.48	7.30	265.56	74.07	68.37	44.86	0.00	0.00	0.00	328.71
Minnesota	2226.67	7.53	8.57	0.00	20.48	60.89	64.61	3.53	56.26	0.00	0.00	0.00
Mississippi	347.95	4.31	127.40	0.00	0.00	42.69	16.46	13.30	0.00	0.00	86.64	0.00
Missouri	766.70	28.76	101.20	1.74	0.00	63.72	47.12	33.49	18.46	0.00	0.00	13.91
Montana	24.60	0.25	10.97	0.00	0.00	1.26	0.00	1.55	0.48	0.00	0.00	0.00
Nebraska	191.13	0.00	39.92	0.00	0.00	33.90	0.00	11.67	9.13	0.00	0.00	1.09
Nevada	122.57	3.05	111.96	0.00	4.35	33.58	0.00	2.63	5.08	0.00	0.00	0.00
NewHampshire	79.01	0.42	0.00	0.00	0.00	3.14	8.04	3.73	1.34	0.00	0.00	2.03
New Jersey	1264.60	427.23	1034.38	49.15	742.71	627.44	122.50	49.85	0.00	0.00	0.00	153.54
New Mexico	20.69	0.42	17.61	1.35	1.89	0.63	0.00	0.00	3.80	0.00	0.00	0.00
New York	1895.60	145.34	439.58	0.00	74.50	1442.93	239.26	47.24	0.00	0.00	0.00	202.80
North Carolina	112.37	53.72	1311.83	0.00	0.00	107.03	0.00	179.32	0.00	0.00	240.83	0.00
North Dakota	120.49	0.68	2.04	0.00	0.00	0.63	0.00	4.23	0.00	0.00	0.00	6.32
Ohio	969.12	193.39	7.81	20.61	222.95	130.26	203.48	1.91	745.68	0.00	0.00	134.63
Oklahoma	270.32	5.58	152.43	53.70	0.00	37.04	7.75	11.08	0.86	0.00	0.00	0.00
Oregon	259.41	12.94	59.01	0.00	74.09	0.00	32.42	6.26	82.83	206.85	0.00	93.93
Pennsylvania	131.85	72.33	0.00	1630.10	0.00	201.51	0.00	0.00	0.00	0.00	0.00	0.00
RhO/De Island	184.16	0.76	0.00	0.00	0.00	10.67	8.03	6.26	0.00	0.00	0.00	4.55
South Carolina	917.67	30.63	8.12	0.00	0.00	82.24	67.09	70.41	0.00	0.00	283.21	0.00
South Dakota	39.02	0.00	10.29	0.00	0.00	0.63	0.00	1.12	0.00	0.00	2.19	0.00
Tennessee	986.99	75.12	114.85	0.00	0.00	126.18	72.57	0.00	0.00	0.00	1139.46	0.00
Texas	1671.02	152.62	149.05	0.00	1050.59	973.33	241.15	5.64	0.00	3878.78	341.53	0.00
Utah	217.24	9.90	160.23	1.87	4.52	47.40	4.71	1.33	5.80	0.00	0.00	0.00
Vermont	13.50	2.88	0.00	0.00	0.00	1.88	0.39	1.17	0.00	0.00	0.00	1.10
Virginia	570.35	158.96	366.89	21.96	0.00	56.50	0.00	48.36	0.00	0.00	0.00	86.56
Washington	785.71	26.90	5.74	0.00	56.32	0.00	91.80	612.74	161.61	646.98	0.00	0.00
West Virginia	0.00	0.08	28.17	7.45	0.00	1.88	8.02	3.28	0.00	0.00	0.00	30.92
Wisconsin	643.61	47.04	8.07	20.28	0.00	185.50	52.90	31.82	0.00	0.00	0.00	23.42
Wyoming	24.82	0.00	3.67	0.00	0.00	0.94	0.00	1.64	2.08	0.00	0.00	0.00

Table 53 Truck Mode Ratio

D \ O	LA/LB	Oakland	Seattle	Tacoma	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfport
Alabama	0.477	0.286	0.185	1.000	0.589	0.915	0.226	0.545	0.583	0.994	0.443	0.000
Arizona	0.887	0.921	0.605	1.000	0.843	0.882	0.799	0.995	0.334	1.000	0.766	0.000
Arkansas	0.675	0.355	0.330	0.999	0.839	0.865	0.566	0.997	0.787	0.561	0.468	0.000
California	0.949	0.942	0.824	0.529	0.412	0.767	0.528	0.810	0.712	0.148	0.498	0.000
Colorado	0.594	0.262	0.719	0.844	0.690	0.753	0.087	0.248	0.973	0.000	0.894	0.000
Connecticut	0.920	0.569	0.348	1.000	0.976	0.889	0.536	0.984	0.598	0.953	0.872	0.000
Delaware	0.588	0.872	0.891	1.000	0.969	0.941	0.978	0.999	0.174	0.000	0.484	0.000
Dist Columbia	0.357	0.919	0.850	1.000	0.883	1.000	0.066	0.718	0.000	0.000	0.632	1.000
Florida	0.655	0.748	0.262	0.604	0.778	0.967	0.695	0.865	0.898	0.948	0.975	1.000
Georgia	0.398	0.600	0.351	1.000	0.904	0.981	0.643	0.724	0.878	0.375	0.428	0.000
Idaho	0.853	0.979	0.814	1.000	0.936	0.000	0.712	1.000	0.220	0.000	0.000	0.000

Illinois	0.546	0.409	0.395	0.744	0.653	0.552	0.837	0.780	0.814	0.989	0.898	0.000
Indiana	0.746	0.366	0.581	1.000	0.708	0.978	0.915	0.907	0.746	0.982	0.811	0.000
Iowa	0.420	0.549	0.171	1.000	0.733	0.080	0.519	0.732	0.600	0.000	0.376	0.000
Kansas	0.829	0.194	0.670	1.000	0.691	0.703	0.898	0.857	0.719	0.000	0.921	0.000
Kentucky	0.715	0.810	0.614	0.974	0.765	0.648	0.708	0.924	0.867	0.000	0.781	1.000
Louisiana	0.273	0.940	0.962	1.000	0.840	0.900	0.284	0.621	0.966	0.947	0.210	0.000
Maine	0.644	0.648	0.963	1.000	0.966	0.951	0.988	0.386	0.074	0.000	0.499	0.000
Maryland	0.604	0.366	0.611	1.000	0.914	0.971	0.360	0.597	0.641	0.423	0.716	0.000
Massachusetts	0.771	0.937	0.209	1.000	0.779	0.930	0.727	0.721	0.054	0.000	0.810	0.000
Michigan	0.624	0.832	0.609	0.996	0.610	0.752	0.818	0.928	0.494	0.834	0.545	0.000
Minnesota	0.617	0.664	0.743	1.000	0.745	0.802	0.702	0.292	0.980	0.841	0.849	0.000
Mississippi	0.440	0.565	0.130	1.000	0.710	0.974	0.253	0.680	0.563	0.906	0.401	0.000
Missouri	0.499	0.219	0.119	1.000	0.686	0.913	0.550	0.951	0.906	0.962	0.823	0.000
Montana	0.898	0.714	0.928	1.000	0.668	1.000	0.634	0.000	0.000	0.000	0.012	0.000
Nebraska	0.643	0.113	0.335	1.000	0.969	1.000	0.375	0.870	0.991	0.000	0.923	0.000
Nevada	0.929	0.961	0.964	1.000	0.763	0.945	0.399	0.991	0.076	0.667	0.626	0.000
NewHampshire	0.670	0.290	0.515	1.000	0.861	0.987	0.984	0.539	0.000	0.568	0.356	0.000
New Jersey	0.747	0.409	0.315	0.649	0.966	0.952	0.557	0.703	0.762	0.272	0.366	0.000
New Mexico	0.893	0.593	0.509	1.000	0.916	0.993	0.984	1.000	0.943	0.000	0.557	0.000
New York	0.602	0.619	0.865	0.995	0.899	0.902	0.390	0.899	0.944	0.946	0.808	0.000
North Carolina	0.490	0.301	0.777	1.000	0.931	0.944	0.818	0.952	0.211	0.468	0.884	0.000
North Dakota	0.962	0.672	0.633	1.000	0.989	0.000	0.000	0.278	0.000	0.000	0.738	0.000
Ohio	0.596	0.436	0.357	0.993	0.598	0.351	0.555	0.674	0.467	0.890	0.911	0.000
Oklahoma	0.432	0.467	0.553	1.000	0.294	0.972	0.932	0.983	0.929	0.000	0.728	0.000
Oregon	0.649	0.820	0.501	0.920	0.680	0.840	0.112	0.584	0.171	0.047	0.925	0.000
Pennsylvania	0.768	0.557	0.472	1.000	0.865	0.712	0.586	0.649	0.850	1.000	0.589	0.000
RhO/De Island	0.497	0.126	0.780	1.000	0.815	0.810	0.535	1.000	0.024	0.444	0.957	0.000
South Carolina	0.590	0.932	0.540	1.000	0.728	0.999	0.950	0.915	0.548	0.165	0.332	0.000
South Dakota	0.377	0.364	0.568	1.000	0.859	0.000	0.727	1.000	0.000	0.000	0.000	0.000
Tennessee	0.371	0.222	0.357	1.000	0.873	0.960	0.580	0.908	0.623	1.000	0.829	0.000
Texas	0.398	0.569	0.532	0.898	0.850	0.925	0.832	0.661	0.894	0.523	0.381	0.000
Utah	0.433	0.165	0.787	1.000	0.864	1.000	0.000	0.974	0.999	0.000	0.307	0.000
Vermont	0.519	0.869	0.170	1.000	0.958	0.991	0.987	0.912	1.000	0.000	0.167	0.000
Virginia	0.784	0.506	0.511	0.993	0.808	0.797	0.423	0.937	0.485	0.340	0.222	0.000
Washington	0.855	0.923	0.718	0.971	0.695	0.736	0.998	0.860	0.694	1.000	0.862	0.000
West Virginia	0.690	0.350	0.675	1.000	0.868	0.936	0.320	0.470	0.998	0.000	0.000	0.000
Wisconsin	0.893	0.943	0.719	0.777	0.359	0.637	0.490	0.751	0.976	0.000	0.672	0.000
Wyoming	0.487	0.705	0.607	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 54 Rail Mode Ratio

D\O	LA/LB	Oakland	Seattle	Tacoma	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfport
Alabama	0.000	0.179	0.087	0.000	0.000	0.000	0.013	0.053	0.393	0.001	0.000	0.000
Arizona	0.027	0.007	0.052	0.000	0.003	0.000	0.000	0.000	0.564	0.000	0.000	0.000
Arkansas	0.012	0.289	0.000	0.000	0.002	0.000	0.377	0.000	0.145	0.348	0.000	0.000
California	0.003	0.022	0.044	0.393	0.011	0.000	0.060	0.115	0.234	0.838	0.062	0.000
Colorado	0.005	0.011	0.054	0.156	0.000	0.000	0.000	0.502	0.000	0.000	0.000	0.000
Connecticut	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.000
Delaware	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.649	0.000	0.000	0.000
District Columbia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Florida	0.002	0.002	0.000	0.000	0.000	0.000	0.002	0.005	0.008	0.037	0.005	0.000
Georgia	0.010	0.000	0.000	0.000	0.000	0.003	0.025	0.012	0.063	0.001	0.033	0.000

Idaho	0.001	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Illinois	0.042	0.160	0.023	0.000	0.008	0.000	0.007	0.047	0.138	0.003	0.000	0.000
Indiana	0.016	0.000	0.028	0.000	0.009	0.000	0.004	0.078	0.239	0.000	0.000	0.000
Iowa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.181	0.351	0.000	0.000	0.000
Kansas	0.001	0.000	0.008	0.000	0.066	0.000	0.000	0.000	0.281	0.000	0.000	0.000
Kentucky	0.001	0.000	0.000	0.000	0.021	0.000	0.000	0.000	0.007	0.000	0.000	0.000
Louisiana	0.001	0.000	0.008	0.000	0.010	0.000	0.095	0.000	0.009	0.000	0.000	0.000
Maine	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.614	0.859	0.000	0.365	0.000
Maryland	0.006	0.010	0.001	0.000	0.000	0.000	0.000	0.001	0.063	0.577	0.000	0.000
Massachusetts	0.032	0.000	0.013	0.000	0.000	0.000	0.082	0.129	0.942	0.000	0.000	0.000
Michigan	0.017	0.001	0.107	0.000	0.003	0.120	0.011	0.046	0.423	0.000	0.062	0.000
Minnesota	0.074	0.000	0.019	0.000	0.000	0.000	0.031	0.624	0.006	0.023	0.000	0.000
Mississippi	0.001	0.000	0.041	0.000	0.000	0.000	0.062	0.000	0.301	0.000	0.000	0.000
Missouri	0.009	0.006	0.108	0.000	0.000	0.000	0.013	0.000	0.090	0.000	0.000	0.000
Montana	0.000	0.063	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Nebraska	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
Nevada	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.104	0.000	0.000	0.000
New Hampshire	0.000	0.000	0.157	0.000	0.000	0.000	0.016	0.189	0.000	0.432	0.000	0.000
New Jersey	0.043	0.035	0.001	0.000	0.017	0.000	0.121	0.047	0.187	0.638	0.115	0.000
New Mexico	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.057	0.000	0.000	0.000
New York	0.040	0.001	0.001	0.000	0.000	0.000	0.067	0.004	0.042	0.000	0.115	0.000
North Carolina	0.042	0.331	0.000	0.000	0.001	0.000	0.061	0.012	0.063	0.463	0.003	0.000
North Dakota	0.000	0.000	0.130	0.000	0.000	0.000	0.000	0.722	0.000	0.000	0.000	0.000
Ohio	0.014	0.011	0.025	0.000	0.000	0.000	0.005	0.071	0.454	0.000	0.001	0.000
Oklahoma	0.000	0.000	0.004	0.000	0.012	0.000	0.000	0.000	0.018	0.000	0.000	0.000
Oregon	0.093	0.016	0.000	0.001	0.000	0.000	0.337	0.000	0.663	0.000	0.000	0.000
Pennsylvania	0.008	0.004	0.004	0.000	0.006	0.000	0.032	0.080	0.109	0.000	0.003	0.000
Rhode Island	0.000	0.002	0.000	0.000	0.000	0.000	0.412	0.000	0.567	0.556	0.000	0.000
South Carolina	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.007	0.312	0.000	0.001	0.000
South Dakota	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tennessee	0.006	0.000	0.007	0.000	0.000	0.001	0.071	0.004	0.213	0.000	0.000	0.000
Texas	0.043	0.011	0.085	0.074	0.033	0.003	0.004	0.258	0.072	0.467	0.006	0.000
Utah	0.000	0.001	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Vermont	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Virginia	0.018	0.306	0.000	0.000	0.002	0.000	0.025	0.001	0.453	0.456	0.140	0.000
Washington	0.010	0.001	0.006	0.023	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
West Virginia	0.000	0.488	0.000	0.000	0.000	0.035	0.000	0.530	0.000	0.000	0.000	0.000
Wisconsin	0.011	0.000	0.002	0.000	0.001	0.000	0.247	0.060	0.006	0.000	0.005	0.000
Wyoming	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

As mentioned in the previous step the FAF3 zone system consists of 123 freight analysis zones for freight assignment. Therefore, it is necessary that the O/D matrix will be rebuilt for states from the FAF3 zone system. In this step we use two kinds of factors to divide states to FAF3 zones. To begin we build an O/D matrix for freight volume assigned by truck mode then railway mode O/D matrix will be constructed next.

First of all, the total freight volume in the each state is evenly divided by number of FAF3 zones in the each state. As Table 6 shows each state consists of 1 or more zones. The freight volume in 2019 from LA/LB port to Alabama by truck, for example, is 138,626 tons. Also, Alabama consists of three zones, Birmingham AL, Mobile AL, and Remainder of Alabama. In this case, each freight volume from LA/LB port to each destination is 46,208.67 tons which is the result of total volume divided by 3. In this way, the first case O/D matrix is adjusted from original O/D pairs.

Table 55 Number of Zones in each State

State	No. of FAF3 zones	State	No. of FAF3 zones	State	No. of FAF3 zones
Alabama	3	Maine	1	Oklahoma	3
Arizona	3	Maryland	3	Oregon	2
Arkansas	1	Massachesettes	2	Pennsylvania	3
California	5	Michigan	3	RhO/De Island	1
Colorado	2	Minnesota	2	South Carolina	3
Connecticut	3	Mississippi	1	South Dakota	1
Delaware	1	Missouri	3	Tennessee	3
D.C	1	Montana	1	Texas	9
Florida	5	Nebraska	1	Utah	2
Georgia	3	Nevada	2	Vermont	1
Idaho	1	New Hampshire	1	Virginia	4
Illinois	3	New Jersey	3	Washington	2
Indiana	3	New Mexico	1	West Virginia	1
Iowa	1	New York	5	Wisconsin	2
Kansas	2	North Carolina	4	Wyoming	1
Kentucky	2	North Dakota	1		
Louisiana	4	Ohio	5		

In another case, each state`s volume is divided by population proportion. United States consists of a total of 3,143 counties including the District of Columbia. The county level of population data is collected from U.S Census (Census, 2013). Then the counties are aggregated from FAF3 zones. After the aggregation, total population is calculated by state and by FAF3 zone. For example (see Table 7), the total freight flow from LA/LB port to Illinois by truck is 1,449,318.6 tons. Total population of Illinois is 12,830,632 where population of Zone 171 (Chicago area) is 8,700,058, population of Zone 172 (St. Louis area) is 703,664, and population of Zone 179 (Remainder of Illinois) is 3,426,910. By using these values, each proportion for each state is computed. Finally, the freight volume to each zone is split into the proportions.

Table 56 Example of Adjusting O/D Matrix

O/D	Illinois			
LA/LB	1,449,318.6			
	Total	Zone 171	Zone 172	Zone 179
Illinois population	12,830,632	8,700,058	703,664	3,426,910
Proportion	100%	67.8%	5.5%	26.7%
Freight tonnage	1,449,318.6	982,738.5	79,484.3	387,095.8

4.0 Scenario Preparation

In the previous steps, we conducted two cases of adjusting the O/D matrix. The research regions are considered as two categories. The study categorizes all FAF3 zones and Midwest regions for the assignment model. As a result of these processes a total twelve scenarios are prepared for freight volume by truck assignment.

Table 57 Assignment Scenarios

Scenario	Year	Research subject regions	Proportion of State Freight Volume
1	2012	All FAF3 zones	State Volume / Numbers of FAF3 Zones in the State
2	2019		
3	2020		
4	2012	Midwest Regions	State Volume / Numbers of FAF3 Zones in the State
5	2019		
6	2020		
7	2012	All FAF3 zones	State Volume / Population Proportion
8	2019		
9	2020		
10	2012	Midwest Regions	State Volume / Population Proportion
11	2019		
12	2020		

5.0 Assignment of Truck Freight Flow

In this project, single matrix equilibrium using time methodology is used. Firstly, link travel time is calculated and added to each link. Speed limit data and link distance were prepared in the previous step. Using the databases link travel time is calculated by CUBE. Then, based on the prepared network, the freight volume by truck is assigned using the computer link travel time.

The output of the freight assignments are illustrated as Figures 3 to 14.

Figure 39 Result of Scenario 1: Truck Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Number of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

Figure 40 Result of Scenario 2: Truck Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Number of FAF3 Zones in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

Figure 41 Result of Scenario 3: Truck Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Number of FAF3 Zones in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

Figure 42 Result of Scenario 4: Truck Assignment (2012), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal and before Prince Rupert expansion.

Figure 43 Result of Scenario 5: Truck Assignment (2019), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal, but before Prince Rupert expansion.

Figure 44 Result of Scenario 6: Truck Assignment (2020), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal and Prince Rupert expansion.

Figure 45 Result of Scenario 7: Truck Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

Figure 46 Result of Scenario 8: Truck Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

Figure 47 Result of Scenario 9: Truck Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

Figure 48 Result of Scenario 10: Truck Assignment (2012), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

Figure 49 Result of Scenario 11: Truck Assignment (2019), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

Figure 50 Result of Scenario 12: Truck Assignment (2020), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

6.0 Assignment of Railroad Freight Flow

For the railroad assignment step zone connectors are set up so that distance is zero with some assumptions. There are two major routes connecting the port of Prince Rupert, Canada and the United States. One is the route via the Washington state border and the other route is via the North Dakota border. The railroad network database provided by nationalatlas.org does not include railroads in Canadian territory. Also, the exact distance information of railroad from the port of Prince Rupert to United States is not provided by any reputable organizations. Canadian territory consists of mountainous areas, however, large amounts of railways run parallel with roadways. If we assume that the distance of the railroad and the distance of the roadway are same between origin and destination then the distance between Prince Rupert port and the Washington state border is approximately 912 miles and the distance between Prince Rupert port and the North Dakota state border is approximately 1,533 miles. In addition, the distance between the borders of Washington and North Dakota is approximately 1,300 miles. So, we can assume that there is no freight flow from Prince Rupert to east of Mississippi river regions via Seattle or Washington state. Also, it is expected that freight volume from the port of Prince Rupert would tend to use Canadian National railway service. Therefore, we assume that the distance of zone connectors do not affect the freight volume assignment and only the distance of railroads in the United States would affect the assignment.

A total of twelve scenarios are prepared for the assignment step. The scenarios are built using the same methodologies as freight O/D matrix by truck. Also, the assignment method is same with the truck mode. The output of the freight assignments are illustrated is Figure 15 through 26.

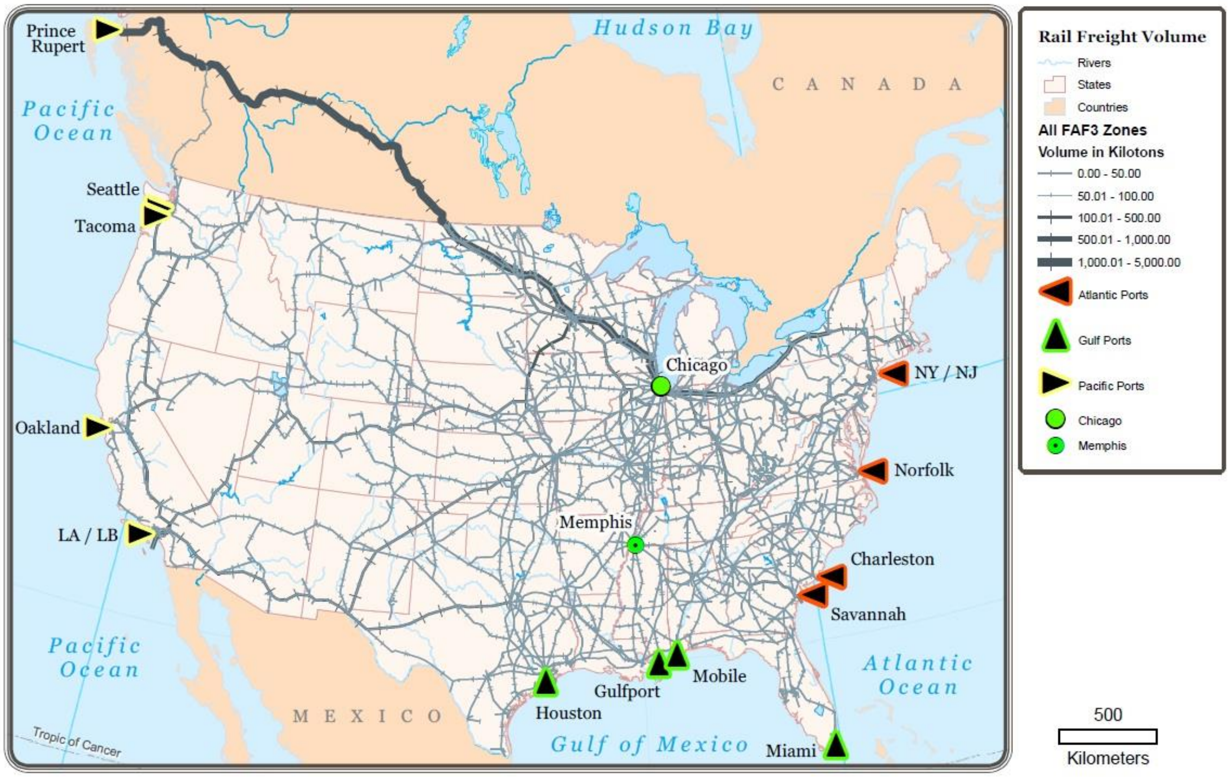


Figure 51 Result of Scenario 1: Railroad Assignment (2012), All Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

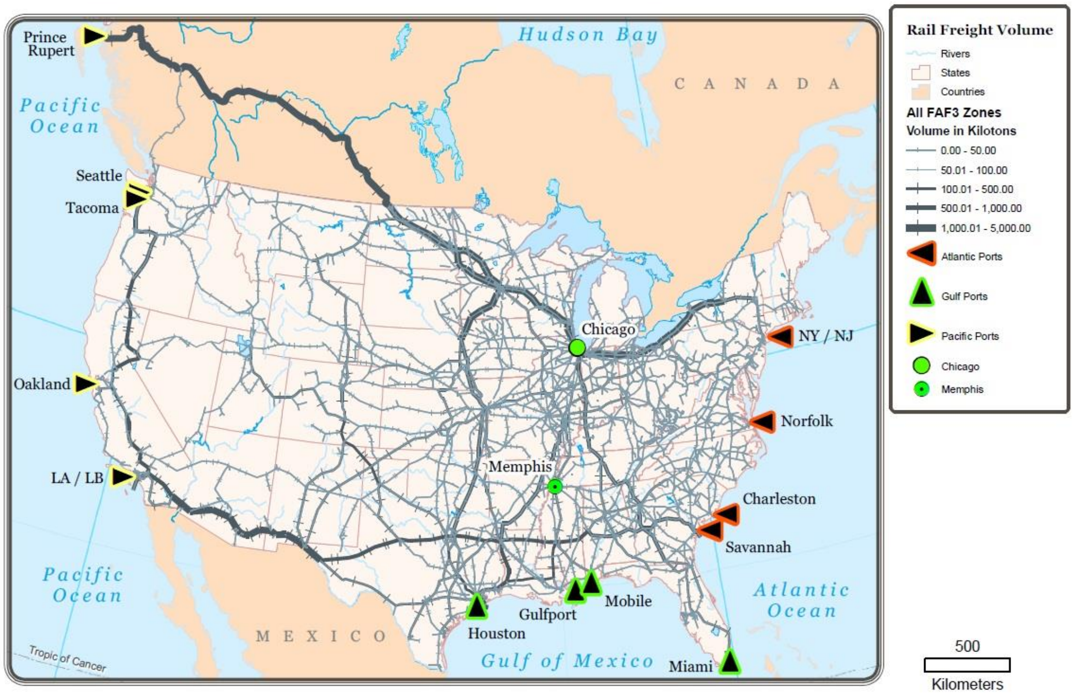


Figure 52 Result of Scenario 2: Railroad Assignment (2012), All Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

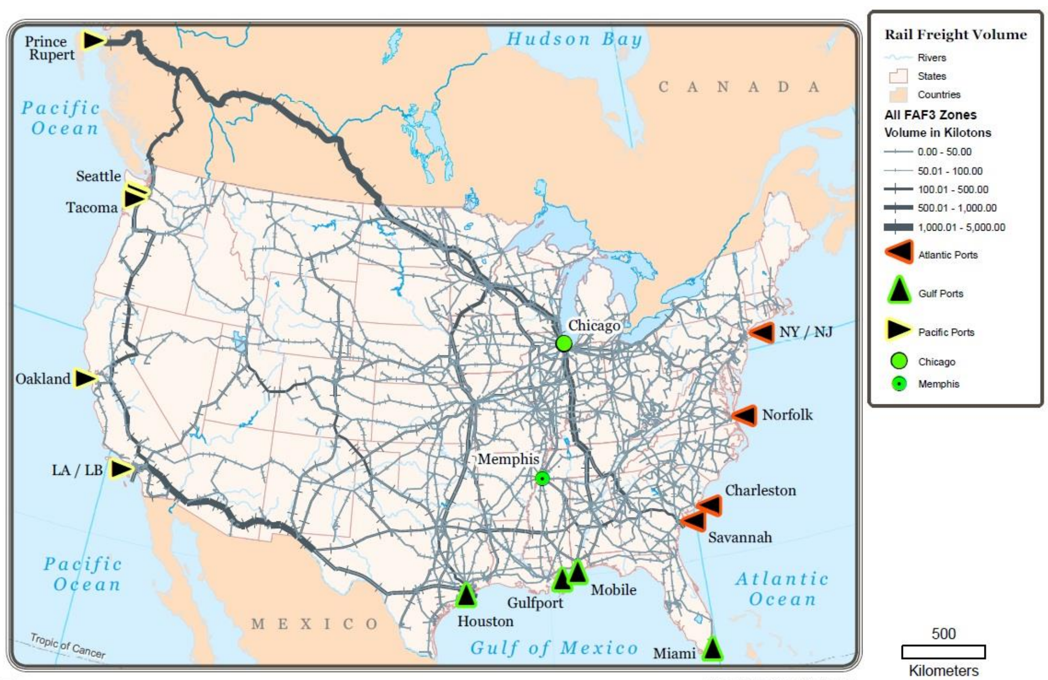


Figure 53 Result of Scenario 3: Railroad Assignment (2020), All Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

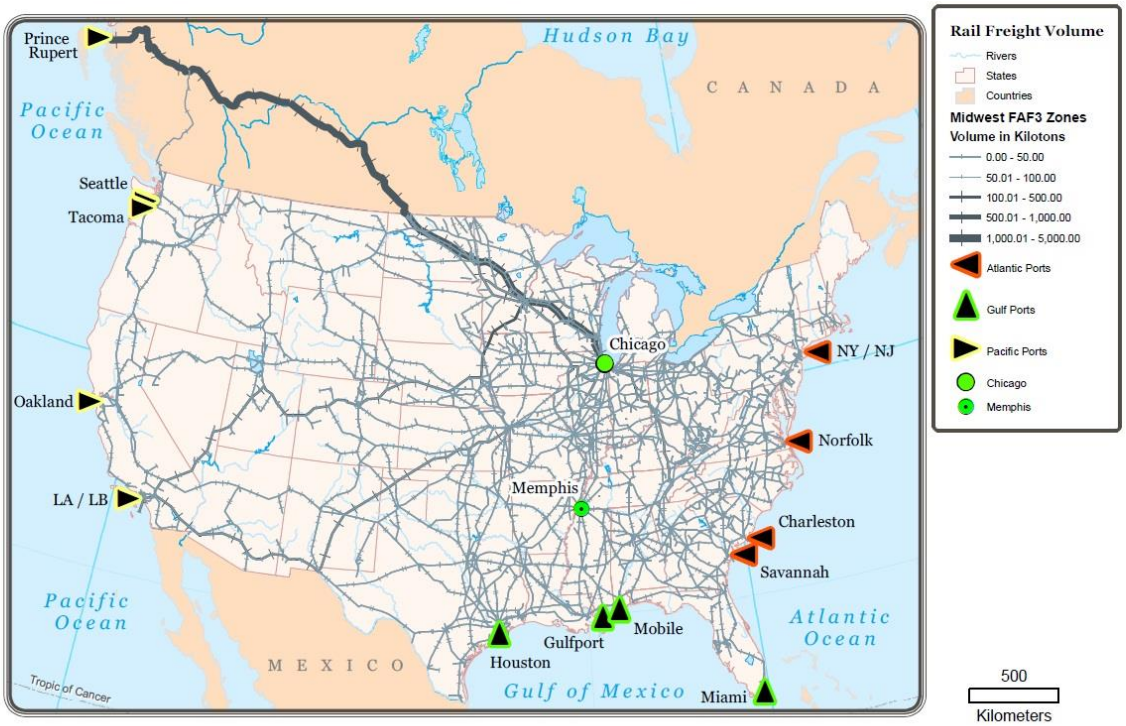


Figure 54 Result of Scenario 4: Railroad Assignment (2012), Midwest Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

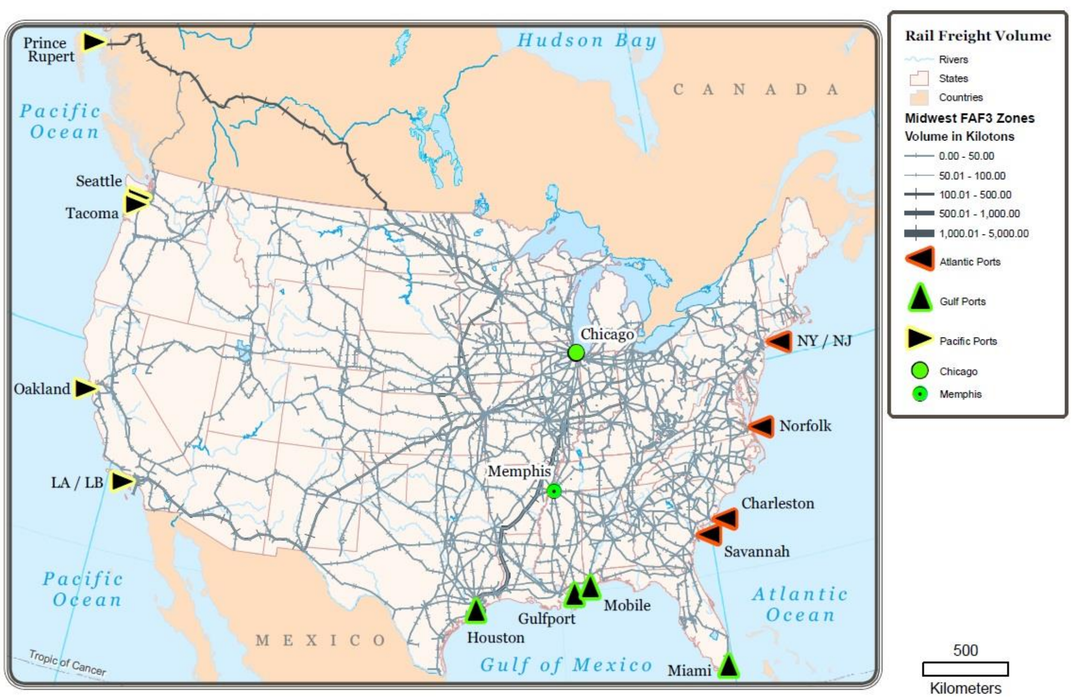


Figure 55 Result of Scenario 5: Railroad Assignment (2019), Midwest Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

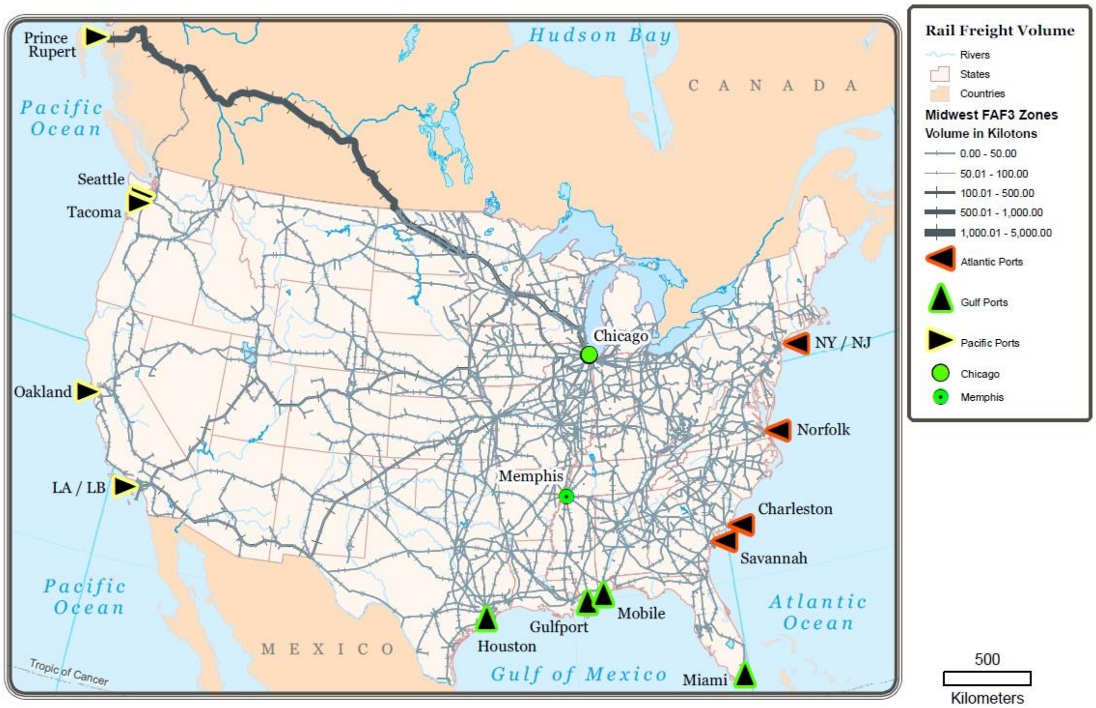


Figure 56 Result of Scenario 6: Railroad Assignment (2020), Midwest Freight Analysis Framework [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in Each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

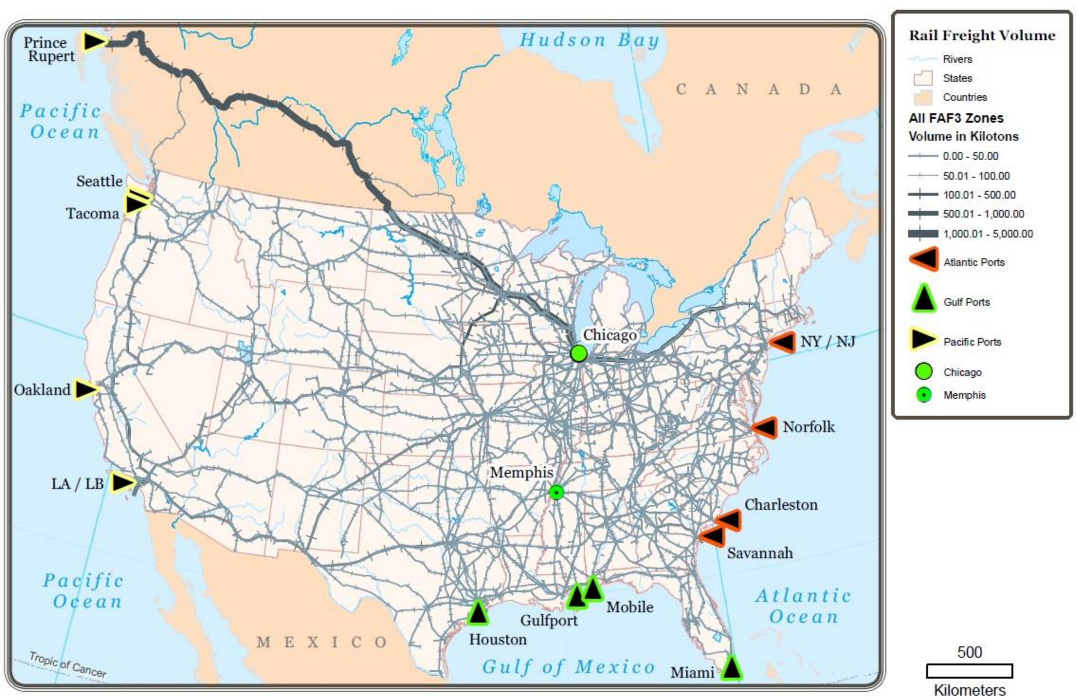


Figure 57 Result of Scenario 7: Railroad Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

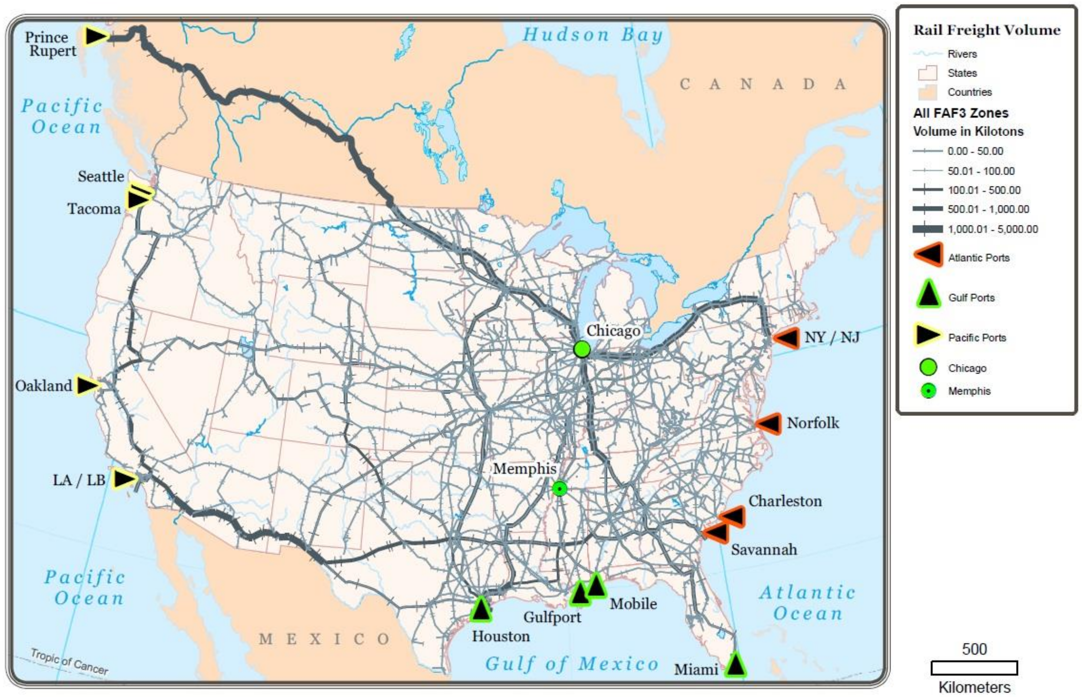


Figure 58 Result of Scenario 8: Railroad Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

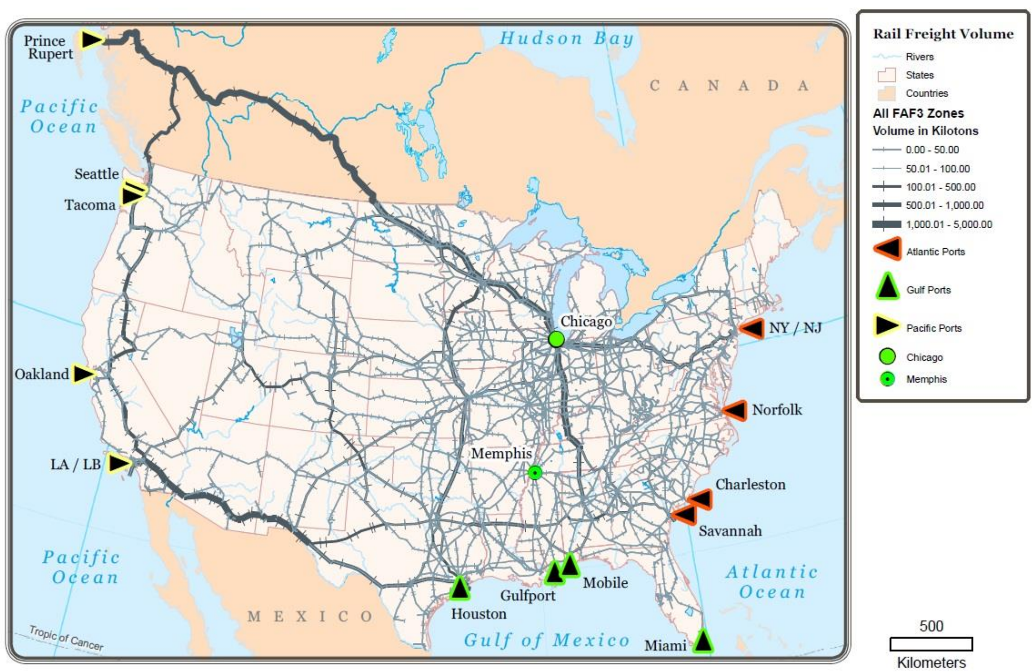


Figure 59 Result of Scenario 9: Railroad Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

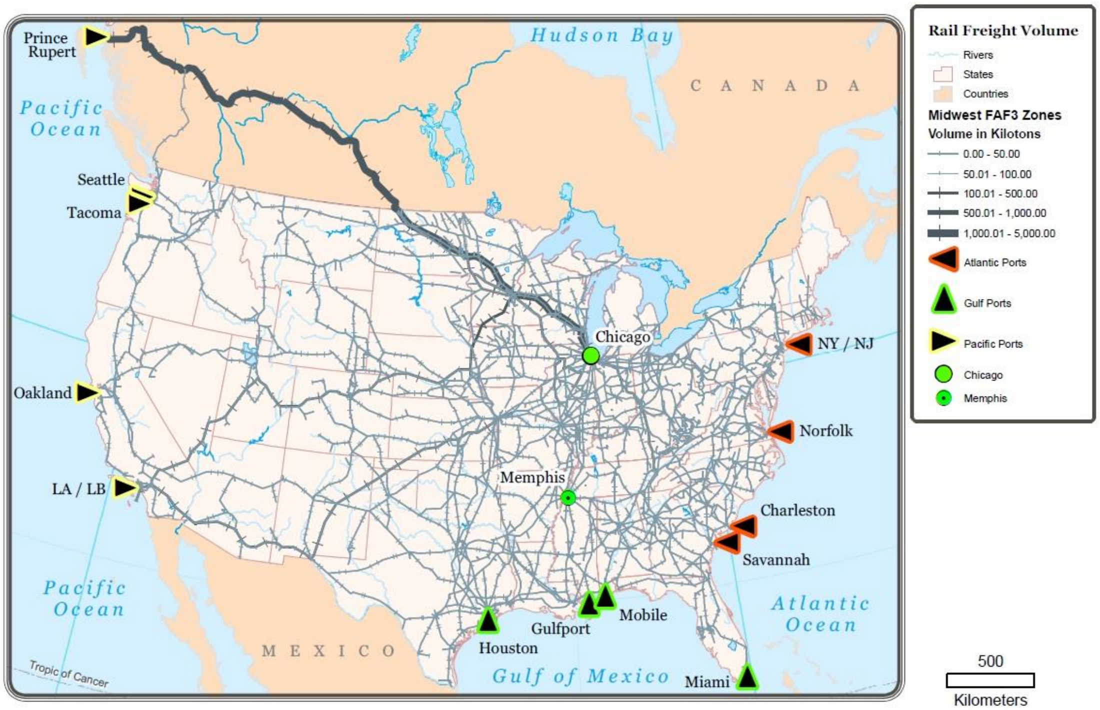


Figure 60 Result of Scenario 10: Railroad Assignment (2012), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

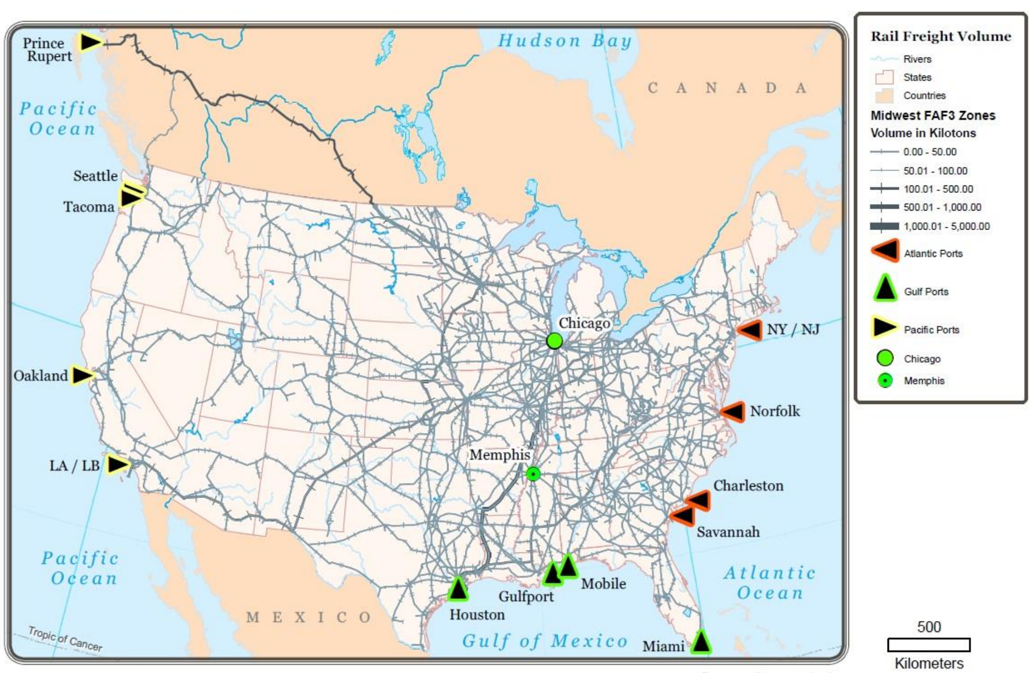


Figure 61 Result of Scenario 11: Railroad Assignment (2019), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

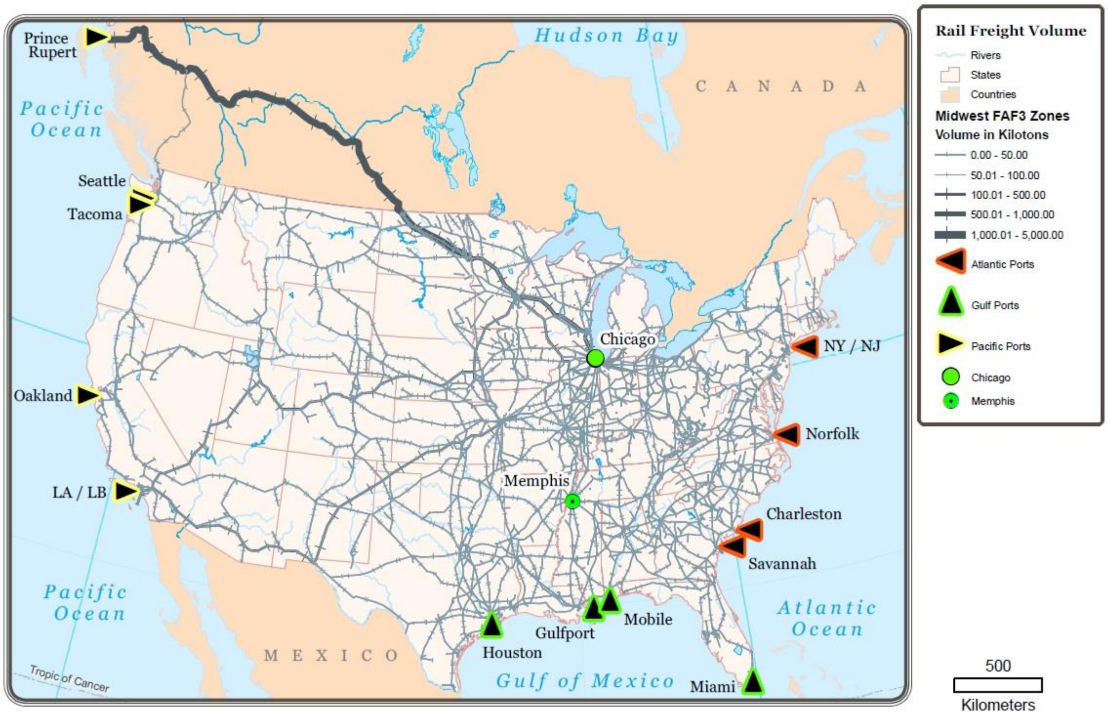


Figure 62 Result of Scenario 12: Railroad Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

7.0 Conclusion

This research contributes to freight assignment as it describes the estimation of freight flow at the FAF3 zones using various scenarios. The FAF3 zone system and additional 13 international ports are built for the assignment task. The O/D tables are also modified to meet the developed zone system. As a result of the task, the Figure 3 to 26 show the results of the assignments for freight flow with regard to the expansion projects. Large amount of freight volume from Asia is diverted from ports at west coast to east and gulf coast in 2019 after the Panama Canal expansion. In addition, the freight volume directly arrived to U.S is also diffused to Prince Rupert port after the port expansion in 2020.

As mentioned above, this task focuses on the freight assignment of volumes of tons rather than number of trucks or railway carriages. Assignment of truck trips or rail trips can be performed using trip O/D tables that can be converted from the volume O/D tables by using the conversion factors provided by FHWA. However, the estimated O/D table in this research consists of total volume of all of commodity flow instead of each commodity flow. The traffic counts for further research are added in this network database. If each commodity flow O/D table would be estimated, the assignment of trips can be performed, as well as analysis of congestion or bottleneck due to the expansion project can be accomplished.

References

1. Census, U. (2013, Sep. 10). *AMERICAN FactFinder*. Retrieved from United States Census Bureau: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

2. Southworth, F., Davidson, D., Hwang, H.-L., & Peterson, B. E. (2010). *The Freight Analysis Framework, Version 3: Overview of the FAF3 Naitonal Freight Flow Tables.* FHWA.

CHAPTER 6: VISUALIZATION VIA GIS MODELING

1.0 Introduction

This chapter presented visualizations (maps) from the models run in transportation network modeling, economic development modeling, and the dynamic website; and developing a GIS model to identify areas in the CFIRE region that are in need of new or expanded intermodal transportation networks.

2.0 Visualization Process for GIS Modeling

Transportation network modeling generated spatial data using the FAF3 zone system. The responsibility of the Geographic Information Technology Laboratory (GITL) and the Department of Geography and Geology at the University of Southern Mississippi (Southern Miss) was to gather the data from transportation network modeling and create visualizations of the data. Data received from the Civil and Environmental Engineering (CEE) Department at the University of Alabama in Huntsville was in World Geographic Standard 1984 (WGS84) projection utilizing coordinate degrees for spatial data control. The GITL projected all data to Albers Equal Area Conic Projection with standard lines of 29.5 and 45.5 °N and a central Meridian of 90 °W. This projection was chosen to minimize distance distortions found in the WGS84 coordinate system. Further the GITL included the detailed Canadian rail and road network and assigned the spatial data as per the calculations from the Geographic Information System (GIS) model from CEE. These 24 visualizations can be seen throughout transportation network modeling's report (Figures 1 and 2).

3.0 GIS Model and Visualization Process for Economic Development Modeling

The GIS model evaluated the information produced in transportation network modeling concerning truck and rail transportation volume changes that are likely to occur after the 2019 opening of the Panama Canal and then the 2020 expansion of the Prince Rupert Port in Canada. The focus of the model identified areas where there was a large increase in volume by rail and truck in an area that had intersections of major freight routes inside the CFIRE region.

The model gathered all cities recognized in the USA from The model identified the existing intermodal locations for all of the USA using information from the Department of Transportation. The model utilized the rail and highway network identified in transportation network modeling. Using Environmental Systems Research Institute (ESRI) ArcGIS INFO 10.2, distance calculations were performed to identify all cities within 5 miles of a main rail and mail highway route utilized by the affected freight routes. The model eliminated any existing, larger intermodal points to focus on smaller areas that can be created or expanded by filtering the results to only look at cities with less than 100,000 in population. The model then ran analysis to identify city centers that were on either major rail or major road networks with the largest increases in freight traffic. The model was run on each of the possible scenarios from transportation network modeling (Tables 1-4).

A master list was created with all possible intermodal points that met the model's criteria including a count of all times that the city fell within the highest probability of an intermodal location in each of the given scenarios (Table 5). The top candidates for intermodal facilities were then sent to task 6 for further analysis and confirmation. The GITL projected all data to Albers Equal Area Conic Projection with standard lines of 29.5 and 45.5 °N and a central Meridian of 90 °W and delivered the 12 visualization to task 6 showing the key locations to be included into task 6's reports. The 12 intermodal scenarios were turned into visualizations for task 6 to ascertain feasibility of expansion to the locations revealed by transportation network modeling (Figures 3-14).

4.0 Visualization Process for Website

Transportation network modeling was to create all maps for the website, https://www.usm.edu/logistics-trade-transportation/ri-6-run-scenarios. The maps produced above were included on the website along with the 6 Freight Distribution Scenarios focused on the total freight expected to enter the main East, West, and Gulf ports as they traveled to Memphis, TN or Chicago, IL. Three visualizations were made for each of the 3 regions and each of the 6 scenarios for a total of 18 maps. The visualizations were divided up into the western region (Los Angeles/ Long Beach, CA; Oakland, CA; Seattle, WA; Tacoma, WA), eastern region (New York/ New Jersey; Norfolk, VA; Savannah, GA), and gulf region (Houston, TX; Gulfport, MS; Mobile, AL; Miami, FL). The visualizations showed the freight in kilotonnes coming into the ports as of 2012 and the freight from those ports that went to Memphis, TN and Chicago, IL. The subsequent series maps showed the percent change of volume of freight expected by 2020 after the Panama Canal and Prince Rupert expansions through the 3 scenarios for the interactive website (Figures 15-23).

5.0 Tables and Figures:

Table 1: All FAF Zones by state volume/ number of FAF Zones per state.

All FAF	All FAF	ALL FAF
	State Volume / Numbers	
2012	2019	2020
Result 1	Result 2	Result 3
Fargo, ND	Fargo, ND	Fargo, ND
Joplin, MO	Meridian, MS	Joplin, MO
Meridian, MS	Farragut, TN	Meridian, MS
Belleview, IA	Goodlettsville, TN	Farragut, TN
Farragut, TN	Prattville, AL	Goodlettsville, TN
Goodlettsville, TN	East Ridge, TN	Prattville, AL
St. Cloud, MI	Terre Haute, IN	East Ridge, TN
Prattville, AL	Effingham, IL	Terre Haute, IN
	Hattiesburg, MS	Frankfort, KY

Table 2: Midwest FAF Zones by state volume/ number of FAF Zones per state.

Midwest FAF	Midwest FAF	Midwest FAF
	State Volume / Numbers	
2012	2019	2020
Result 4	Result 5	Result 6
Fargo, ND	Fargo, ND	Fargo, ND
	Joplin, MO	Joplin, MO
	Meridian, MS	Belleview, IA
	Belleview, IA	La Crosse, WI
	Effingham, IL	
	Mount Vernon, IL	

Table 3: All FAF Zones by state volume/ population portion per state.

All FAF	All FAF	ALL FAF
	State Volume/ Population Proportion	
2012	2019	2020
Result 7	Result 8	Result 9
Joplin, MO	Fargo, ND	Fargo, ND
Meridian, MS	Joplin, MO	Joplin, MO

Belleview, IA	Meridian, MS	Meridian, MS
St. Cloud, MI	Belleview, IA	Farragut, TN
	Farragut, TN	Goodlettsville, TN
	Goodlettsville, TN	St. Cloud, MI
	ST. Cloud, MI	Prattville, AL
	Prattville, AL	East Ridge, TN
	East Ridge, TN	Terre Haute, IN
	Terre Haute, IN	Jacksonville, IL
	Hattiesburg, MS	
	Cambridge, OH	

Table 4: Midwest FAF Zones by state volume/ population portion per state.

Midwest FAF	Midwest FAF	Midwest FAF
	State Volume/ Population Proportion	
2012	2019	2020
Result 10	Result 11	Result 12
Fargo, ND	Joplin, MO	Fargo, ND
Joplin, MO	Meridian, MS	Joplin, MO
Belleview, IA	Belleview, IA	Goodlettsville, TN
Farragut, TN	Effingham, IL	St. Cloud, MI
St. Cloud, MI		East Ridge, TN

Table 5: The list of cities that met the model's criteria and number of times the city met the criteria in the 12 scenarios created in task 4.

Intermodal Point	Counts
Fargo, ND	10
Joplin, MO	10
Meridian, MS	8
Belleview, IA	7
Farragut, TN	6
Goodlettsville, TN	6
ST. Cloud, MI	6
Prattville, AL	5
East Ridge, TN	5
Terre Haute, IN	4
Effingham, IL	3
Hattiesburg, MS	2
Frankfort, KY	1

Mount Vernon, IL	1
La Crosse, Wi	1
Cambridge, OH	1
Jacksonville, IL	1

Figure 1

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State 2020

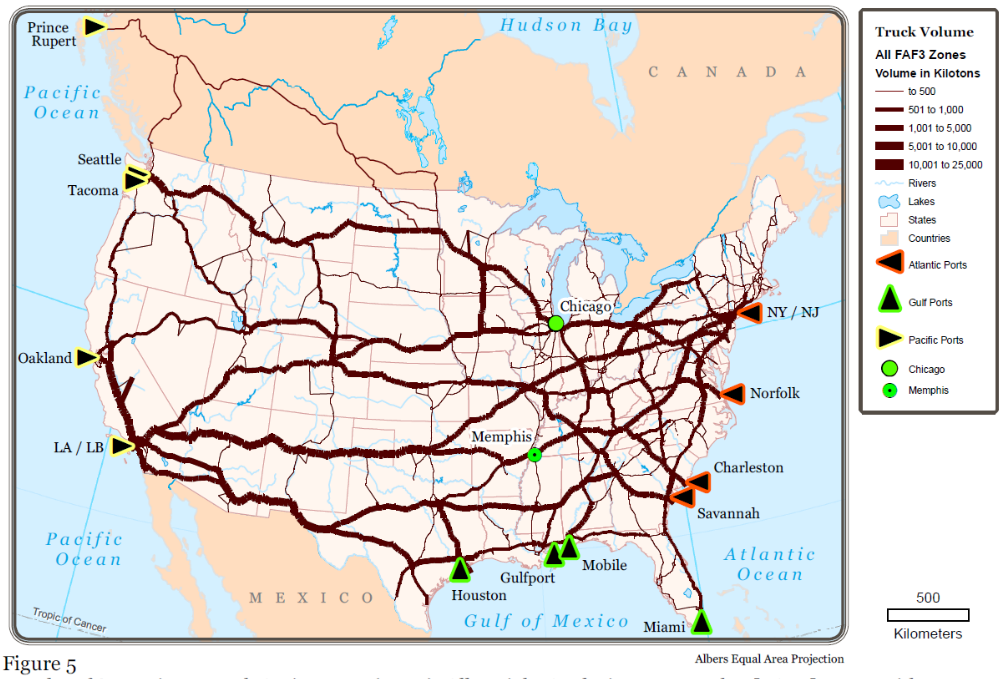


Figure 5
Results of Scenario 3: Truck Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

Figure 2

All FAF3 Zones: Volume/ Population Proportion by State

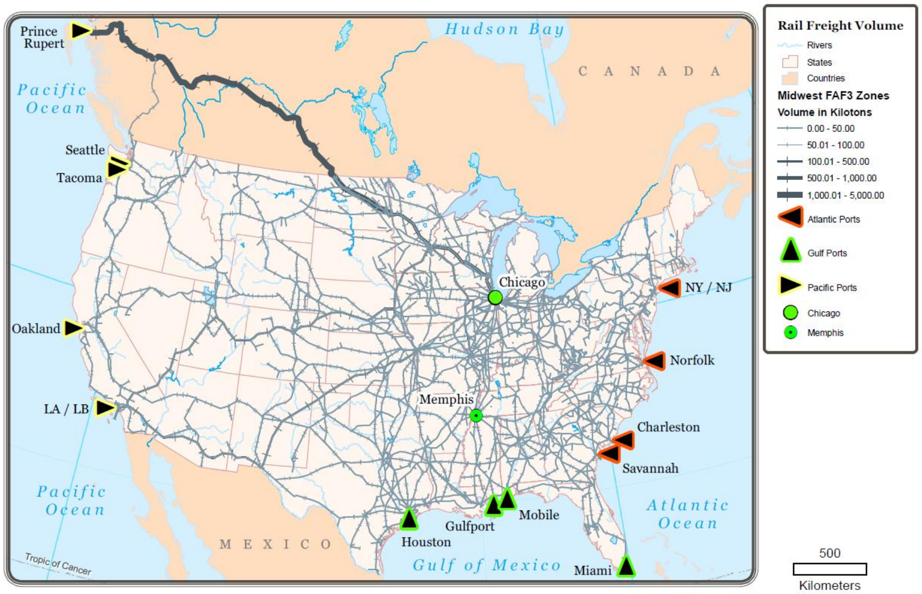
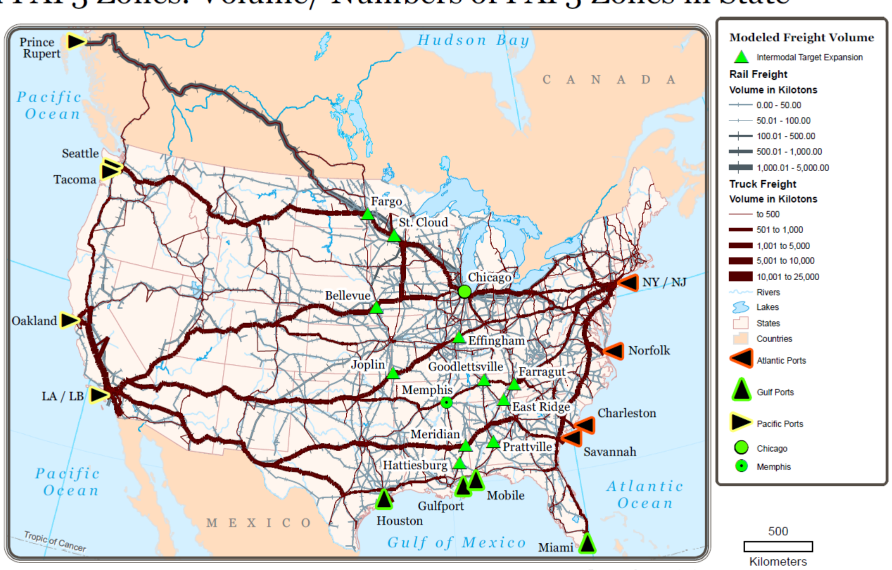


Figure 20
Results of Scenario 6: Freight Assignment (2020), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

Figure 3

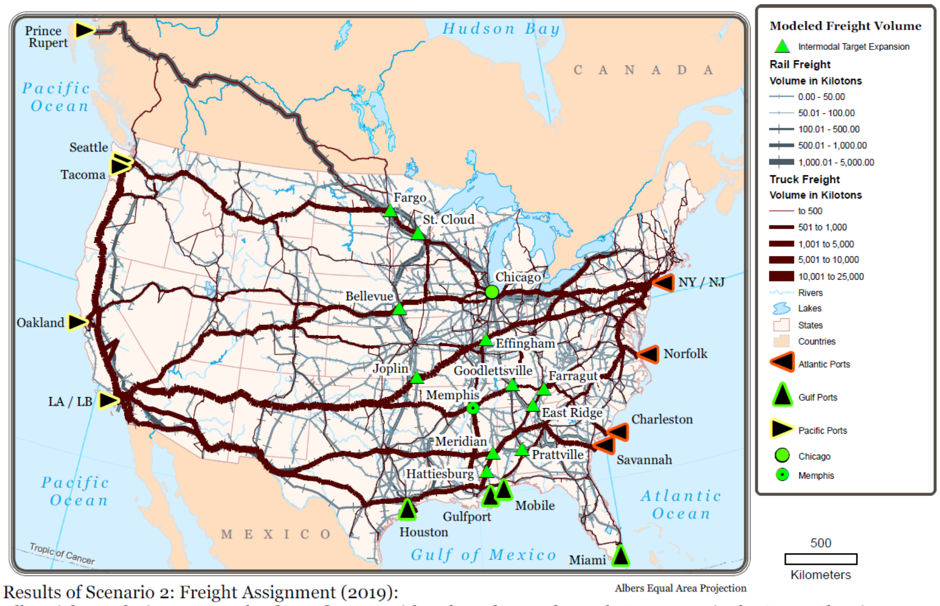
All FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 1: Freight Assignment (2012):
All Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 4

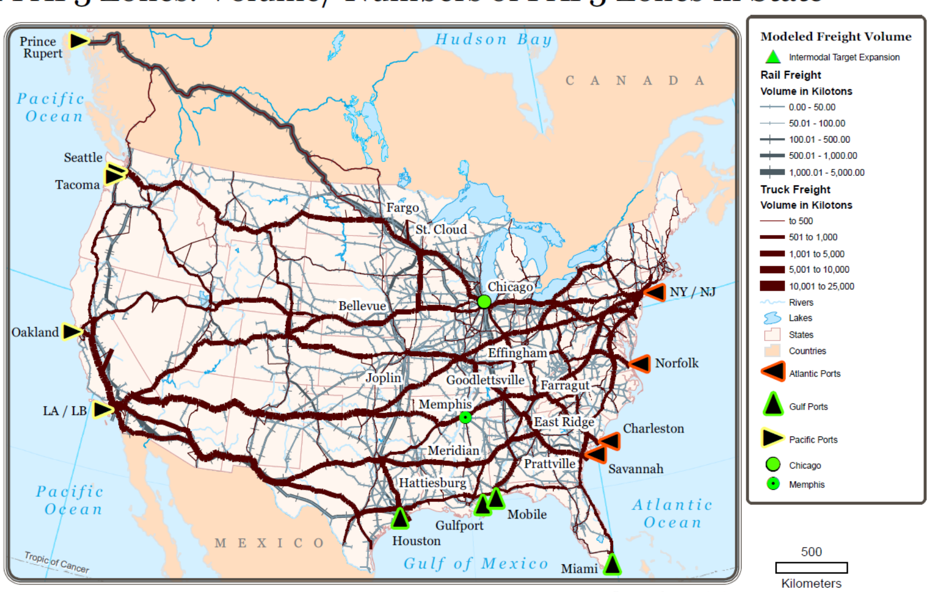
All FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 2: Freight Assignment (2019):
All Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 5

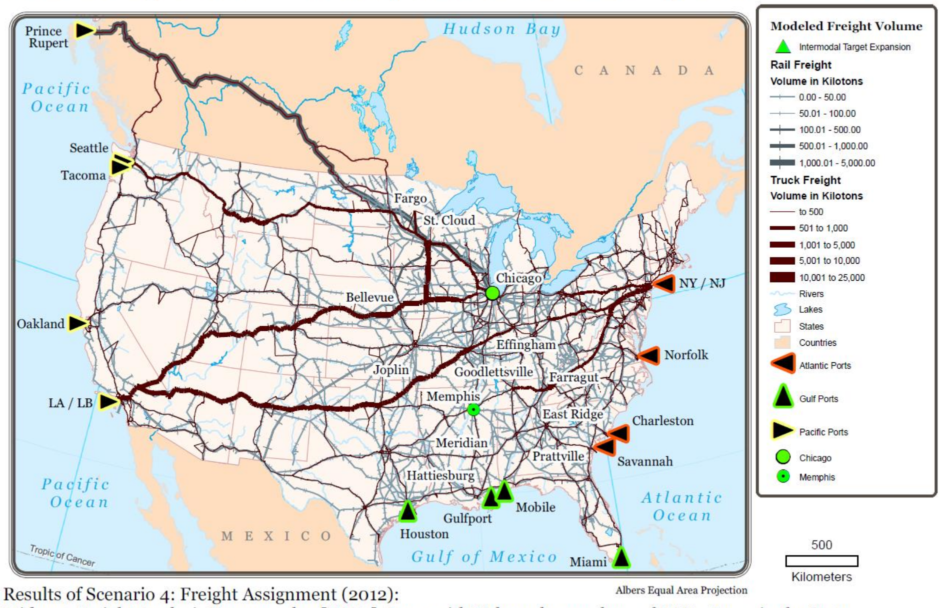
All FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 3: Freight Assignment (2020):
All Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 6

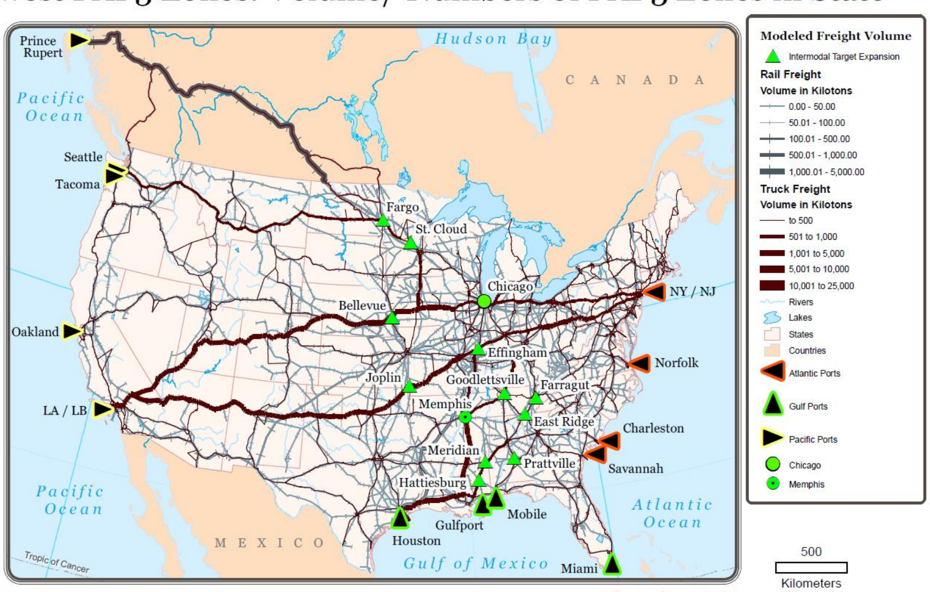
Midwest FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 4: Freight Assignment (2012):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 7

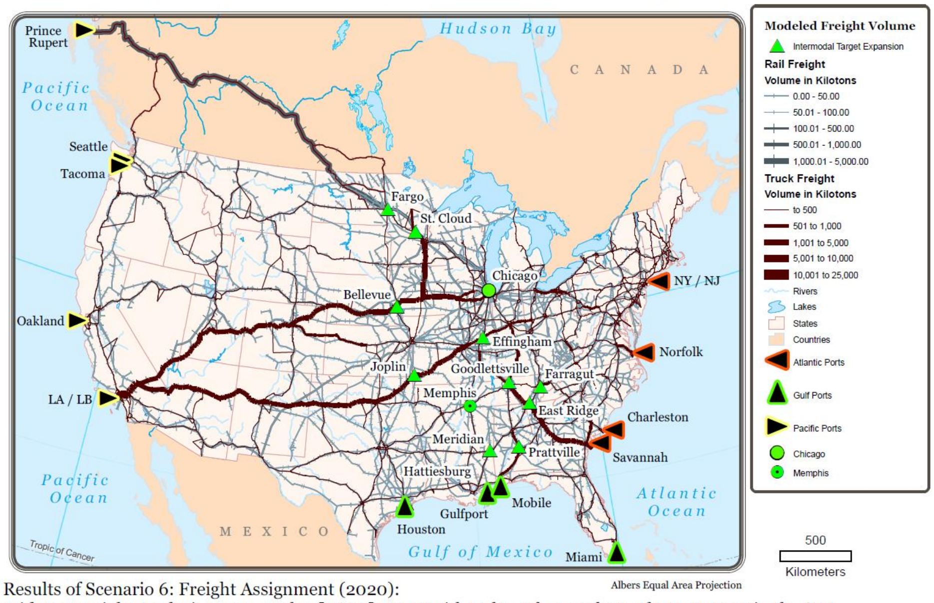
Midwest FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 5: Freight Assignment (2019):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 8

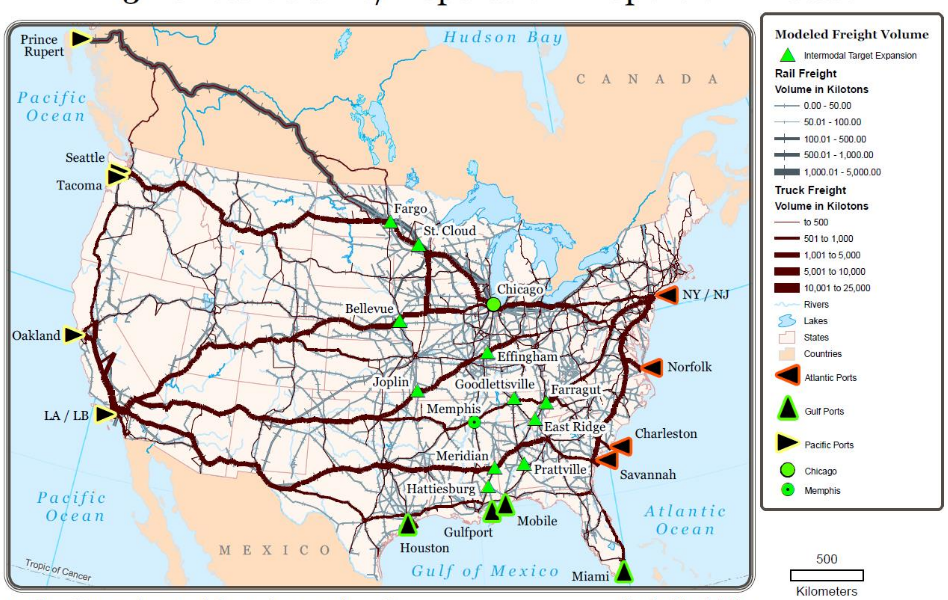
Midwest FAF3 Zones: Volume/ Numbers of FAF3 Zones in State



Results of Scenario 6: Freight Assignment (2020):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

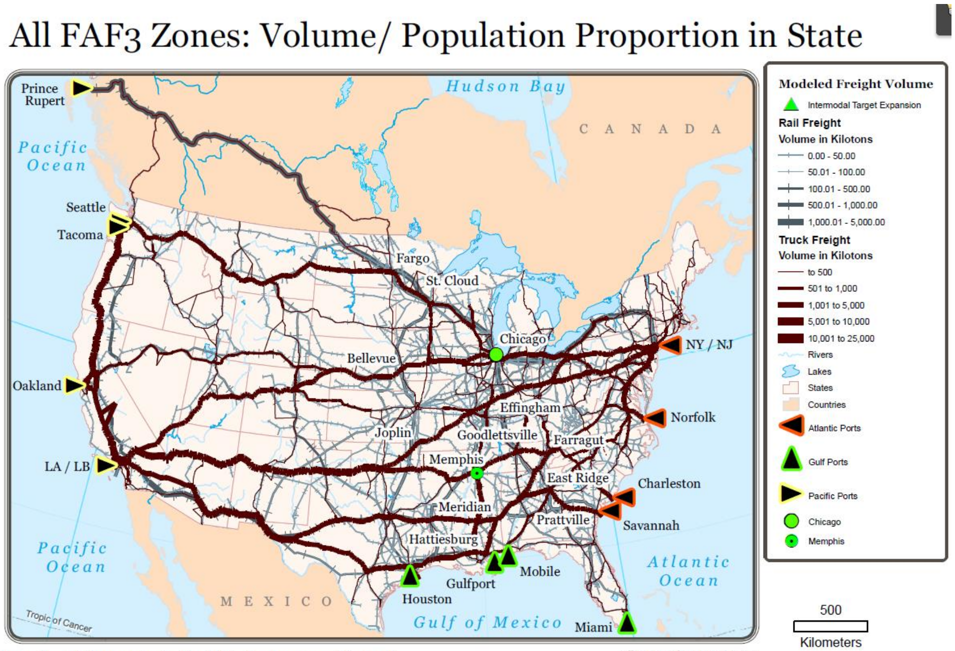
Figure 9

All FAF3 Zones: Volume/ Population Proportion in State



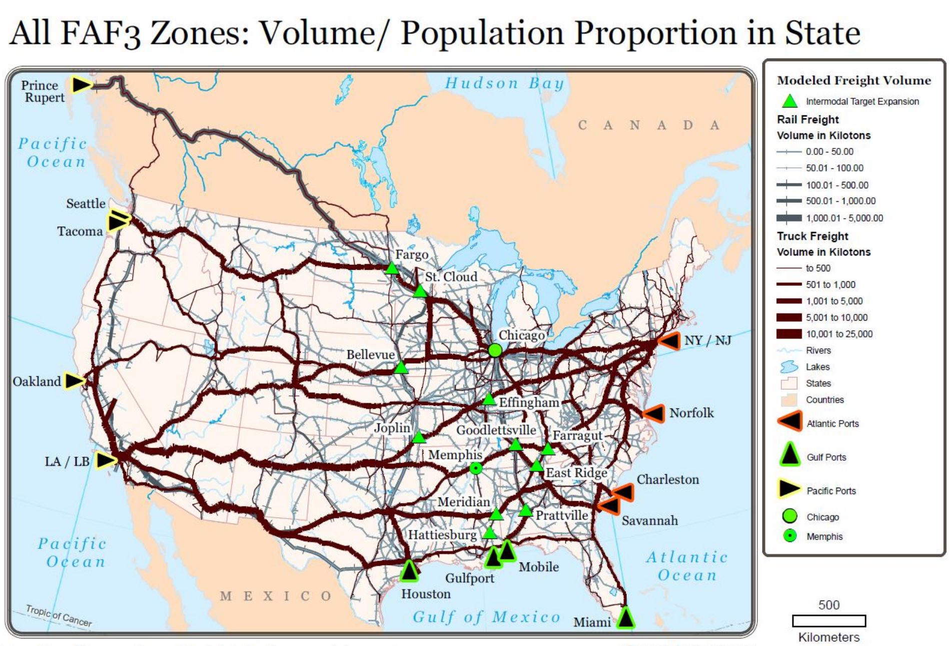
Results of Scenario 7: Freight Assignment (2012):
All Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 10



Results of Scenario 8: Freight Assignment (2019):
All Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

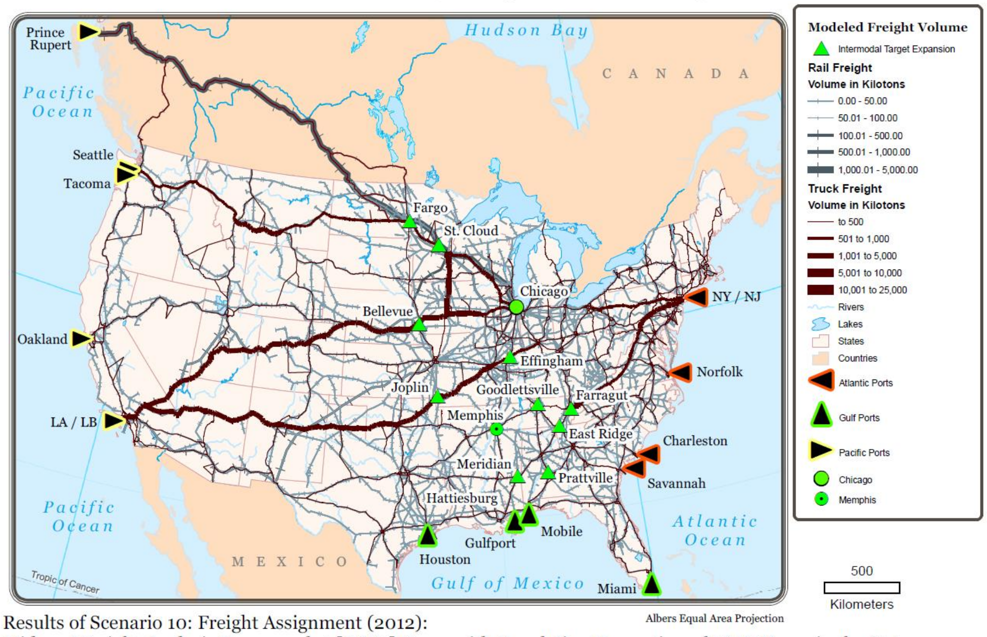
Figure 11



Results of Scenario 9: Freight Assignment (2020):
All Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 12

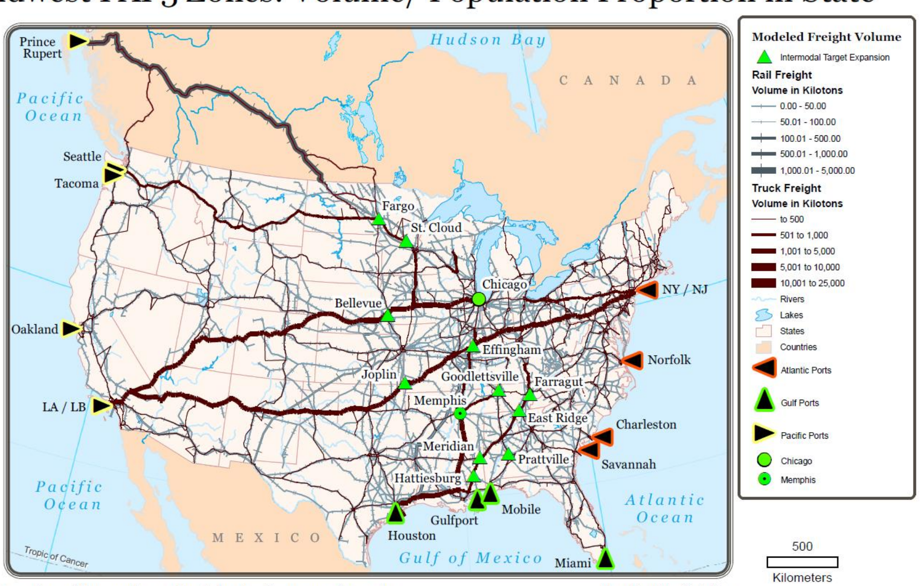
Midwest FAF3 Zones: Volume/ Population Proportion in State



Results of Scenario 10: Freight Assignment (2012):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 13

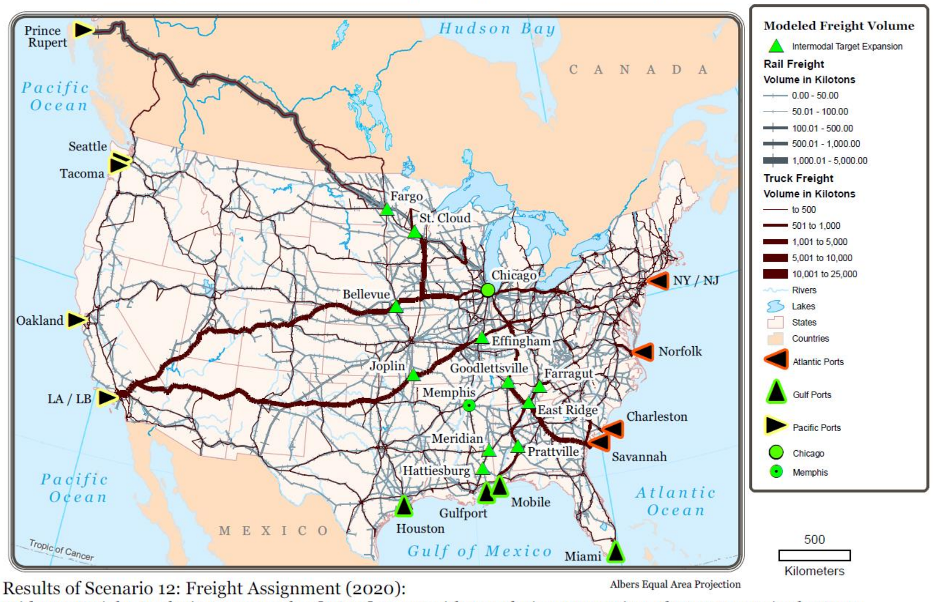
Midwest FAF3 Zones: Volume/ Population Proportion in State



Results of Scenario 11: Freight Assignment (2019):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 14

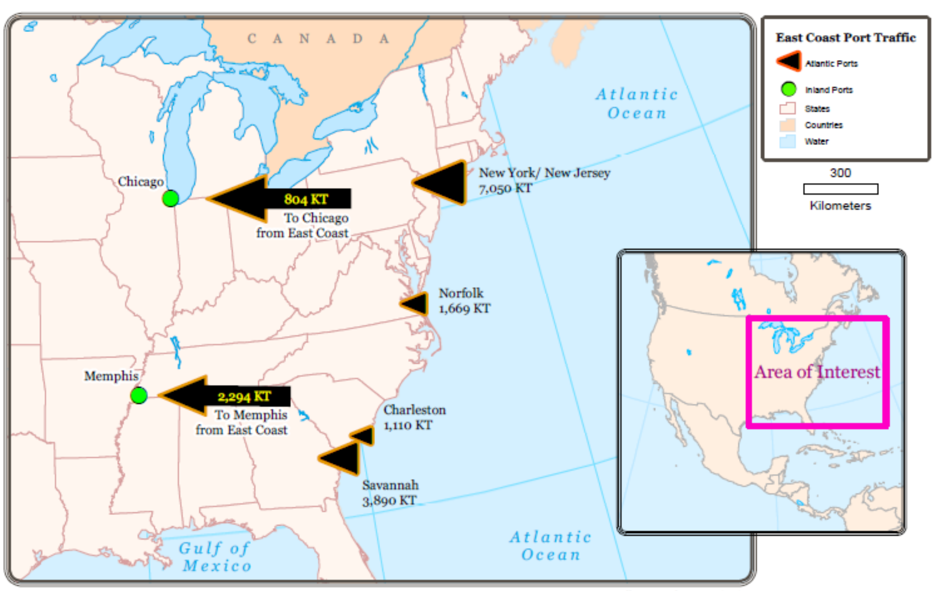
Midwest FAF3 Zones: Volume/ Population Proportion in State



Results of Scenario 12: Freight Assignment (2020):
Midwest Freight Analysis Framework 3 [FAF3] Zones with Population Proportion of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 15

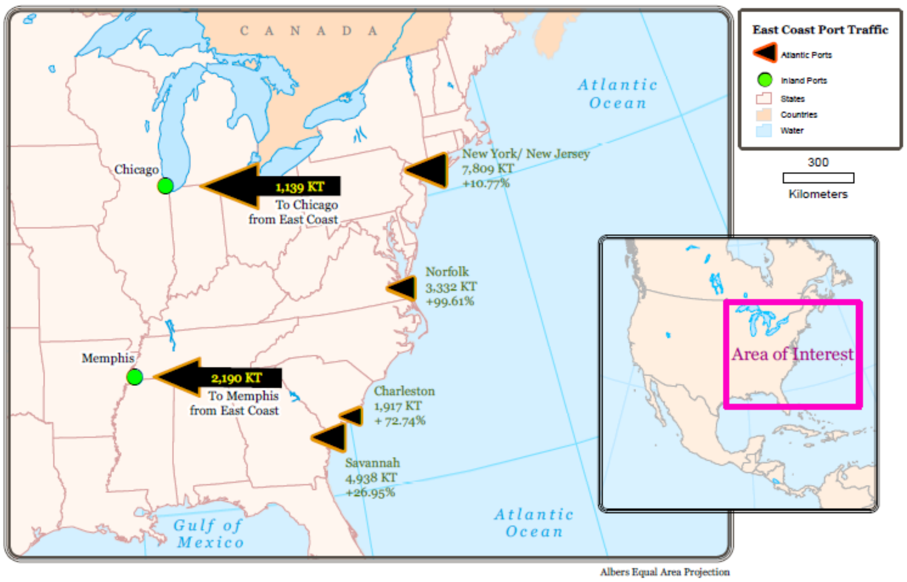
East Coast Port Freight Volume 2012



Freight volume in 2012 to the East Coast Ports = 13,718.91 Kilotons
New York/ New Jersey at 7,049.58; Norfolk, VA at 1,669.34; Charlestion, NC at 1,109.99; and Savannah, GA at 3,890.00.

Figure 16

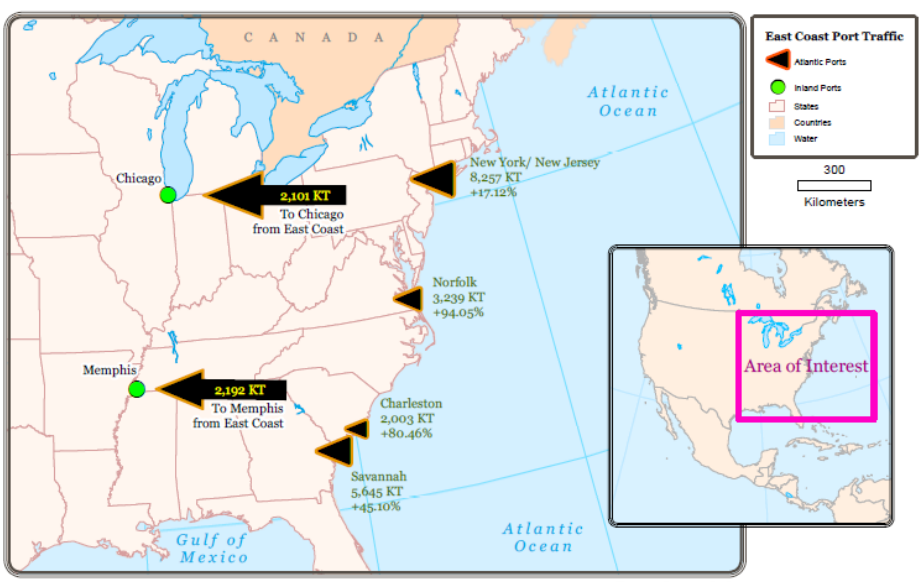
East Coast Port Freight Volume 2019



Freight volume in 2019 to the East Coast Ports = 13,718.91 Kilotons (+31.18% from 2012) New York/ New Jersey at 7,808.70; Norfolk, VA at 3,332.12; Charlestion, NC at 1,917.39; and Savannah, GA at 4,938.41.

Figure 17

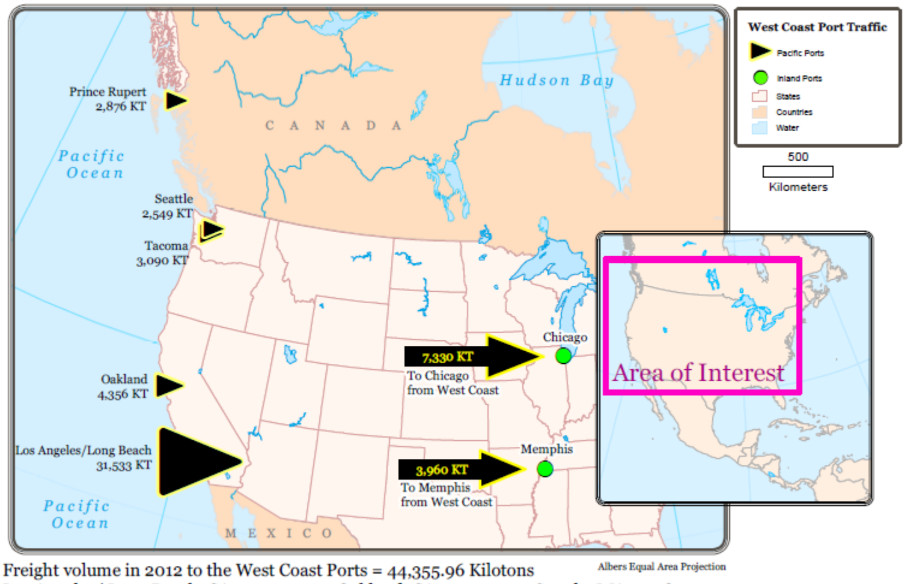
East Coast Port Freight Volume 2020



Freight volume in 2020 to the East Coast Ports = 19,143.75 Kilotons (+39.54% from 2012) New York/ New Jersey at 8,256.76; Norfolk, VA at 3,239.37; Charlestion, NC at 2,003.06; and Savannah, GA at 5,644.57.

Figure 18

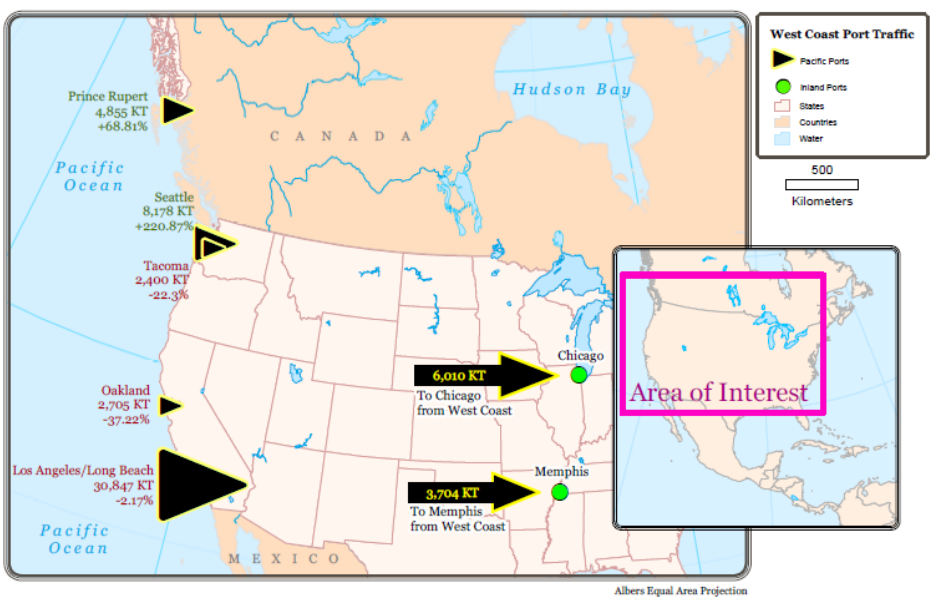
West Coast Port Freight Volume 2012



Freight volume in 2012 to the West Coast Ports = 44,355.96 Kilotons
Los Angeles/ Long Beach, CA at 31,532.55; Oakland, CA at 4,309.15; Seattle, WA 2,548.75; Tacoma, WA at 3,089.69; and Prince Rupert, BC at 2,875.83.

Figure 19

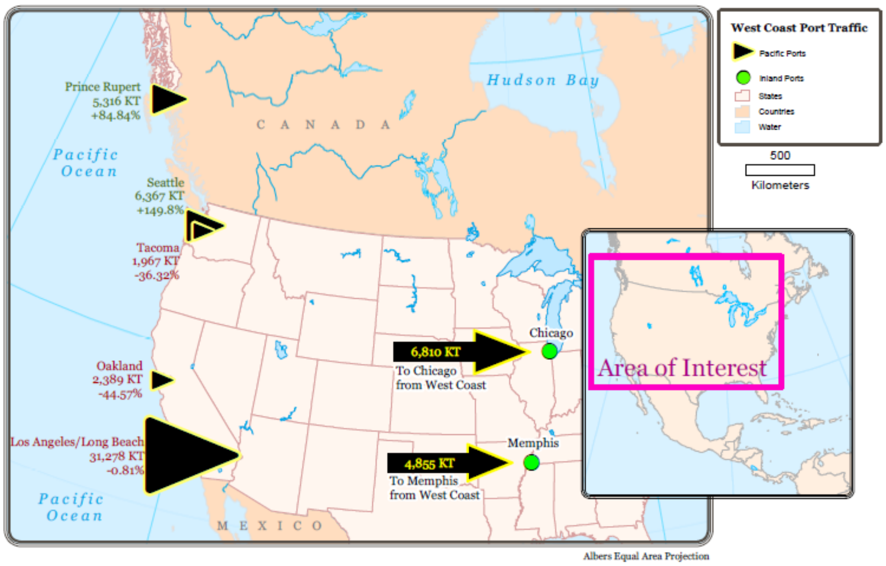
West Coast Port Freight Volume 2019



Freight volume in 2019 to the West Coast Ports = 48,985.73 Kilotons (+10.44% from 2012)
Los Angeles/ Long Beach, CA at 30,846.77; Oakland, CA at 2,705.32; Seattle, WA 8,178.12; Tacoma, WA at 2,400.81; and Prince Rupert, BC at 4,854.70.

Figure 20

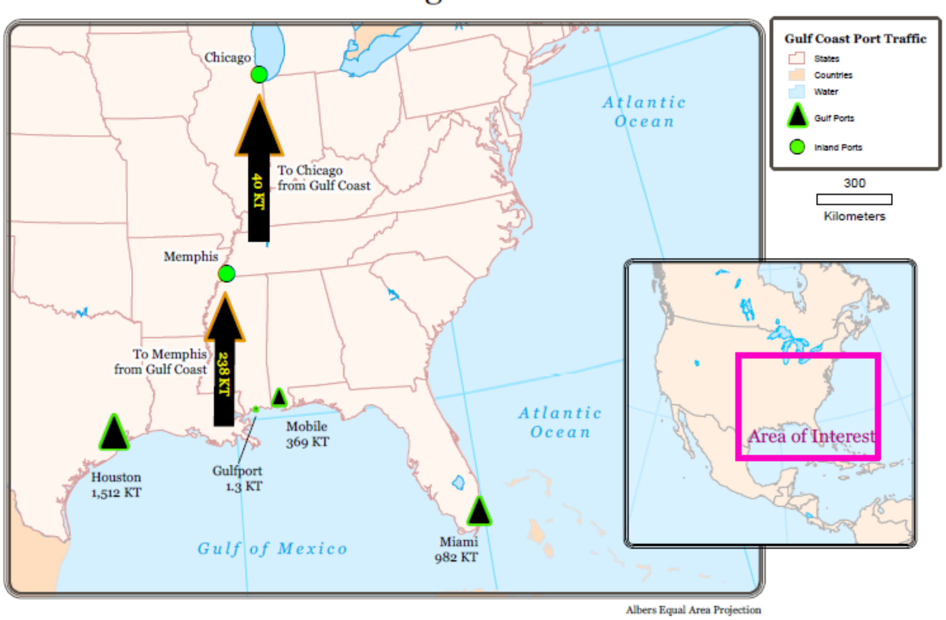
West Coast Port Freight Volume 2020



Freight volume in 2020 to the West Coast Ports = 47,316.71 Kilotons (+6.67% from 2012)
Los Angeles/ Long Beach, CA at 31,278.16; Oakland, CA at 2,388.64; Seattle, WA 6,366.90;
Tacoma, WA at 1,967.39; and Prince Rupert, BC at 5,315.64.

Figure 21

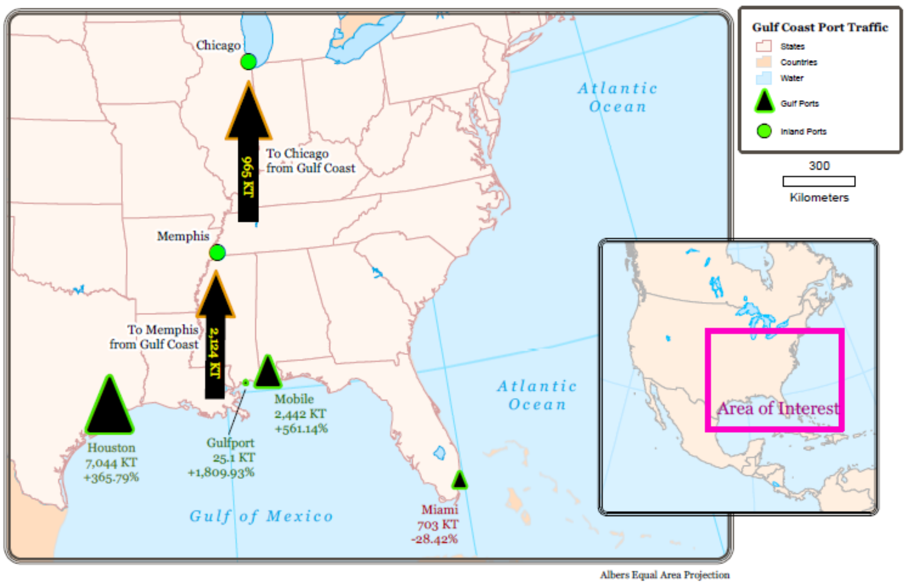
Gulf Coast Port Freight Volume 2012



Freight volume in 2012 to the Gulf Coast Ports = 2,865.04 Kilotons
Houston, TX at 1,512.37; Mobile, AL at 369.36; Miami, FL at 981.99; and Gulfport, MS at 1.32.

Figure 22

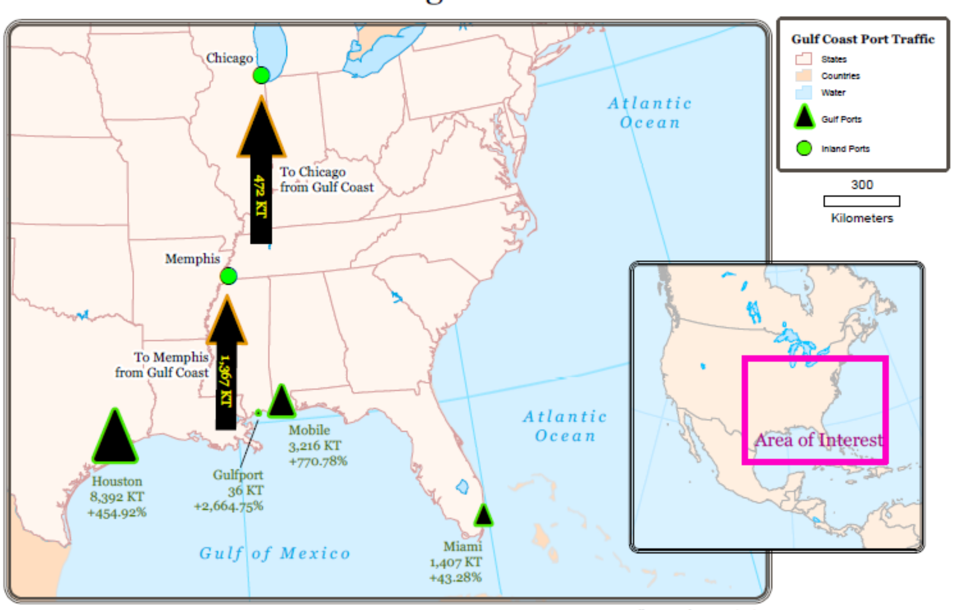
Gulf Coast Port Freight Volume 2019



Freight volume in 2019 to the Gulf Coast Ports = 10,214.50 Kilotons (+256.52% from 2012)
Houston, TX at 7,044.44; Mobile, AL at 2,442.00; Miami, FL at 702.91;
and Gulfport, MS at 25.19.

Figure 23

Gulf Coast Port Freight Volume 2020



Freight volume in 2020 to the Gulf Coast Ports = 13,052.30 Kilotons (+355.57% from 2012)
Houston, TX at 8,392.48; Mobile, AL at 3,216.33; Miami, FL at 1,407.02;
and Gulfport, MS at 36.47.

CHAPTER 7: ECONOMIC IMPACT ANALYSIS

1.0 Introduction

In this section, we conducted economic development analysis to quantify the projected economic growth due to the modeled change in freights movement and handling. Specifically this part of the study converts the expected change in freight tonnage (thousand metric tons of containers) per region from the transportation model component into measures of economic competitiveness. This is an important component of the whole study because facilitating economic growth and prosperity through efficient movement of goods is at the center of any comprehensive transportation plan. This section helps predict where economic growth might occur due to changes in freight capacity.

2.0 Modeling Freight Transportation's Impact on Economic Competitiveness

There are numerous models used to project the impact of transportation on economic competitiveness. Common models include REMI-TranSight and Tredis. These models examine how a change in transportation, which most often is a change in speed, travel time, cost, safety, capacity, reliability or access, impacts the economy. For example, in REMI improvements in transportation would change transportation costs and this change would be made to the production cost variable and the econometric model would show the impact to the economy using numerous measures of economic competitiveness (Cf. ICF Consulting and Decision-Economics HLB 2002). Each of these models need to be purchased for a geographic area. However, for the transportation model developed for this study, the output is change in tonnage and not a change in cost or other variable commonly used in these economic impact models.

Change in transportation tonnage is typically the <u>result</u> of a change in economic competitiveness rather than the cause of economic activity. Or put another way, changes in economic activities influence the demand for freight services. Warehousing is a possible exception to this relationship. Most economic impact models, but not all with TREDIS being an exception, are designed to measure cause and the resulting effect. The movement of goods is what economists term a factor input in the production of goods. For this study, we need to work backward from the effect (i.e., change in freight tonnage) to measures of the cause (i.e., some economic activity as measured by jobs, etc.). This is a simplification of actuality because as Hesse and Rodrigue (2004) point out transport cannot be solely considered as a derived demand, but as an integrated demand where physical distribution and materials management are interdependent.

Decoupling of Freight Movement and Economic Growth

Several studies have found that there is a decoupling of road freight transport and economic growth trends (Pastowski 1997; Kveiborg & Fosgerau 2004; Tight, Delle Site & Meyer-Rühle

2004; McKinnon 2007). Most of this research is coming from Europe and views this trend as an aspect of sustainable logistics. The main cause for this decoupling is a decline in road transport's share of freight movement due to an increase in trucking rates. Several other factors, including the relative growth of the service sector, the diminishing rate of centralization, and the off-shoring of manufacturing, appear to be having an effect. Despite a possible weaker correlation of freight tonnage as a predictor of economic competitiveness, this research does generally find a connection between change in freight tonnage and economic measures at the state level.

Warehousing Industry Driven by Changes in Freight Tonnage

Warehousing is in industry where change in tonnage drives demand as this analysis assumes. For example, the path of goods movement (POGM) model uses tonnage to make projections for warehousing demand. The commercial real estate industry has begun using freight tonnage as a predictor of warehouse demand. Traditionally, real estate demand for warehouse space has been modeled using population or employment measures. However, more recent research supports the path of goods movement (POGM) concept that analyzes the routes along which goods move using shipping weight (in tonnage) to determine strong demand for warehouse space (Mueller & Laposa 1994; Mansour, & Christensen, 2001). Currently, the POGM continues to drive research and investment models for many of the major warehouse investors. Mueller and Mueller (2007) found that weight of shipments and not the value was the most important factor in determining the demand for warehouse space. POGM research found that analyzing the routes along which goods move using shipping weight (in tonnage) was the best way to find locations with strong demand for warehouse space. The two main location points along POGM are shipments' origins and destinations. The objective of the model is to find the best points along the POGM where shipments can "break bulk," be stored and then re-distributed to their final destination should produce the best demand for warehouse space in the future. The output of the POGM is the square footage per person (SFPP) ratio. A comparable approach to POGM was utilized for this study.

This study developed its own methodology to convert the expected change in freight tonnage (thousand metric tons of containers) per state from the Panama Canal expansion into measures of economic competitiveness (i.e., Gross Domestic Product (GDP) by state). GDP by state is the state counterpart of the Nation's gross domestic product. GDP is calculated as the sum of what consumers, businesses, and government spend on final goods and services, plus investment and net foreign trade. The GDP by state estimates are used widely in both the public and private sectors. It is commonly used in econometric modelling and by state and local economic development offices.

3.0 Methodology

In order to model the projected impact of change in import tonnage on GDP by region, we determined the historical statistical relationship of import tonnage to GDP by state in the region. For containerized import tonnage by state, we used the WISERTrade database. The US census only has the confidence to release the state import data from 2008 so only five years of data was used for the analysis (The containerized data is available in the Port HS from 2003 and District HS database from 2002). State GDP was taken from the U.S. Department of Commerce Bureau of Economic Analysis for 2008 to 2012.

4.0 Results and Discussion

A statistical correlation analysis was conducted for all fifty states. The fit of the statistical model varied greatly from a R^2 of 0.05 for Illinois to 0.93 for Alaska (See Figure 1). The fit at the regional level used in this analysis was much better.

Based on the output of the freight distribution scenario analysis conducted in Task 3, GDP and import tonnage was analyzed at the region level. The regions were comprised of the following:

Chicago & North (Midwest region) included North Dakota, South Dakota, Wisconsin, Iowa, Illinois, and Michigan. Total regional 2012 GDP $10,218,063,016.

Memphis and south region included Tennessee, Arkansas, Mississippi, Alabama, Georgia, and Texas. Total regional 2012 GDP $27,364,239,549.

Port Region included Washington, California, New York, New Jersey, Virginia, South Carolina, Georgia, and Florida. Total regional 2012 GDP $91,287,705,929.

Other States region included all other states not included in the afore-mentioned regions.

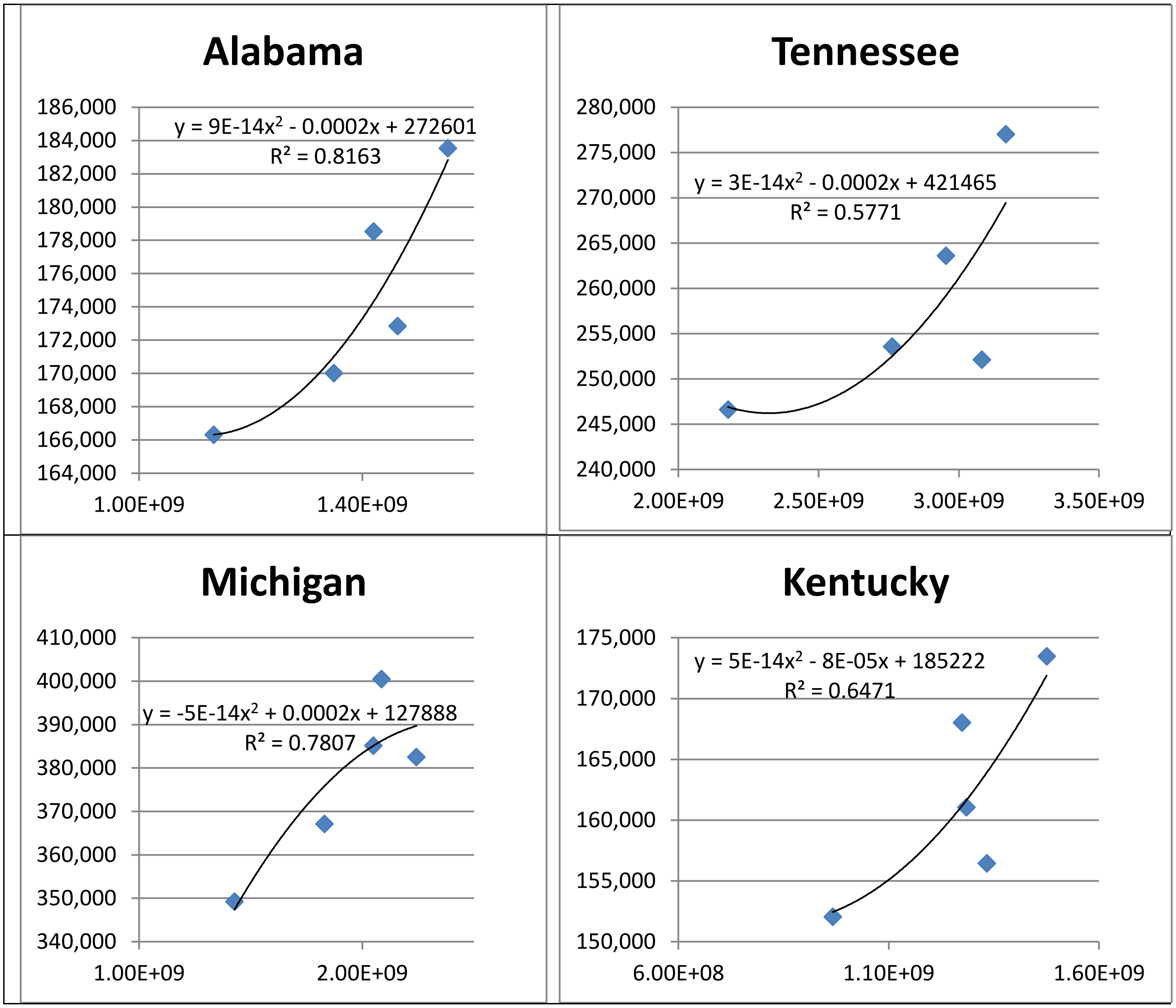


Figure 1. Representative Statistical Models for Import Tonnage as a Predictor of State GDP

The statistical fit was much better at the regional level (Table Two). The R^2 ranged from 0.81 to 0.94. These models were used to converts the expected change in freight tonnage (thousand metric tons of containers) per region from the transportation model component into measures of economic competitiveness. The models are presented in Figure 2.

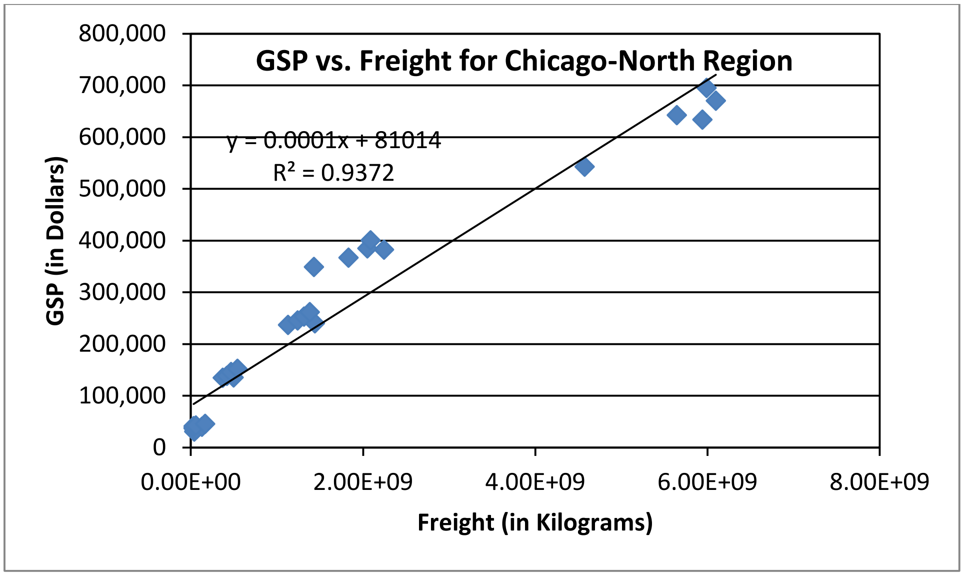


Figure 58a. Statistical Model for Import Tonnage as a Predictor of Regional GDP for Chicago-North Region

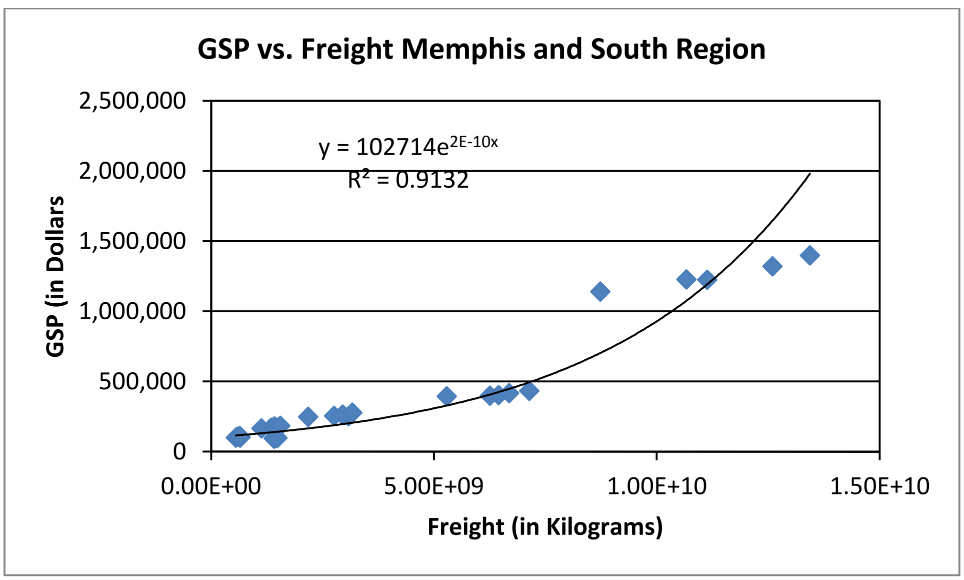


Figure 59b. Statistical Model for Import Tonnage as a Predictor of Regional GDP for Memphis-South Region

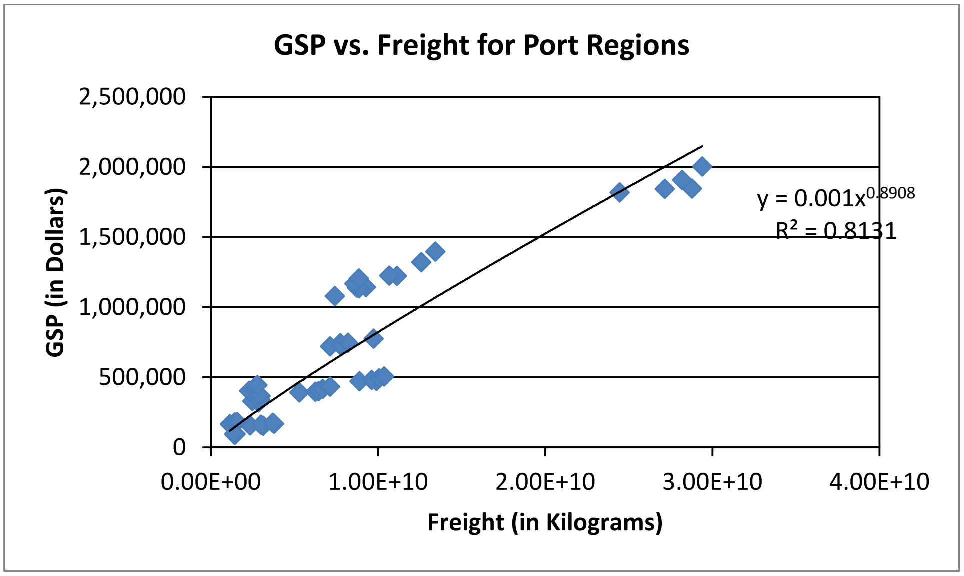


Figure 60c. Statistical Model for Import Tonnage as a Predictor of Regional GDP for Port Region

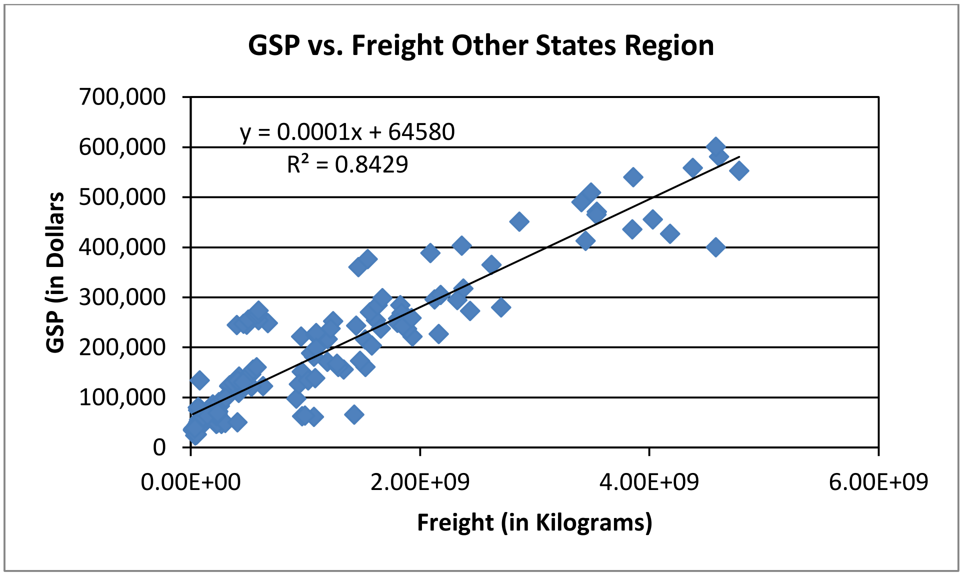


Figure 61d. Statistical Model for Import Tonnage as a Predictor of Regional GDP for Other States Region

5.0 Economic Impact Analysis of the Change in Freight Flow Scenarios

The first scenario analyzed the cases of capacity expansions at the Panama Canal and the Port of Prince Rupert with the 2012 container flow through the West Coast ports (See Table 1). The largest impact is felt on the port states that include Washington, California which would see less imports coming via the West Coast ports. Presumably, these imports would be shifted to non-West Coast ports as the economy adjusted to the expansions at the Panama Canal and the Port of Prince Rupert. The Chicago-North region and other states would see an increase in GSP as a result of the expansion.

Table 1. Scenario 1 Impact on Imports via West Coast Ports

Destination Market Regions	**Equation**	**Scenario 1 (Though West Coast Ports)**		
		2012 Base	**2020**	
		Imports (tons)	**Imports (tons)**	**Δ GSP**
Chicago-North	GSP=0.0001x+81014	95,291.30	88,528.10	$80,338
Memphis-South	GSP=102714exp(2E-10x)	51,473.24	63,117.14	$242
Port States	$GSP=.001x^{(.8908)}$	228,899.19	114,470.40	-$12,932
Other	GSP=0.0001x+64580	200,962.58	349,001.61	$79,384

Where, x= freight in kilograms.

The second scenario modeled the impact of the expansions to the Panama Canal and the Port of Prince Rupert on imports through the Gulf Ports (See Table 2). All the regions will experience an increased tonnage of imports. The increase is more pronounced for Chicago North and Other states regions.

Table 2. Scenario 2: Impact on Imports via Gulf Coast Ports

Destination Market Regions	Equation	Scenario 2 (Though Gulf Coast Ports)		
		2012 Base	2020	
		Imports	Imports	Δ GSP
Chicago-North	GSP=0.0001x+81014	525.72	6,131.11	$81,575
Memphis-South	GSP=102714exp(2E-10x)	3,090.36	17,769.17	$302
Port States	GSP=.001x$^{(.8908)}$	27,942.07	57,935.46	$3,943
Other	GSP=0.0001x+64580	5,686.59	87,844.12	$72,796

Where, x= freight in kilograms.

The third scenario compared the cases of expansion at the Panama Canal and Prince Rupert to the 2012 container flows through the East Coast ports (Table 3). The Chicago-North region and other states would see an increase in imports of fright tonnage and accordingly an increase in the GSP as a result of the expansion. Memphis and Port states region will be a decrease in the freight tonnage due to the expansion.

Table 3. Scenario 3: Impact on Imports via East Coast Ports

Destination Market Regions	Equation	Scenario 3 (Though East Coast Ports)		
		2012 Base	2020	
		Imports	Imports	Δ GSP
Chicago-North	GSP=0.0001x+81014	10,447.71	27,316.80	$82,701
Memphis-South	GSP=102714exp(2E-10x)	29,820.83	28,503.86	-$27
Port States	GSP=.001x$^{(.8908)}$	70,379.66	37,099.30	-$4,267
Other	GSP=0.0001x+64580	67,696.59	155,948.79	$73,405

Where, x= freight in kilograms.

Overall, there appears to be little economic impact on Memphis-South and Port States regions from the Panama Canal and the Port of Prince Rupert expansions. Some port states will adjust their source ports for imports, but the impact on the overall regional economies will be insignificant. However, Chicago-North and other states regions will have significant impacts from the Panama Canal and the Port of Prince Rupert expansions under all three scenarios.

6.0 Analysis of Potential Intermodal Facility Locations

Based on the models, the following areas will see the largest increase in traffic and are prime targets for intermodal development. The reality is that they all technically have some kind of intermodal facility, but they are smaller ones that can be expanded (theoretically). Criteria for selection: <100K population, within 5 miles of a major rail and interstate, and will see heavy traffic due to a 2019/2020 increase in freight volume. Rail volume was rated with a higher value than Truck due to inability to move tracks. The GIS model was adapted from the 12 truck and 12 rail scenarios in Task 4 (See Figure One).

All FAF3 Zones: Volume/ Numbers of FAF3 Zones in State

Results of Scenario 1: Freight Assignment (2012):
All Freight Analysis Framework 3 [FAF3] Zones with Volume by numbers of FAF3 Zones in the State. Showing Intermodal locations (triangles) that are best suited near the CFIRE states because they are under 100,000 population, have intermodal capability, and will see a significant increase in volume due to port expansions.

Figure 3. GIS Model of One of the Scenarios in Task 4

The following cities are expected to see significant increases in freight volume so are potential locations for intermodal facility development.

1. Fargo, ND
2. Joplin, MO
3. Meridian, MS
4. Bellevue, NE
5. St. Cloud, MI
6. Farragut, TN
7. Goodlettsville, TN
8. Prattville, AL
9. East Ridge, TN
10. Effingham, IL
11. Hattiesburg, MS

The following table provides details of existing container intermodal transfer facilities near the identified cities along with major rail lines.

Table 4 Existing Infrastructure Where Largest Increases in Container Traffic is predicted

Location	Existing Intermodal Facilities	Existing Intermodal Facilities
Fargo, ND	BNSF Dilworth Intermodal Facility Less than 10 miles	
Served by four railroads: BNSF, Canada Pacific Railway (CPR)		
Joplin, MO	More than 100 miles	
Served by Kansas City Southern, Burlington Northern-Santa Fe, & Union Pacific.		
Meridian, MS	CN/Kansas City Southern High Oak yard Railroad Yard Less than 100 miles	
Served by Norfolk Southern and Kansas City Southern		
Bellevue, NE	BNSF Omaha Intermodal Facility Less than 10 miles	UP Council Bluffs Intermodal Facility Less than 15 miles
Greater Omaha is served by Union Pacific Railroad, Burlington Northern Santa Fe Railway and Canadian National.		
St. Cloud, MN	BNSF St. Paul Intermodal Facility Less than 100 miles	
Served by Burlington Northern Santa Fe Corporation		
Farragut, TN	NS Thoroughbred Bulk Transfer Terminal	

	Less than 20 miles	
Greater Knoxville is served by Norfolk Southern and CSX		
Goodlettsville, TN	CSX Nashville Intermodal Terminal Less than 20 miles	
Greater Nashville is served by CSX Transportation		
Prattville, AL	CSX Central Alabama Intermodal Container Transfer Facility in Bessemer Less than 90 miles	NS Birmingham Regional Intermodal Facility Less than 100 miles
Greater Montgomery is served by CSX Transportation, Union Pacific, Norfolk Southern, and Canadian National		
East Ridge, TN	More than 100 miles	
Greater Chattanooga served by Norfolk Southern and CSX		
Effingham, IL	More than 100 miles	
Served by CSX Transportation and Norfolk Southern		
Hattiesburg, MS	Kansas City Southern High Oak yard Railroad Yard Less than 100 miles	
Served by Norfolk Southern, CN, and KCS		

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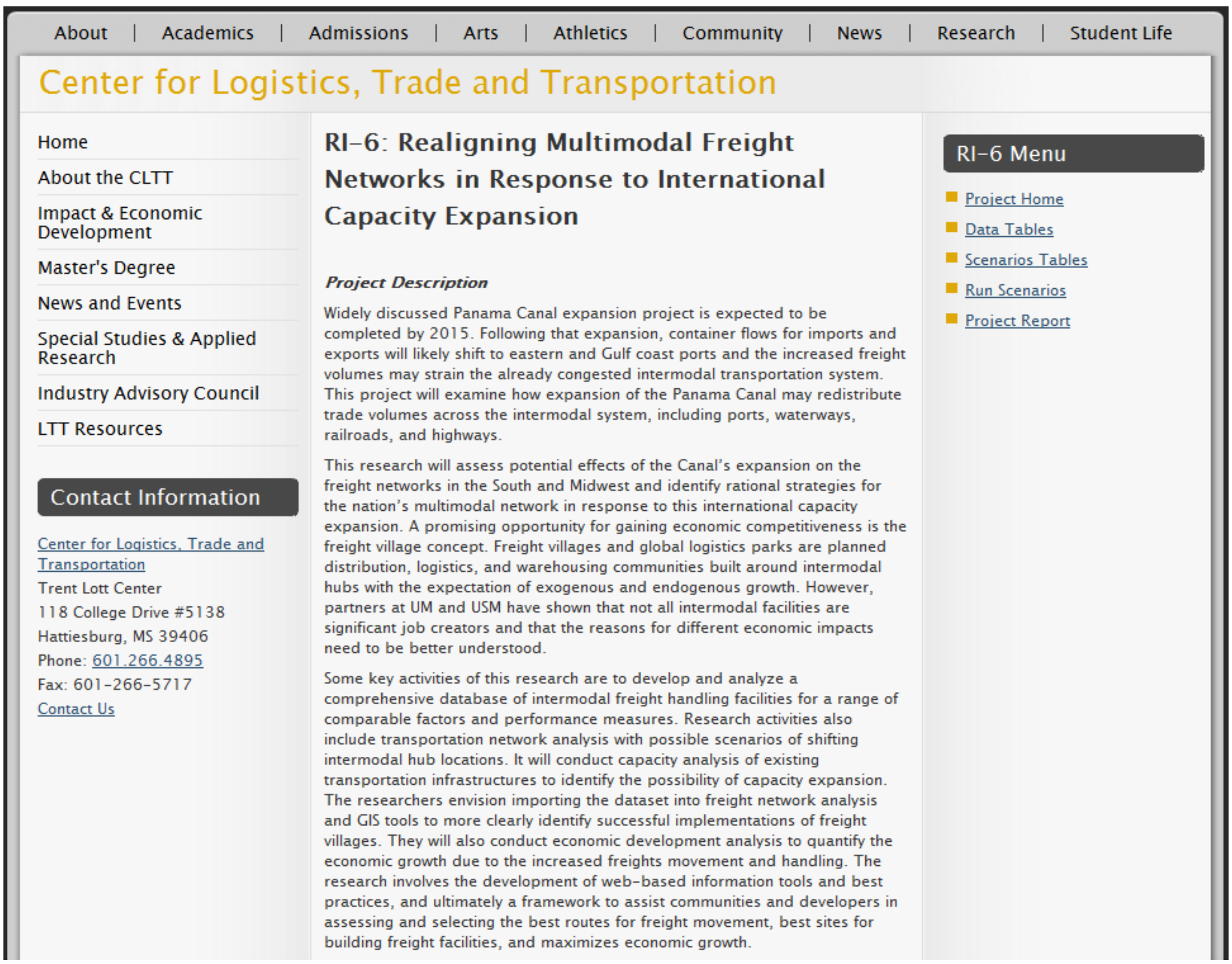
APPENDICES

Dynamic Web-Based Tool Synopsis

The Dynamic Web-based tool is located at the Center for Logistics, Trade and Transportation web site [https://www.usm.edu/logistics-trade-transportation/ri-6-run-scenarios]. A snapshot of the site is shown in the following figure. The use of the dynamic web-based tool is very simple. The stakeholders begin the process by first selecting the desired level of the analysis (Port, U.S Interior or Sensitivity). Upon selecting the analysis level the stakeholders are prompted to select from multiple choices the information needed to perform the analysis as follows: I- Port Level Scenario the stakeholders select: 1- Freight Port of Entry and 2- Expansion Scenario; II- U.S Interior the stakeholders select: 1- Expansion Scenario, 2- Region, 3- State Zones, and 4- Transportation Mode; and III-Sensitivity Analysis Scenario the stakeholders select: 1- Projected Volume and 2- Transportation Mode. A brief description of three run scenarios are elaborated in the next section.



RI-6 Run Scenarios

RI-6: Port Level Scenarios
The ‘Port Level Scenarios’ tool is prepared to provide an examination of the impact of the Panama Canal Expansion for different portions of the country, West Coast Ports, East Coast Ports and Gulf of Mexico Ports. The values show the anticipated volumes of freight at the specific ports and freight headed to Memphis, TN and Chicago, IL.

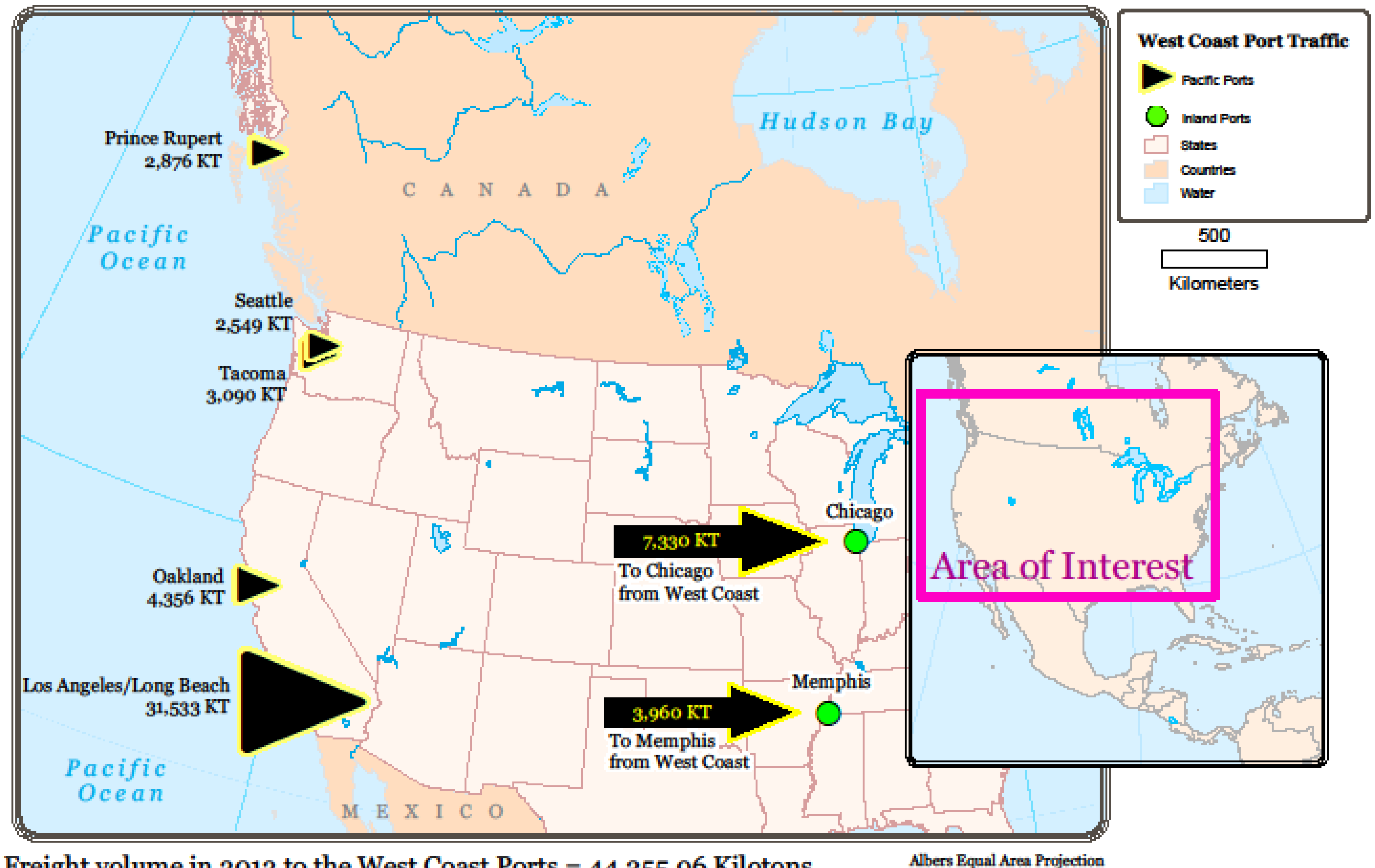
RI-6: U.S. Interior Optimized Scenarios
This ‘U.S. Interior Optimized Scenarios’ tool is prepared to provide conditional flow of containerized import freight volumes from the major U.S. international port gateways to each state’s major container freight stations. Condition can be determined with combinations of capacity expansions, regions, number of FAF3 zones in each state, and transportation mode. Capacity expansions are assumed condition with current, after the Panama Canal’s expansion in 2019, and after the port of Prince Rupert’s expansion in 2020. Regions are focused on the complete U.S. and the Midwest regions. And either number of FAF3 zones or population proportion in each state can be selected for state condition. Lastly, two transportation modes for containerized shipments, truck and rail are provided to select for the U.S. interior optimized scenario analysis. Once ‘Request Scenario Results’ is submitted, optimized flow results are visualized under dialogue box.

RI-6: Sensitivity Analysis Scenarios
The ‘Sensitivity Analysis Scenarios’ tool is prepared to show volume difference between the forecasted volumes associated with the expansion of the Panama Canal. The forecasts are adjusted between 70 percent and 130 percent of the anticipated amount and the user is able to select mode of travel as either Highway or Rail.

APPENDIX A- PORT LEVEL SCENARIOS

RI-6 Port Level Scenarios – West Coast Port (Pacific Ocean) – 2012 Before Panama Canal Expansion

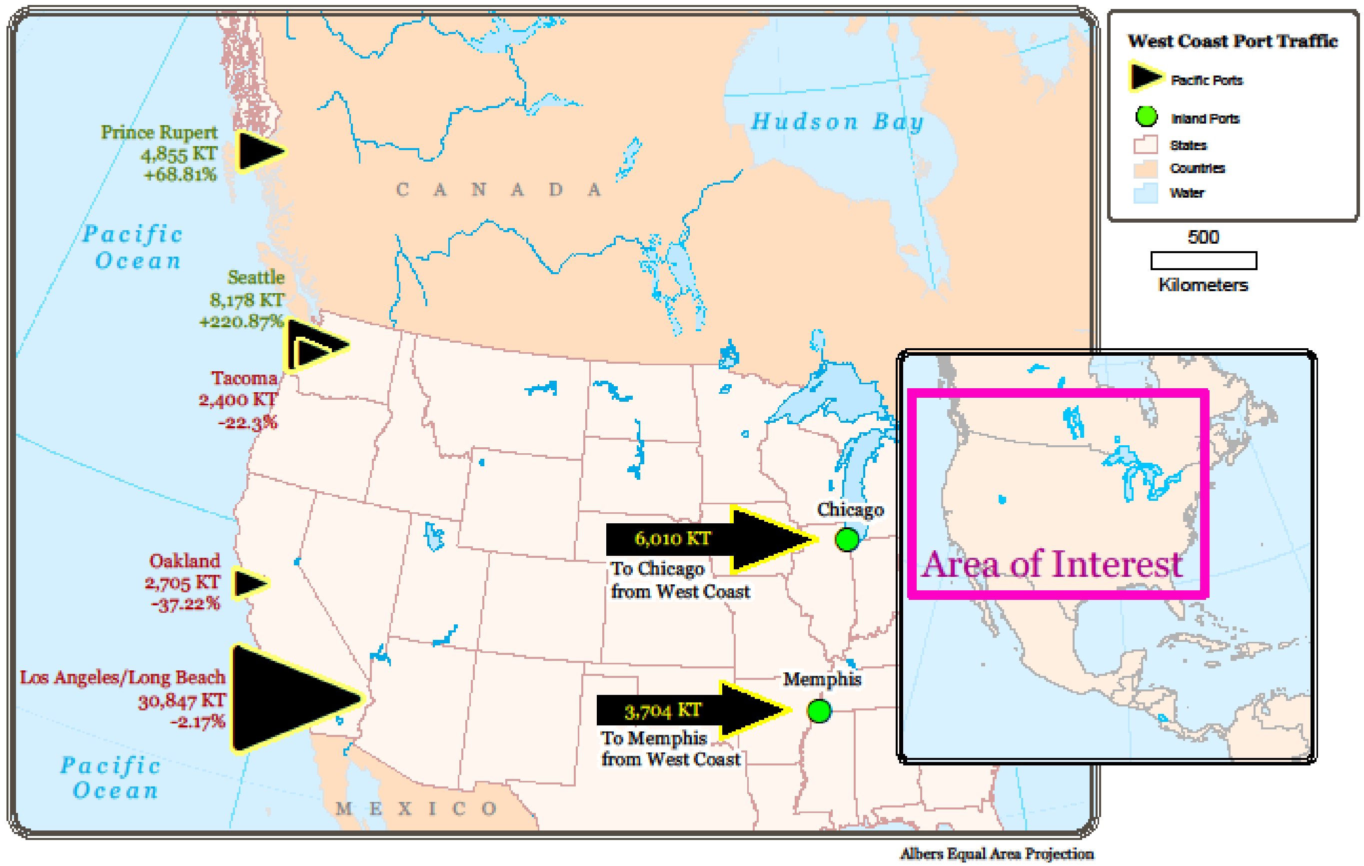
West Coast Port Freight Volume 2012



Freight volume in 2012 to the West Coast Ports = 44,355.96 Kilotons
Los Angeles/ Long Beach, CA at 31,532.55; Oakland, CA at 4,309.15; Seattle, WA 2,548.75; Tacoma, WA at 3,089.69; and Prince Rupert, BC at 2,875.83.

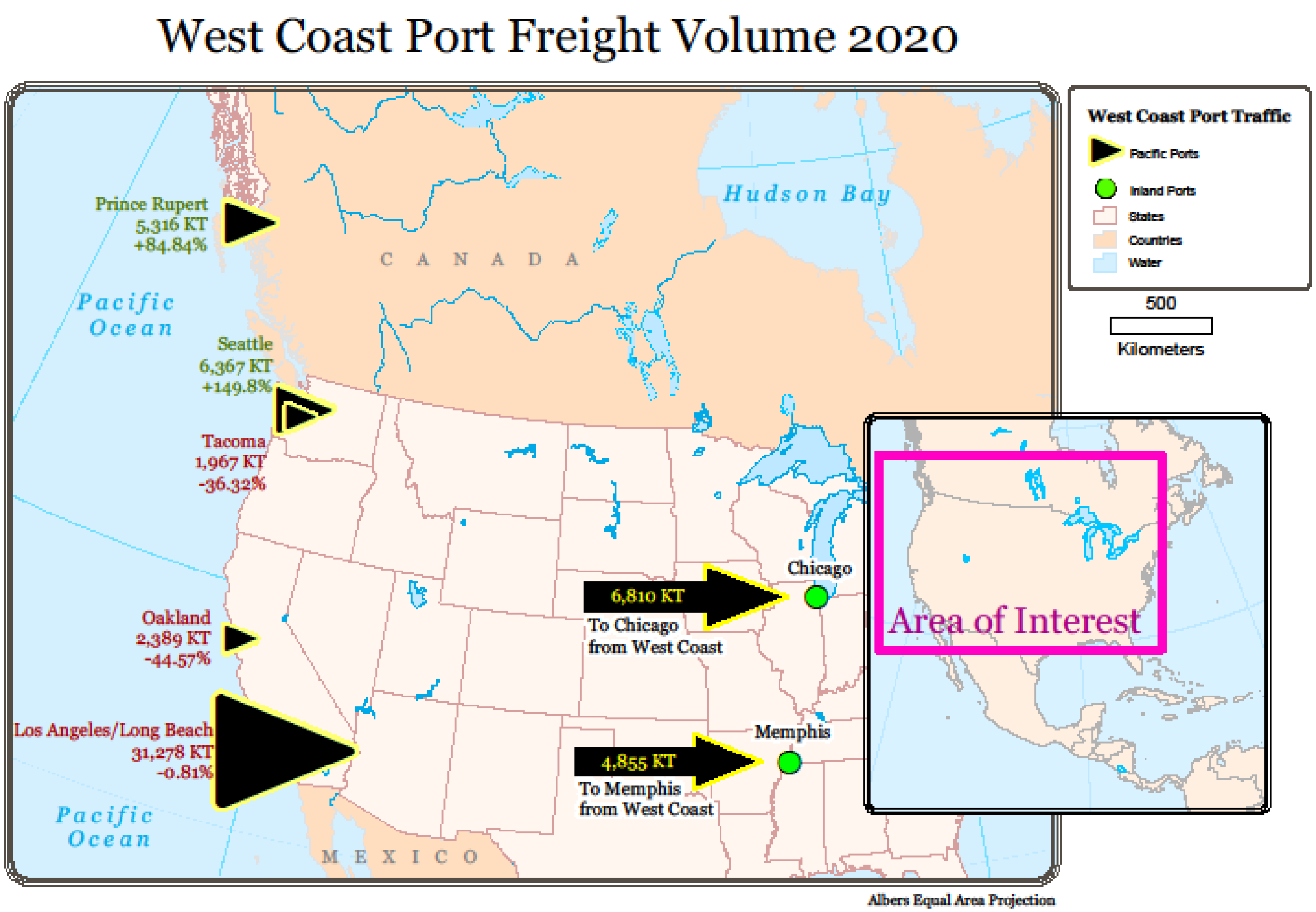
RI-6 Port Level Scenarios – West Coast Port (Pacific Ocean) – 2019 After Panama Canal Expansion and before Prince Rupert

West Coast Port Freight Volume 2019



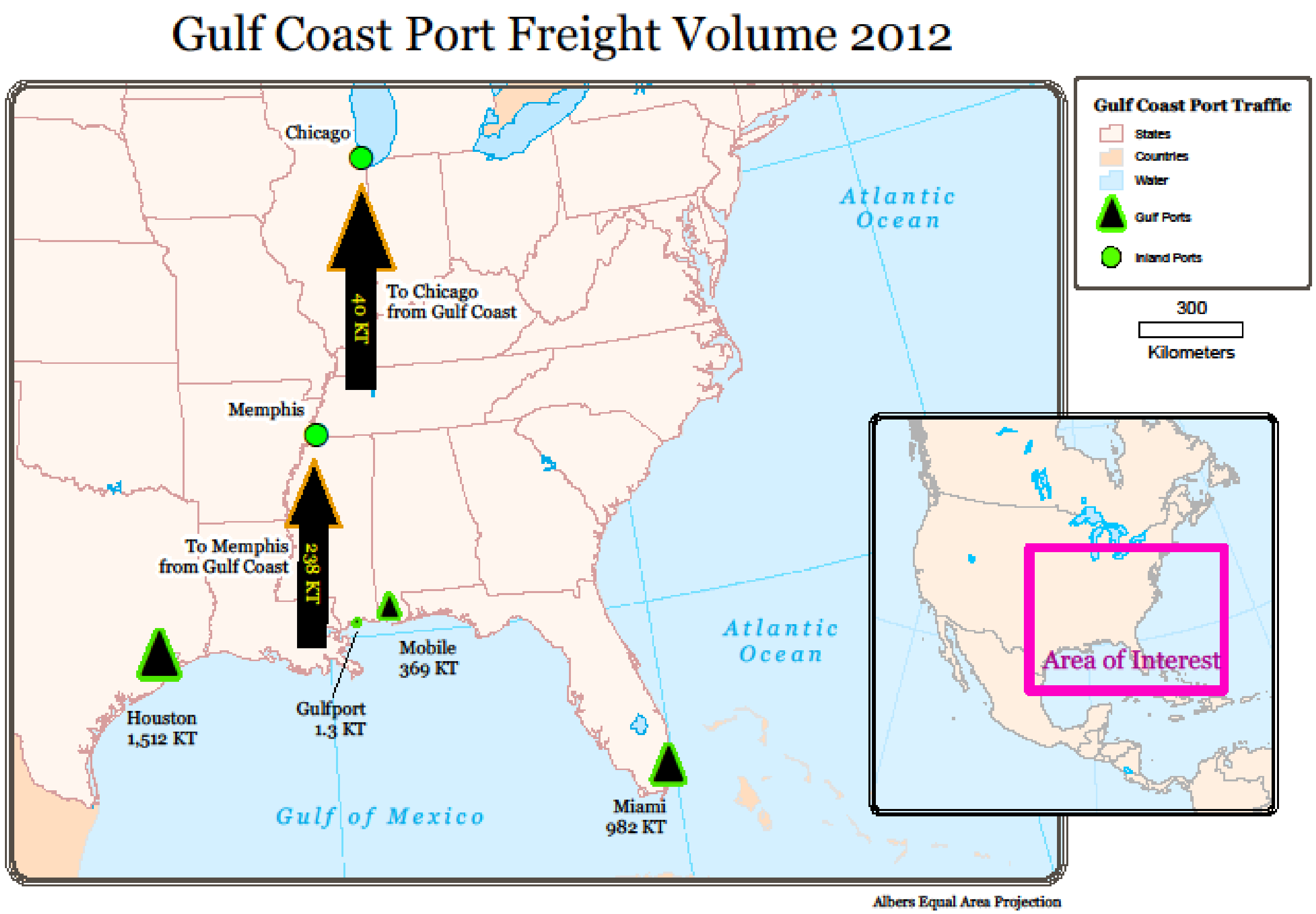
Freight volume in 2019 to the West Coast Ports = 48,985.73 Kilotons (+10.44% from 2012)
Los Angeles/ Long Beach, CA at 30,846.77; Oakland, CA at 2,705.32; Seattle, WA 8,178.12;
Tacoma, WA at 2,400.81; and Prince Rupert, BC at 4,854.70.

Expansion



Freight volume in 2020 to the West Coast Ports = 47,316.71 Kilotons (+6.67% from 2012) Los Angeles/ Long Beach, CA at 31,278.16; Oakland, CA at 2,388.64; Seattle, WA 6,366.90; Tacoma, WA at 1,967.39; and Prince Rupert, BC at 5,315.64.

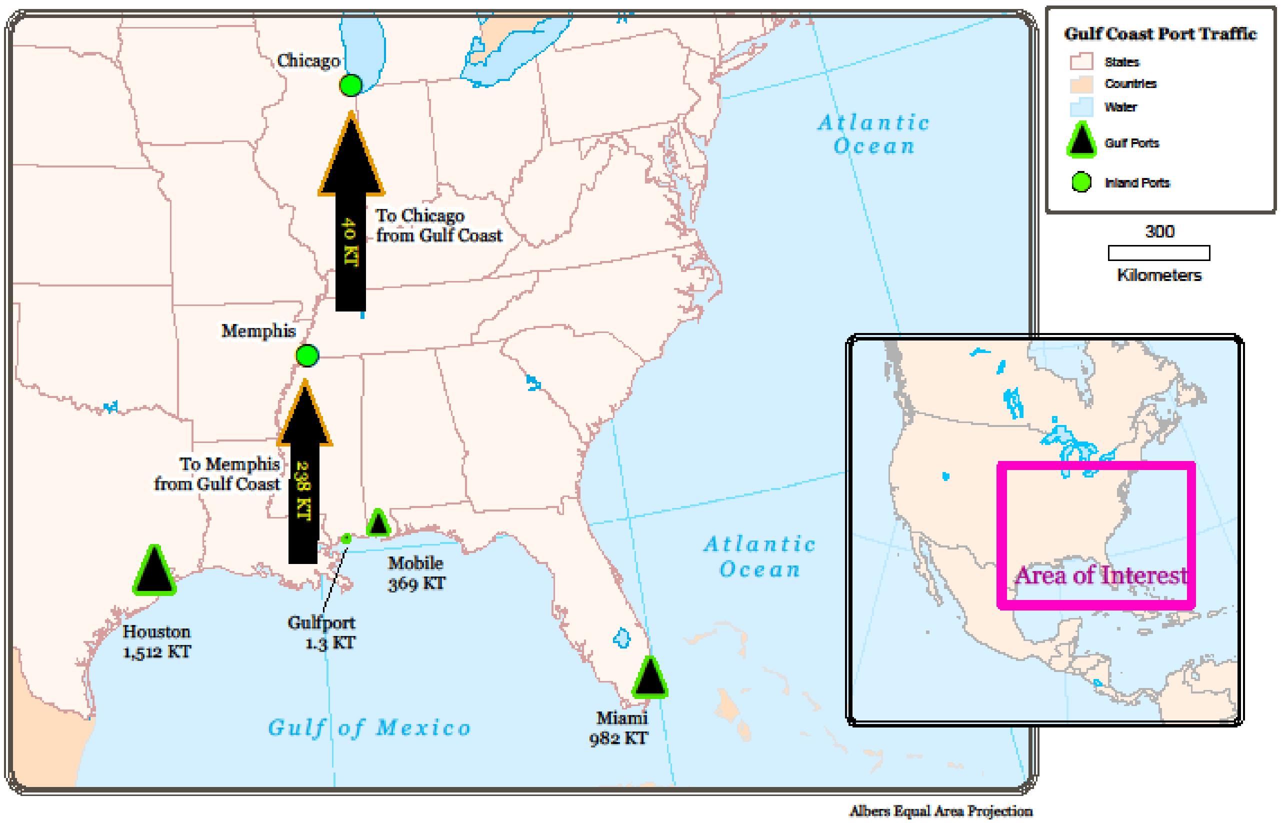
RI-6 Port Level Scenarios – Gulf of Mexico Coast Ports – 2012 Before Panama Canal Expansion



Freight volume in 2012 to the Gulf Coast Ports = 2,865.04 Kilotons
Houston, TX at 1,512.37; Mobile, AL at 369.36; Miami, FL at 981.99; and Gulfport, MS at 1.32.

RI-6 Port Level Scenarios – Gulf of Mexico Coast Ports – 2019 After Panama Canal Expansion and before Prince Rupert Expansion

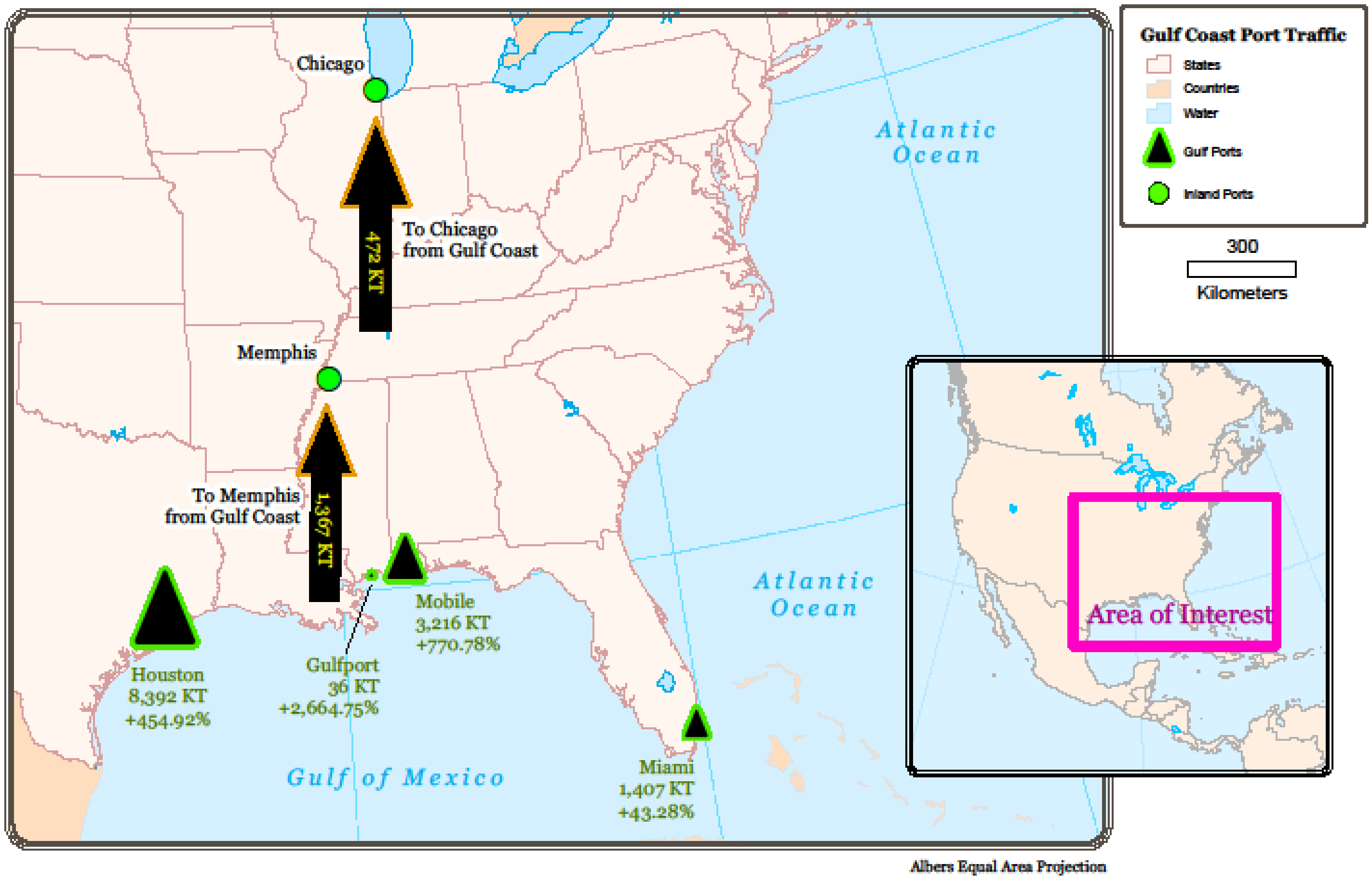
Gulf Coast Port Freight Volume 2012



Freight volume in 2012 to the Gulf Coast Ports = 2,865.04 Kilotons
Houston, TX at 1,512.37; Mobile, AL at 369.36; Miami, FL at 981.99; and Gulfport, MS at 1.32.

RI-6 Port Level Scenarios – Gulf of Mexico Coast Ports – 2020 After Panama Canal Expansion and Prince Rupert Expansion

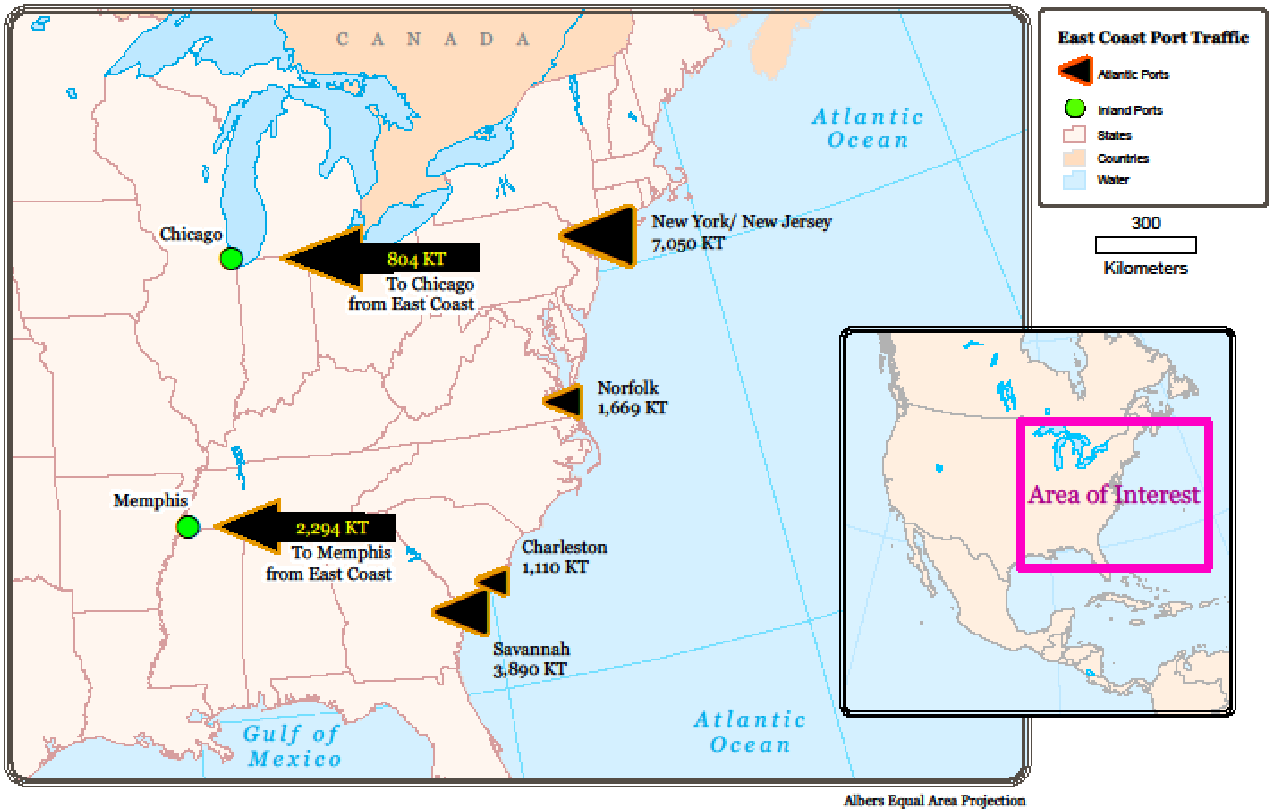
Gulf Coast Port Freight Volume 2020



Freight volume in 2020 to the Gulf Coast Ports = 13,052.30 Kilotons (+355.57% from 2012)
Houston, TX at 8,392.48; Mobile, AL at 3,216.33; Miami, FL at 1,407.02;
and Gulfport, MS at 36.47.

RI-6 Port Level Scenarios – East Coast Ports (Atlantic Ocean) – 2012 Before Panama Canal Expansion

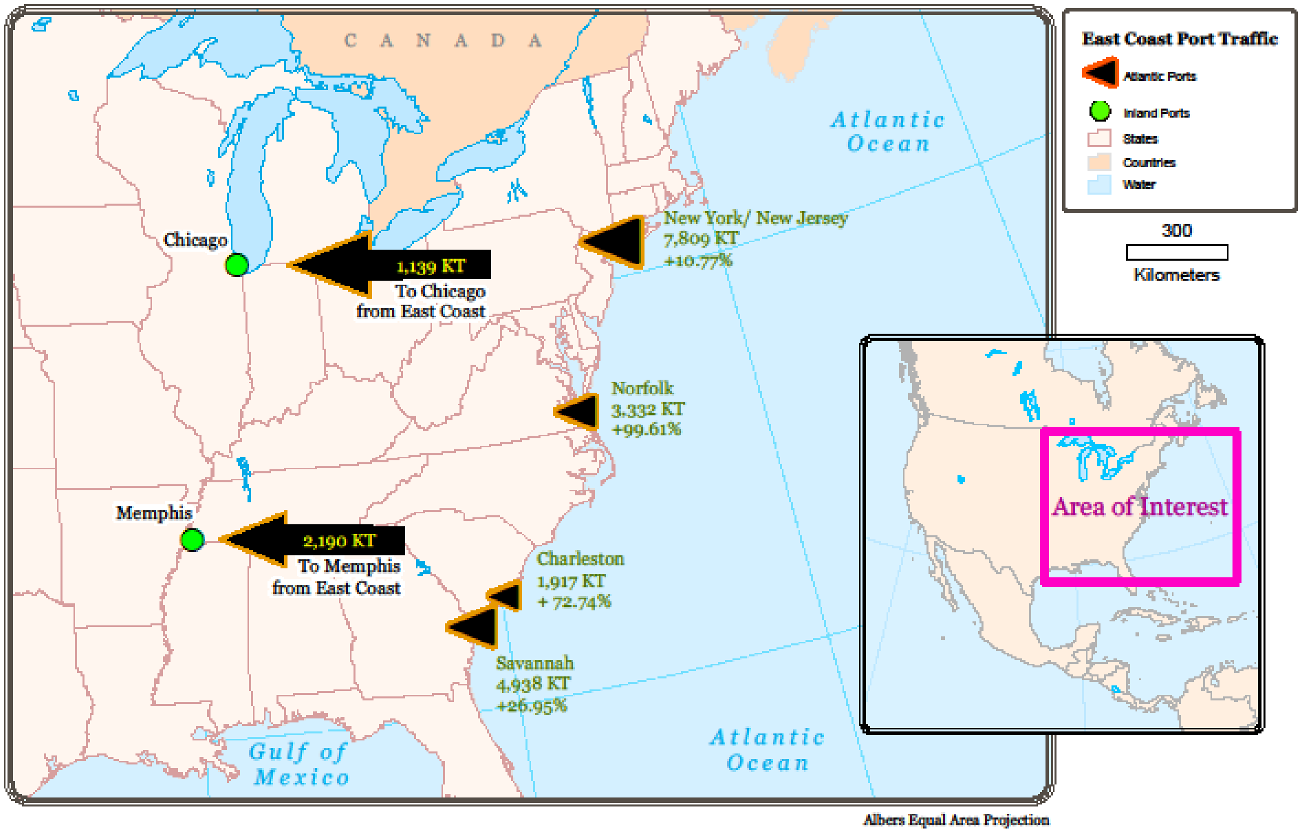
East Coast Port Freight Volume 2012



Freight volume in 2012 to the East Coast Ports = 13,718.91 Kilotons
New York/ New Jersey at 7,049.58; Norfolk, VA at 1,669.34; Charlestion, NC at 1,109.99; and Savannah, GA at 3,890.00.

RI-6 Port Level Scenarios – East Coast Ports (Atlantic Ocean) – 2019 After Panama Canal Expansion and before Prince Rupert Expansion

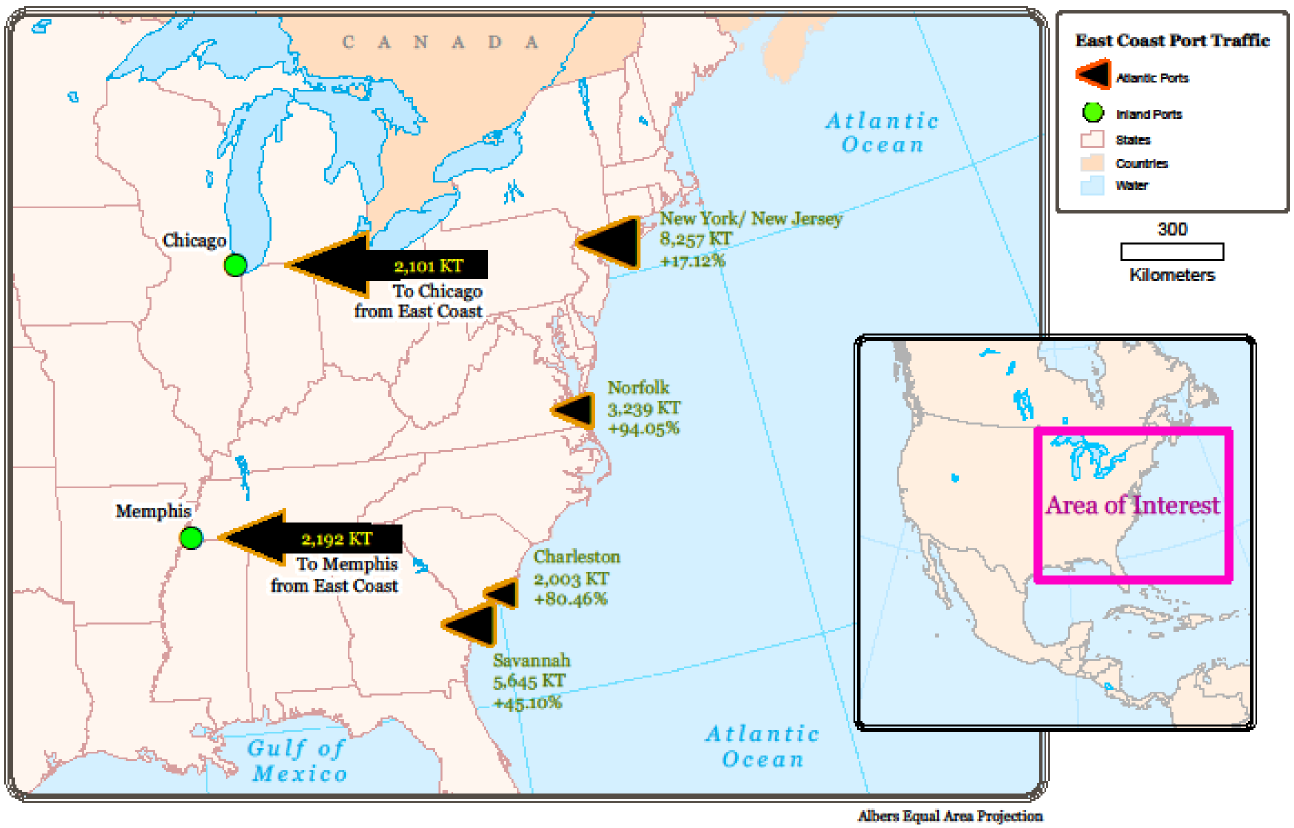
East Coast Port Freight Volume 2019



Freight volume in 2019 to the East Coast Ports = 13,718.91 Kilotons (+31.18% from 2012)
New York/ New Jersey at 7,808.70; Norfolk, VA at 3,332.12; Charlestion, NC at 1,917.39; and Savannah, GA at 4,938.41.

RI-6 Port Level Scenarios – East Coast Ports (Atlantic Ocean) – 2020 After Panama Canal Expansion and Prince Rupert Expansion

East Coast Port Freight Volume 2020



Freight volume in 2020 to the East Coast Ports = 19,143.75 Kilotons (+39.54% from 2012)
New York/ New Jersey at 8,256.76; Norfolk, VA at 3,239.37; Charlestion, NC at 2,003.06; and Savannah, GA at 5,644.57.

APPENDIX B - U.S INTERIOR OPTIMIZED SCENARIOS

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion - The Complete U.S. – Number of FAF3 Zones Per

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

Figure 3
Results of Scenario 1: Truck Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

State – Truck

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert - The Complete U.S. – Number of FAF3 Zones Per State – Truck

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State 2019

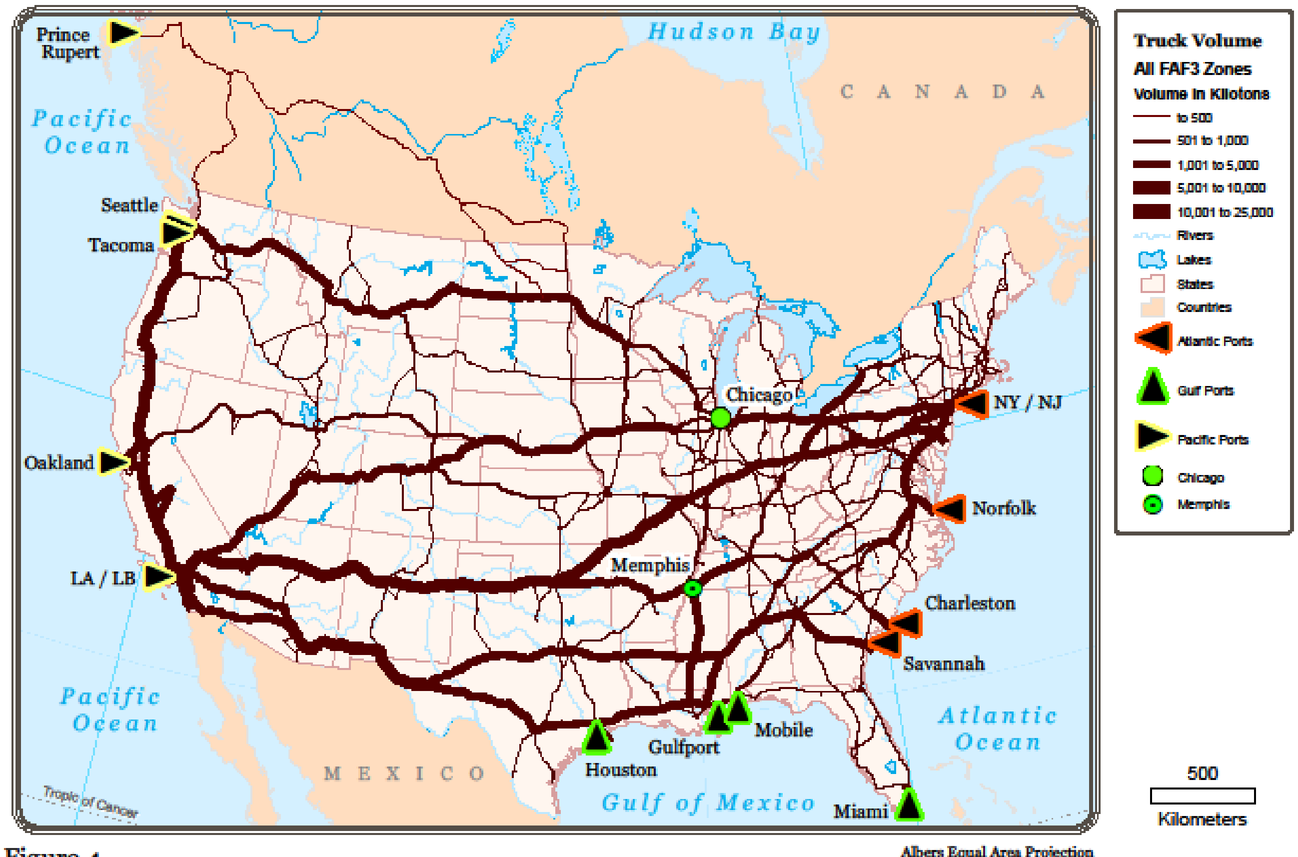


Figure 4
Results of Scenario 2: Truck Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion, but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert - The Complete U.S. – Number of FAF3 Zones Per State – Truck

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State 2020

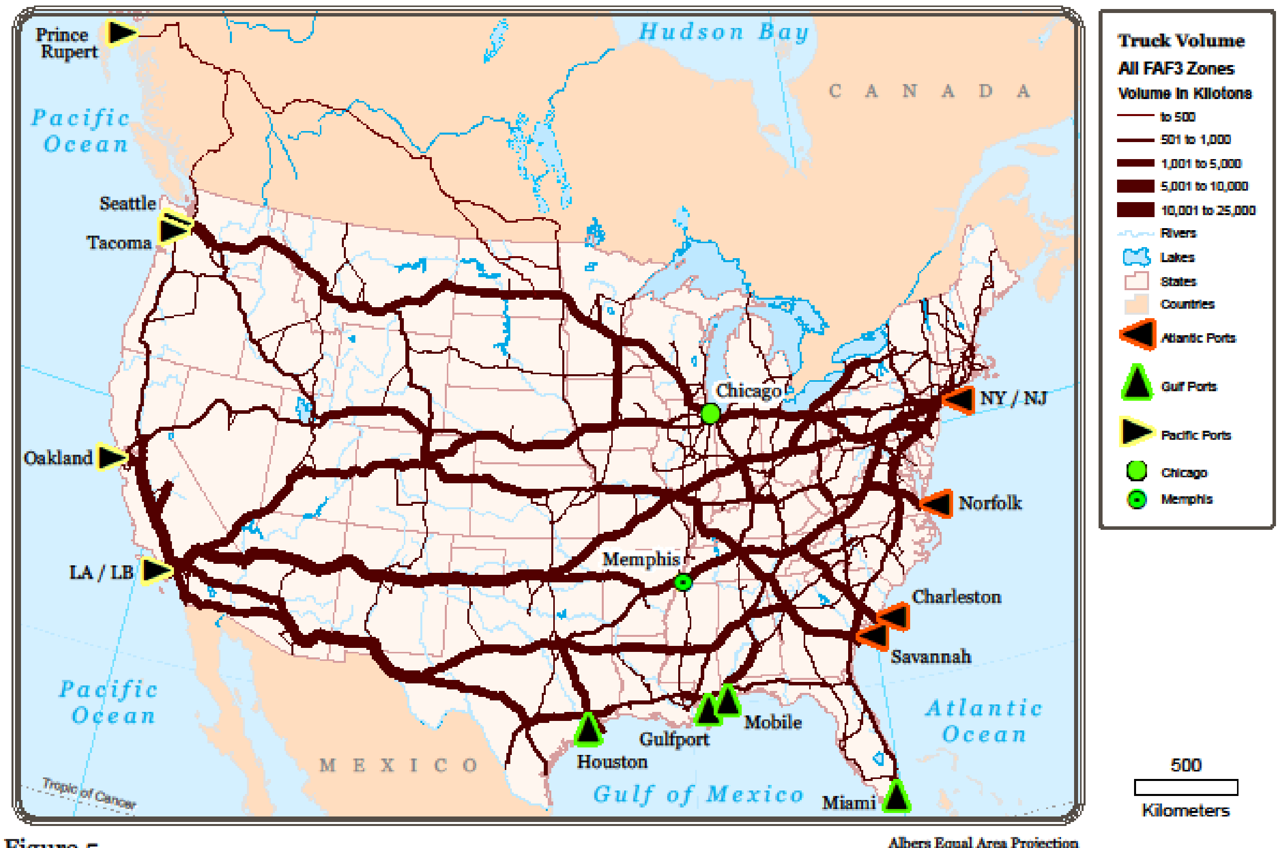


Figure 5
Results of Scenario 3: Truck Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion and Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion– Midwest Region – Number of FAF3 Zones Per State – Truck

Midwest Regions: Volume/ Numbers of FAF3 Zones by State 2012

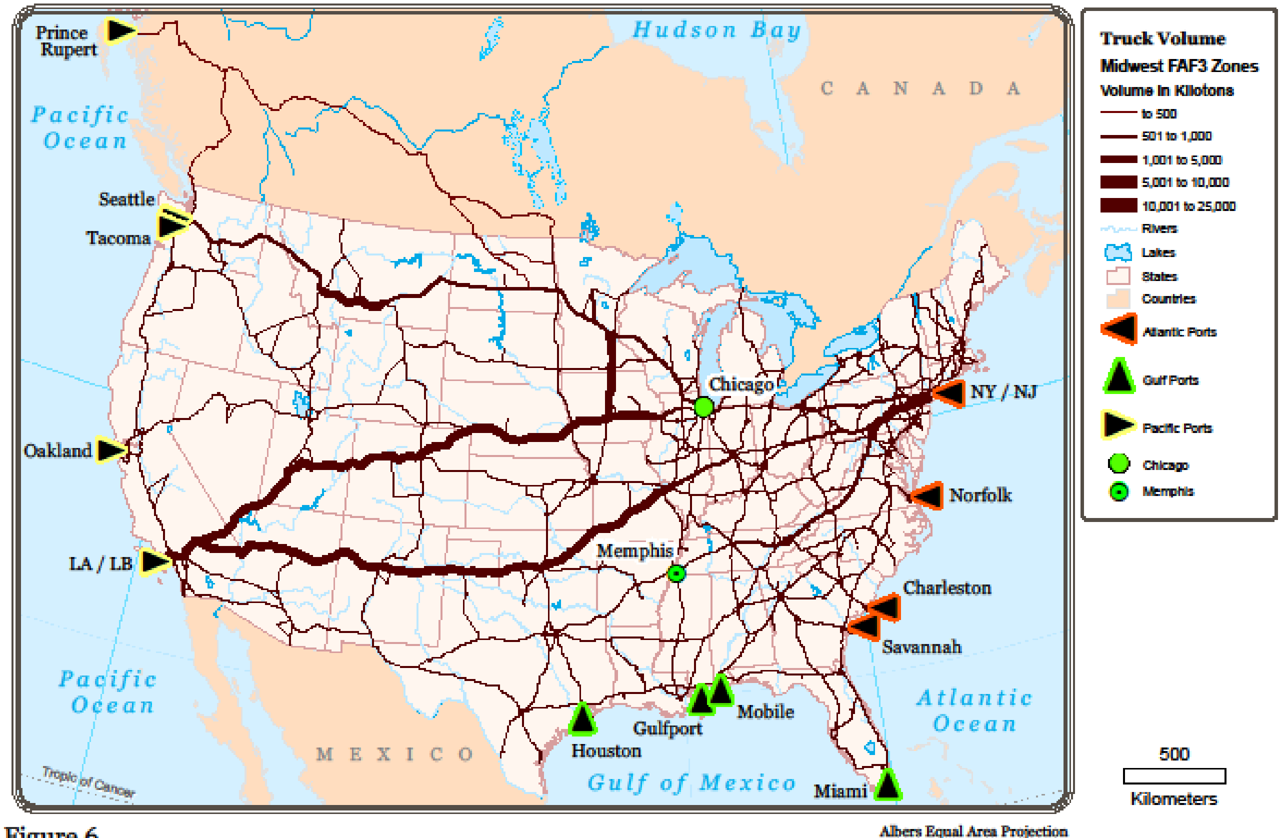


Figure 6

Results of Scenario 4: Truck Assignment (2012), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – Midwest Region – Number of FAF3 Zones Per State – Truck

Midwest Regions: Volume/ Numbers of FAF3 Zones by State 2019

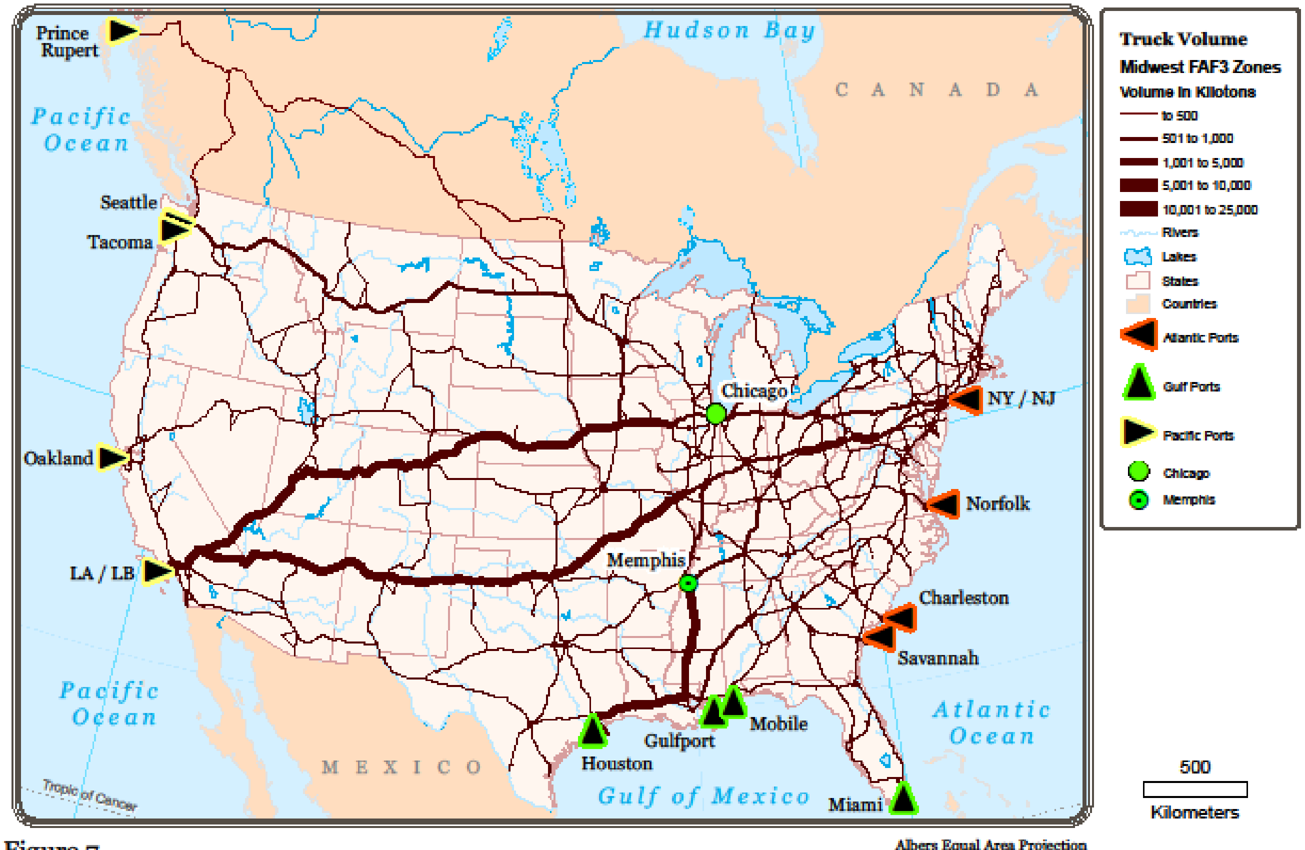


Figure 7
Results of Scenario 5: Truck Assignment (2019), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – Midwest Region – Number of FAF3 Zones Per State – Truck

Midwest Regions: Volume/ Numbers of FAF3 Zones by State 2020

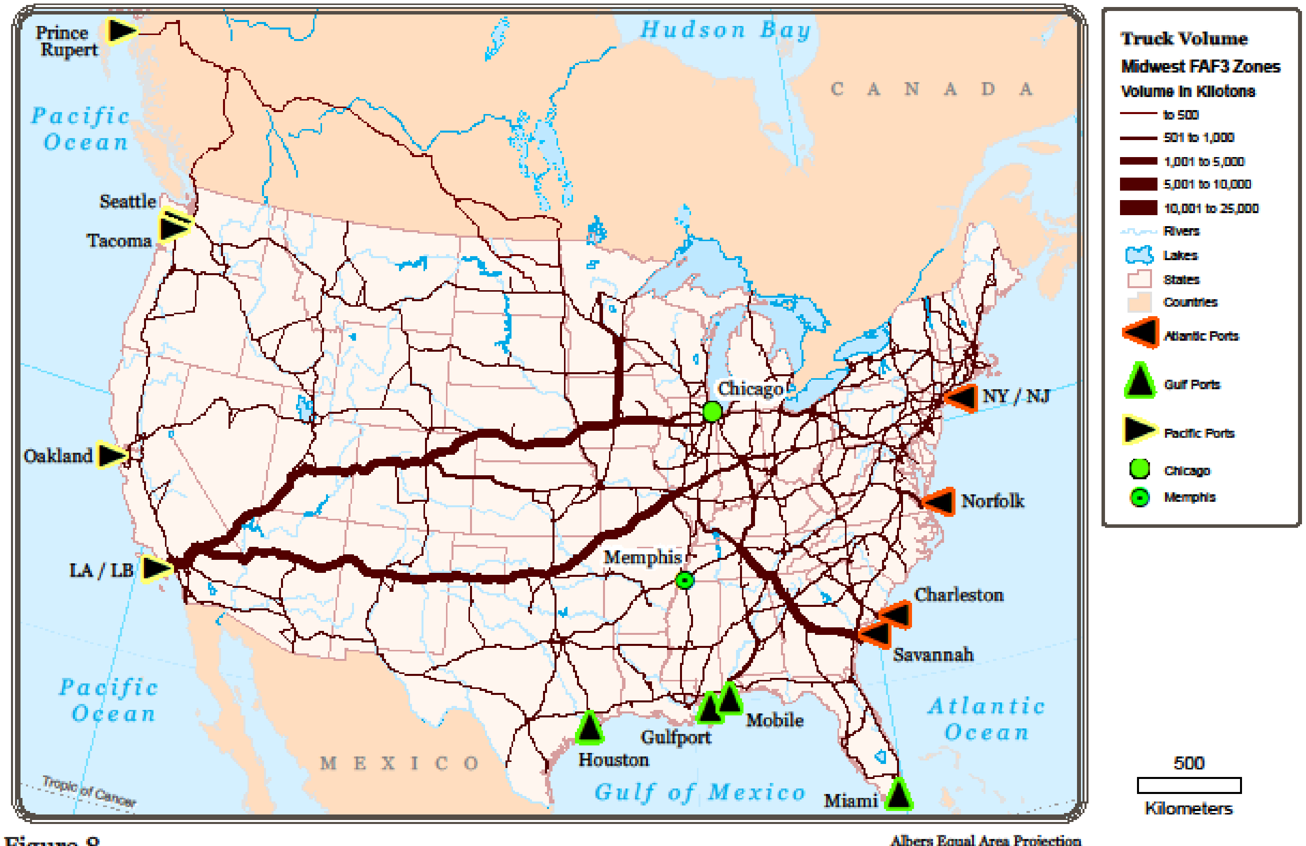


Figure 8
Results of Scenario 6: Truck Assignment (2020), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion – The Complete U.S. – Population Proportion Per State – Truck

ALL FAF3 Regions: Volume/ Population Proportion 2012

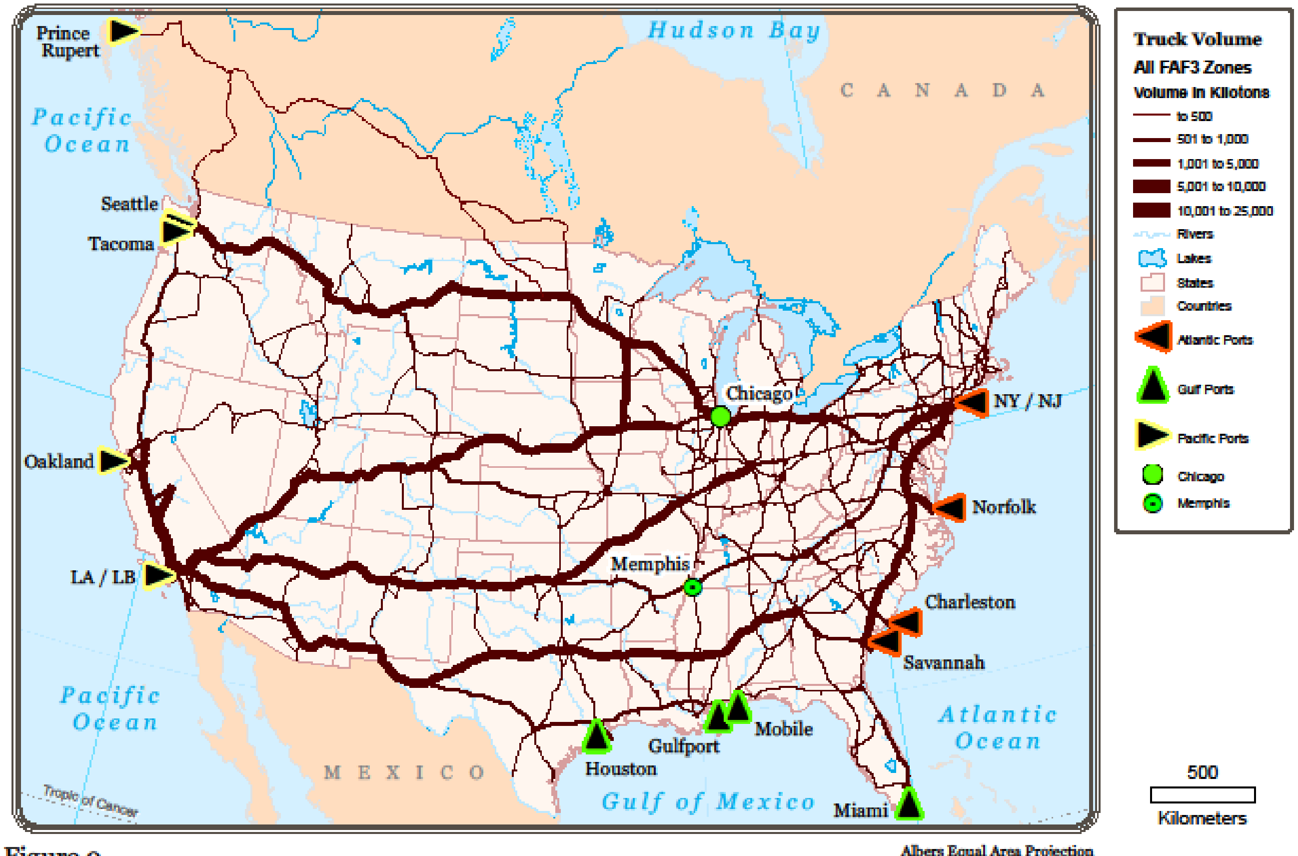


Figure 9
Results of Scenario 7: Truck Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – The Complete U.S. – Population Proportion Per State – Truck

ALL FAF3 Regions: Volume/ Population Proportion 2019

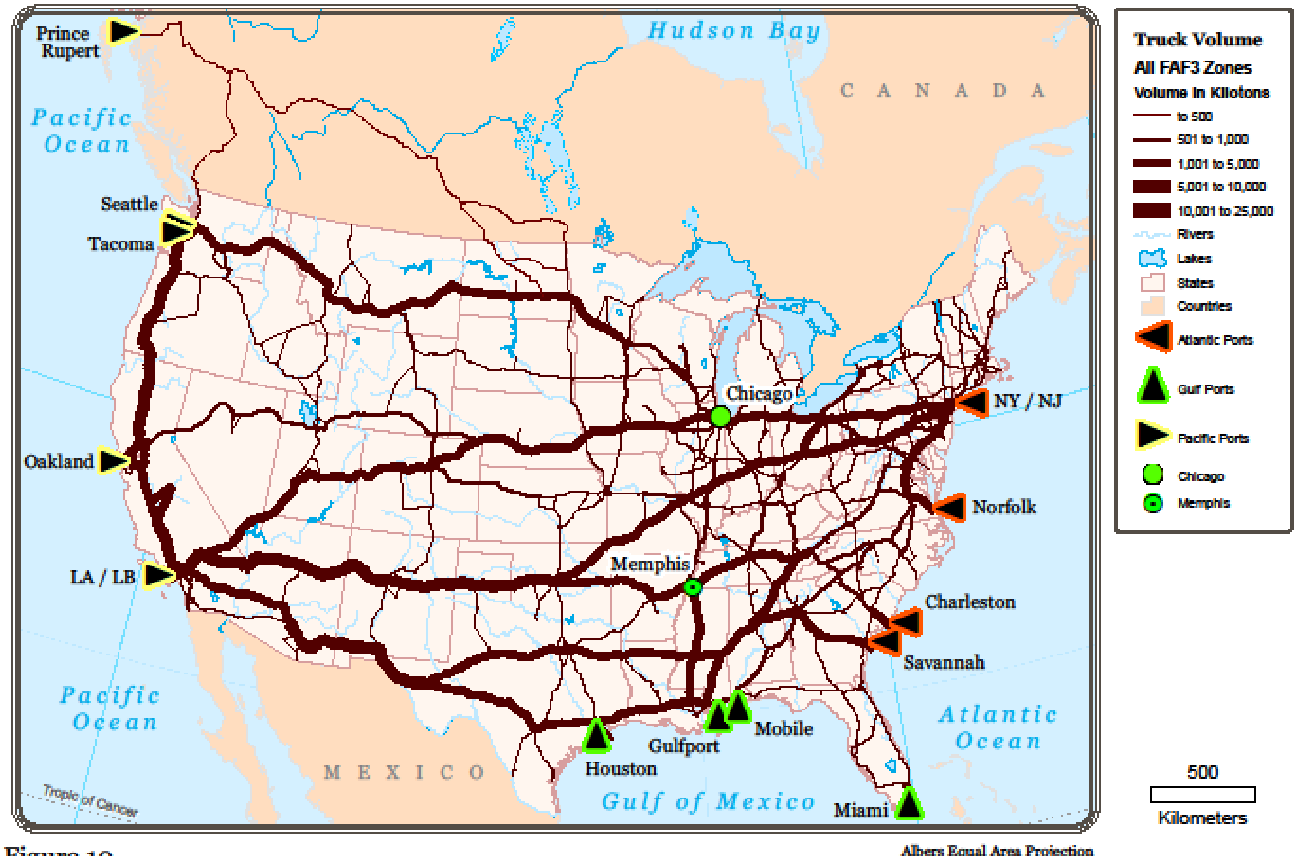


Figure 10
Results of Scenario 8: Truck Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – The Complete U.S. – Population Proportion Per State – Truck

ALL FAF3 Regions: Volume/ Population Proportion 2020

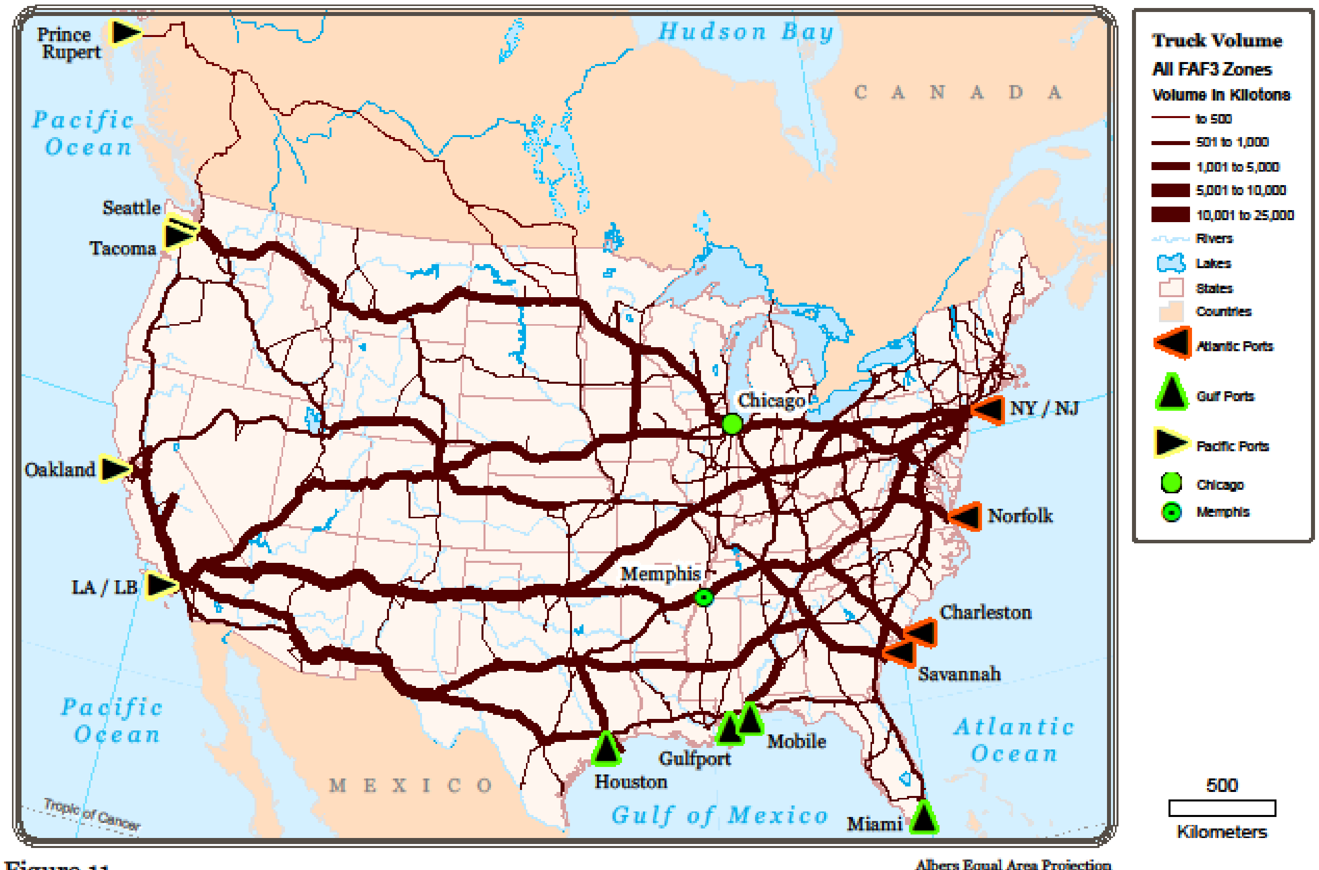


Figure 11
Results of Scenario 9: Truck Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion – Midwest Region – Population Proportion Per State – Truck

Midwest FAF3 Regions: Volume/ Population Proportion 2012

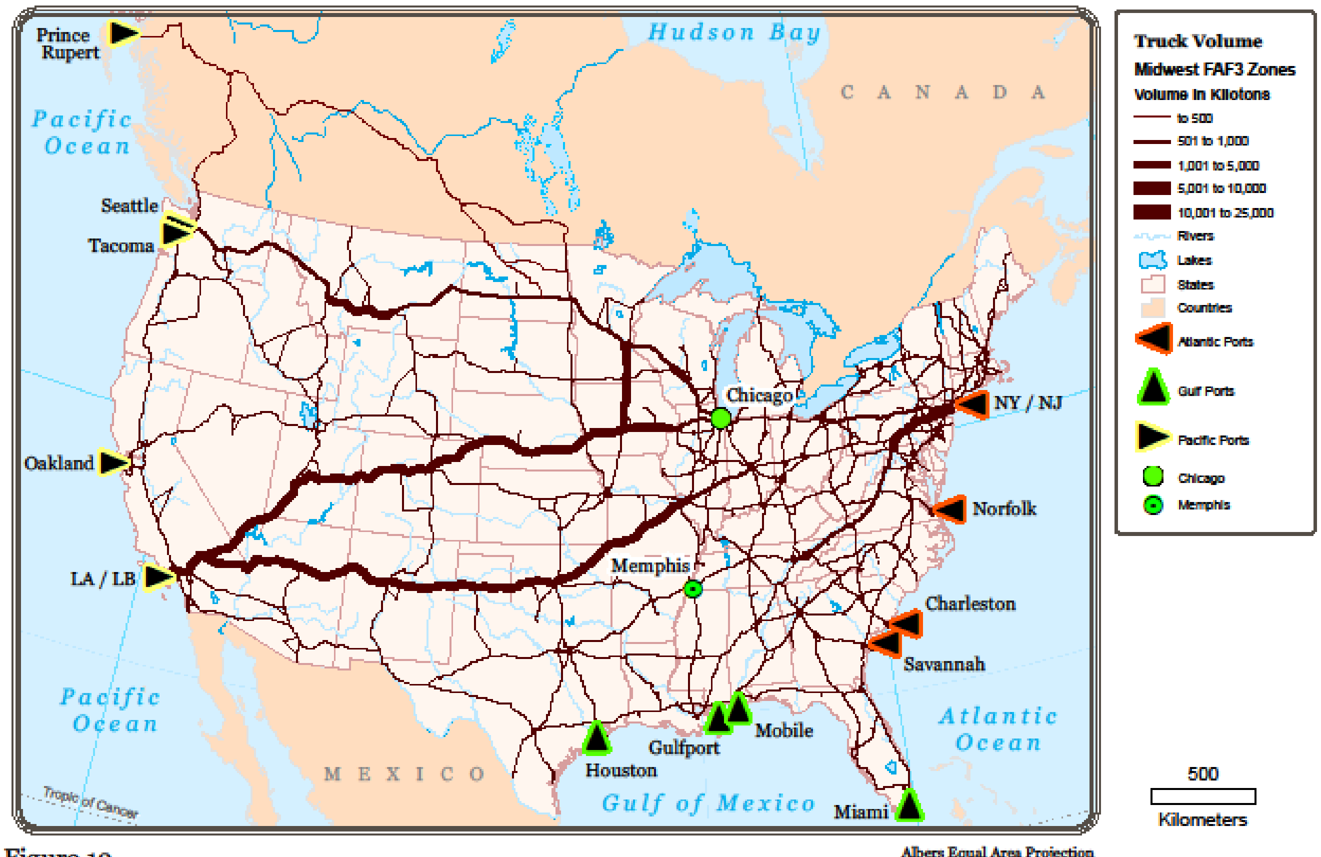


Figure 12
Results of Scenario 10: Truck Assignment (2012), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – Midwest Region – Population Proportion Per State – Truck

Midwest FAF3 Regions: Volume/ Population Proportion 2019

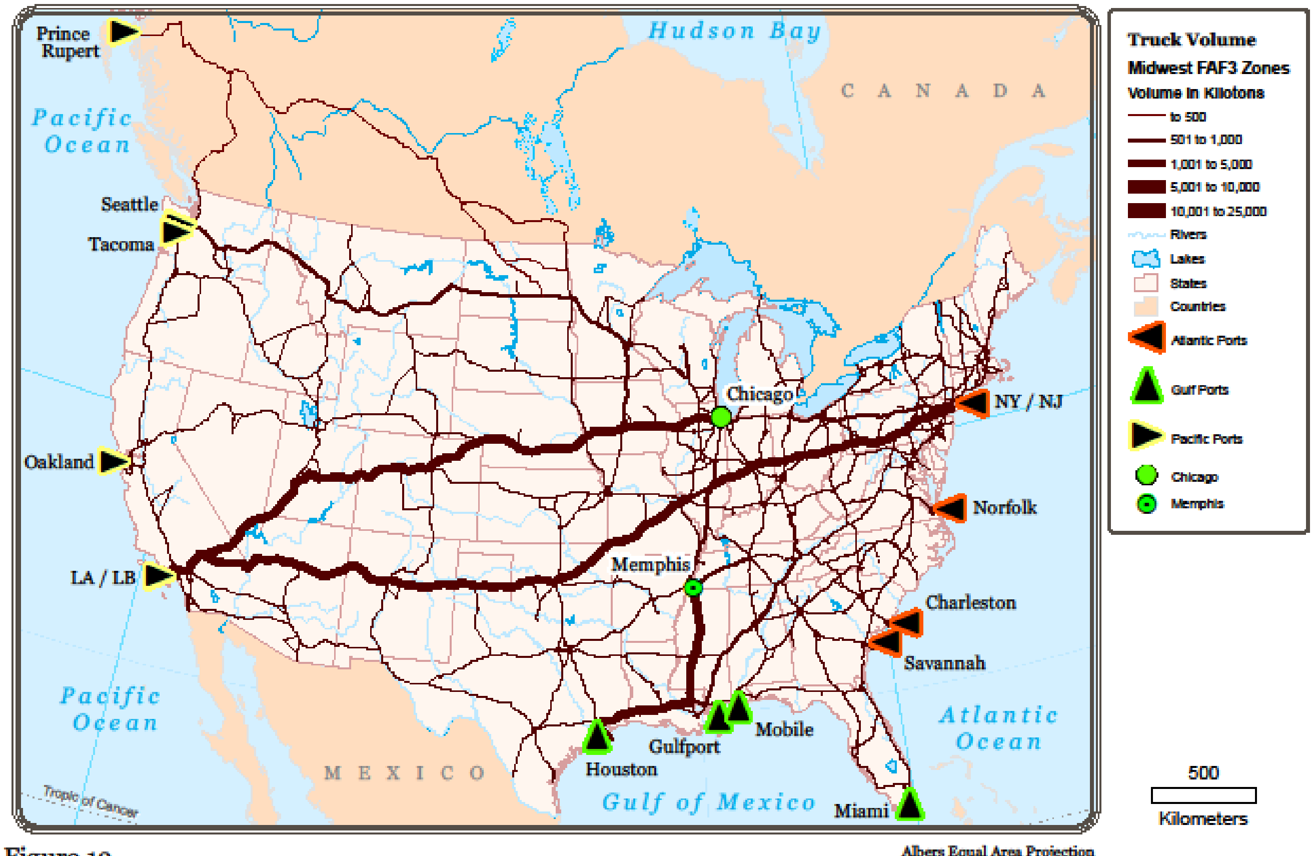


Figure 13
Results of Scenario 11: Truck Assignment (2019), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – Midwest Region – Population Proportion Per State – Truck

Midwest FAF3 Regions: Volume/ Population Proportion 2020

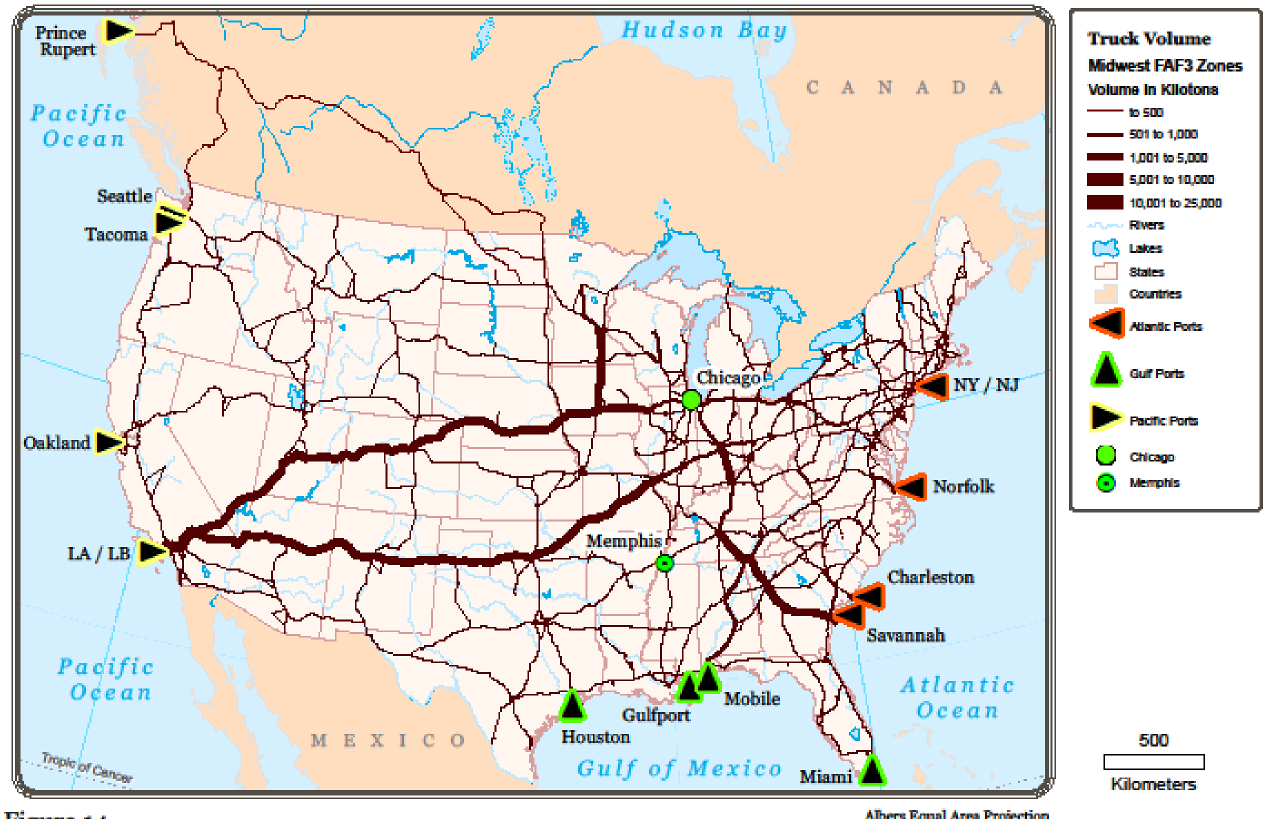


Figure 14
Results of Scenario 12: Truck Assignment (2020), Midwest Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion - The Complete U.S. – Number of FAF3 Zones Per State – Rail

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

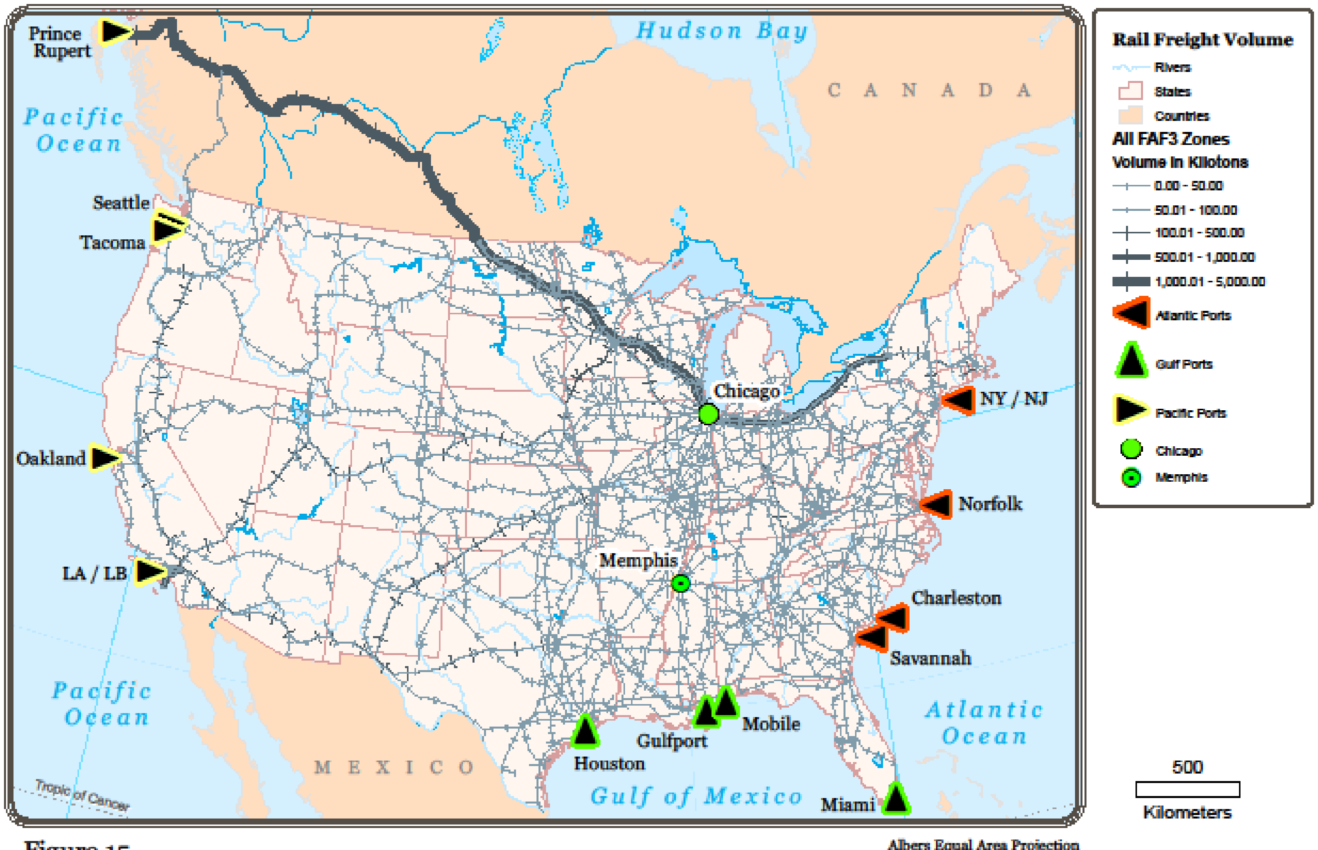


Figure 15
Results of Scenario 1: Freight Assignment (2012), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert - The Complete U.S. – Number of FAF3 Zones Per State – Rail

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

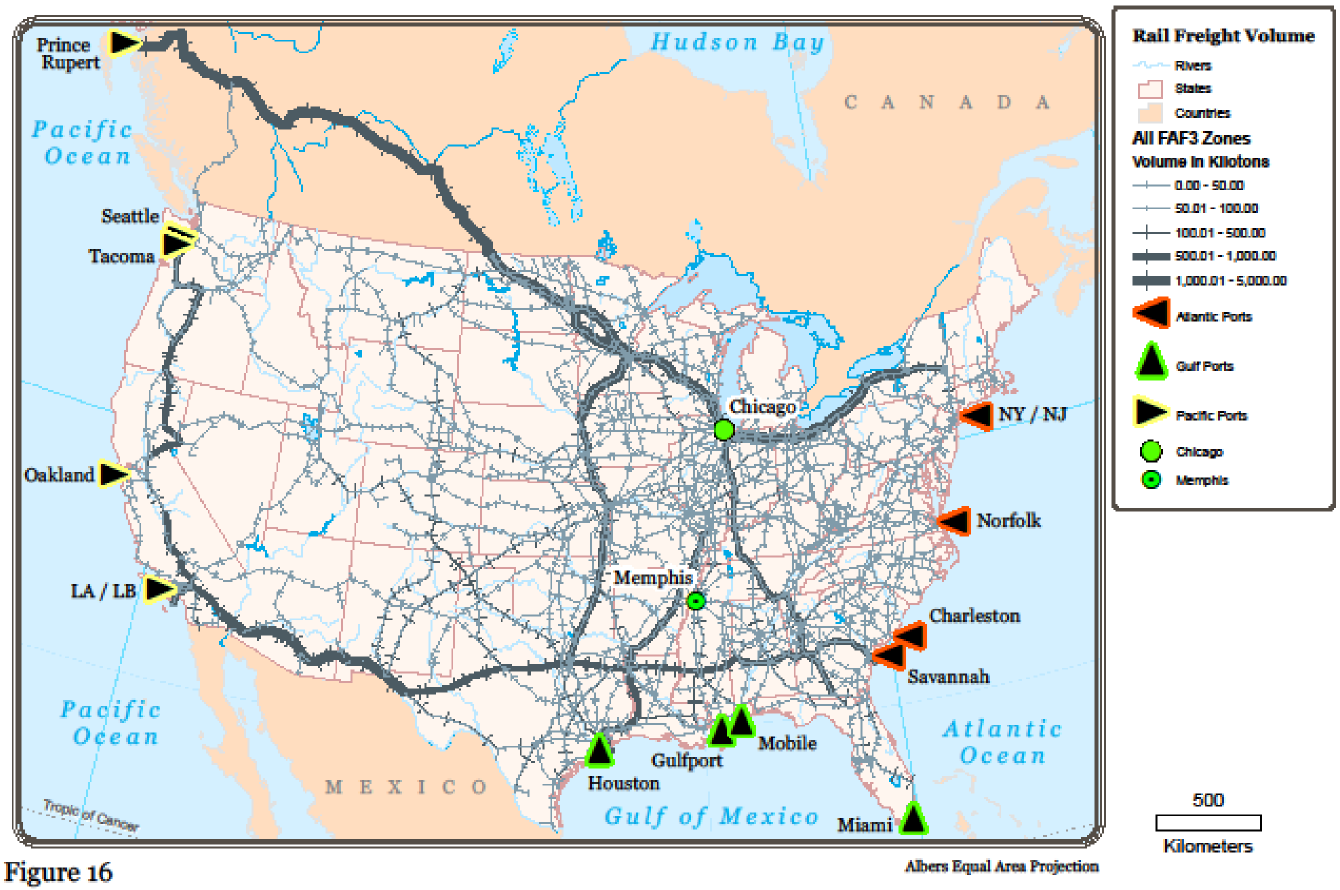


Figure 16
Results of Scenario 2: Freight Assignment (2019), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert - The Complete U.S. – Number of FAF3 Zones Per State – Rail

ALL FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

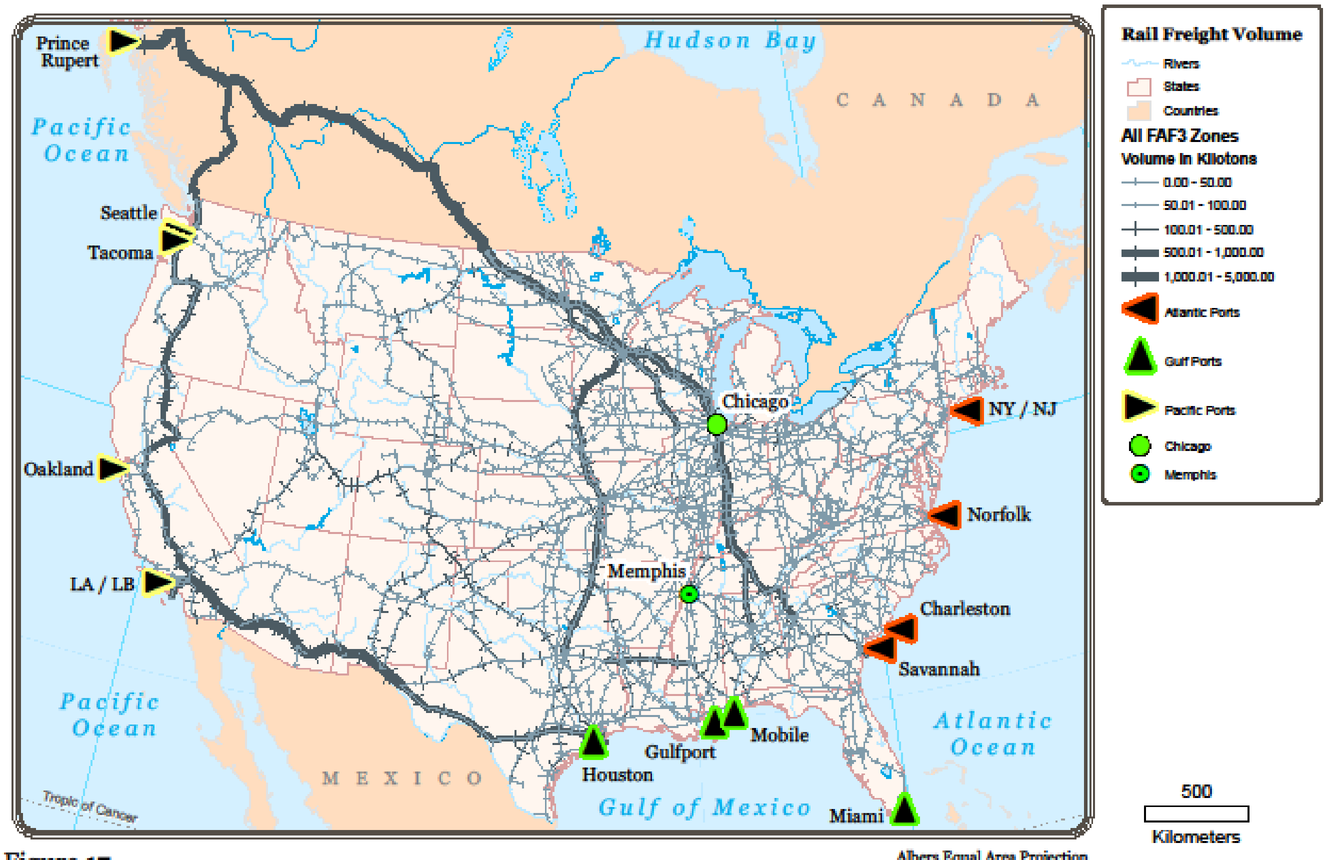


Figure 17
Results of Scenario 3: Freight Assignment (2020), All Freight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion– Midwest Region – Number of FAF3 Zones Per State – Rail

Midwest FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

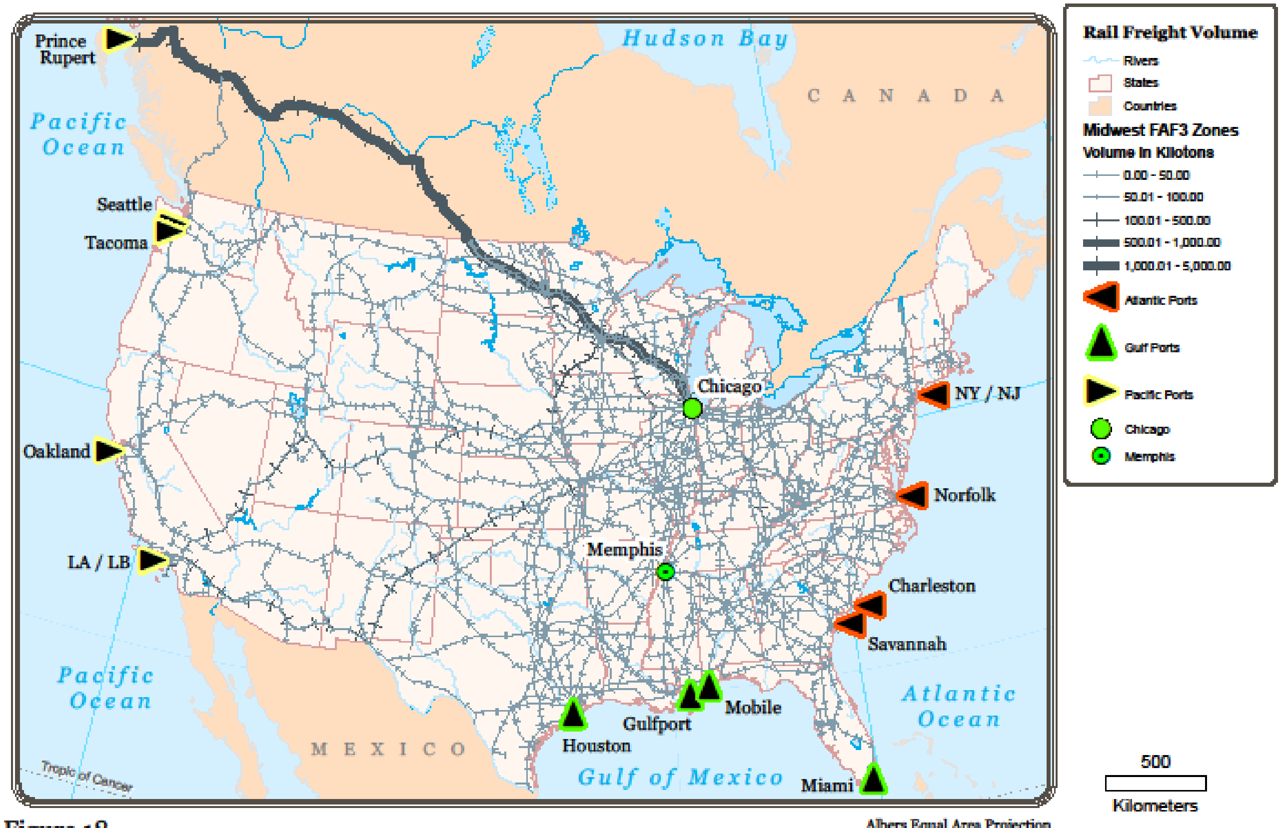


Figure 18
Results of Scenario 4: Freight Assignment (2012), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – Midwest Region – Number of FAF3 Zones Per State – Rail

Midwest FAF3 Zones: Volume/ Numbers of FAF3 Zones by State

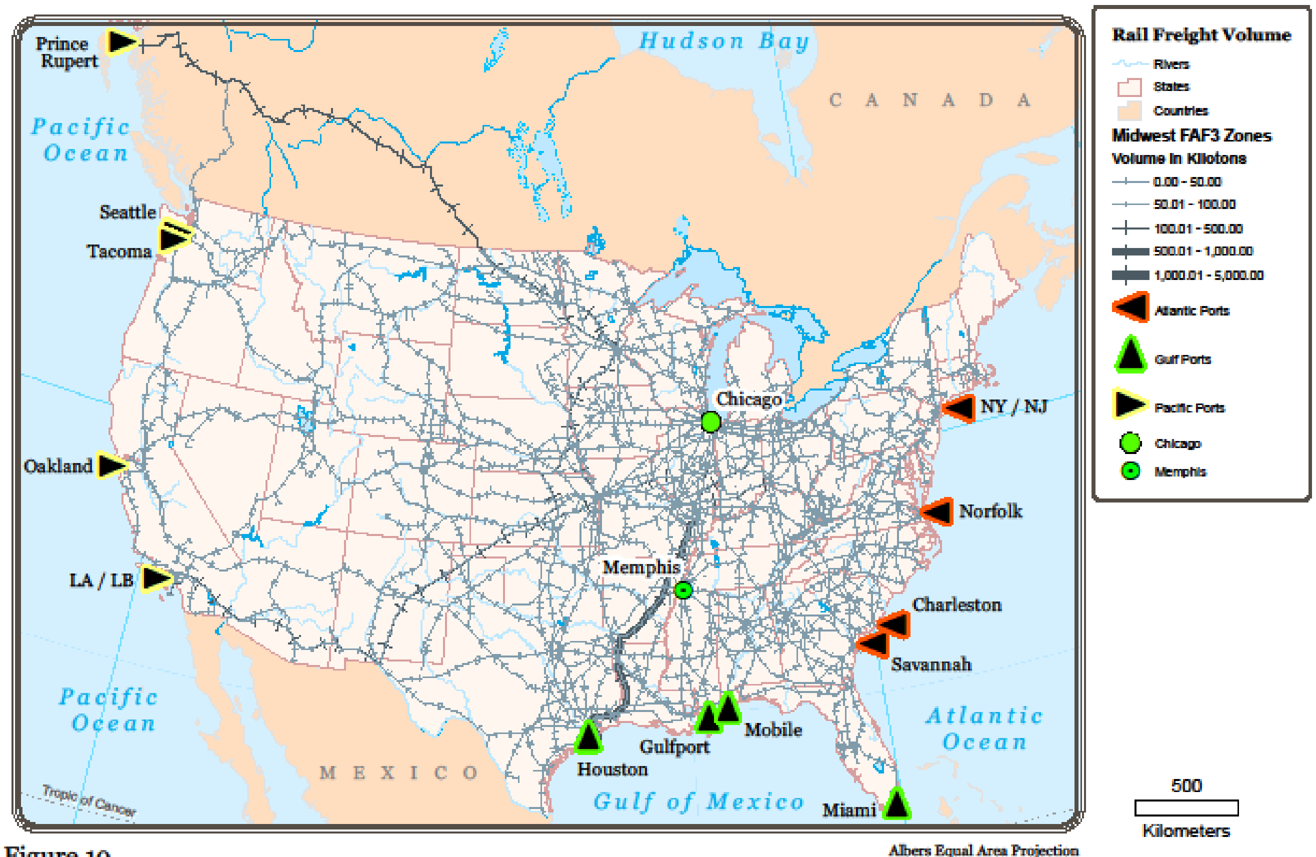


Figure 19
Results of Scenario 5: Freight Assignment (2019), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – Midwest Region – Number of FAF3 Zones Per State – Rail

All FAF3 Zones: Volume/ Population Proportion by State

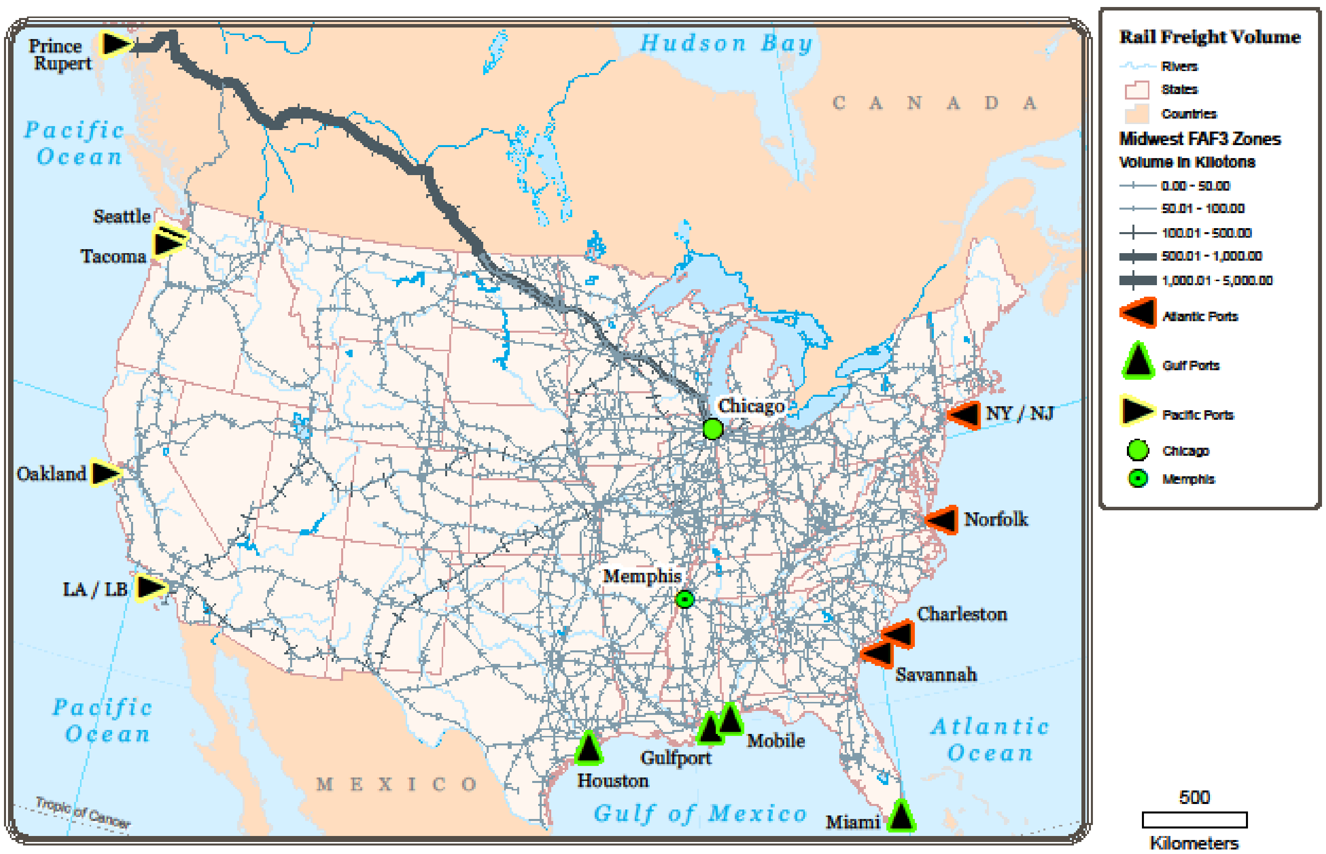


Figure 20
Results of Scenario 6: Freight Assignment (2020), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2012 Before Panama Canal Expansion – The Complete U.S. – Population Proportion Per State – Rail

All FAF3 Zones: Volume/ Population Proportion by State

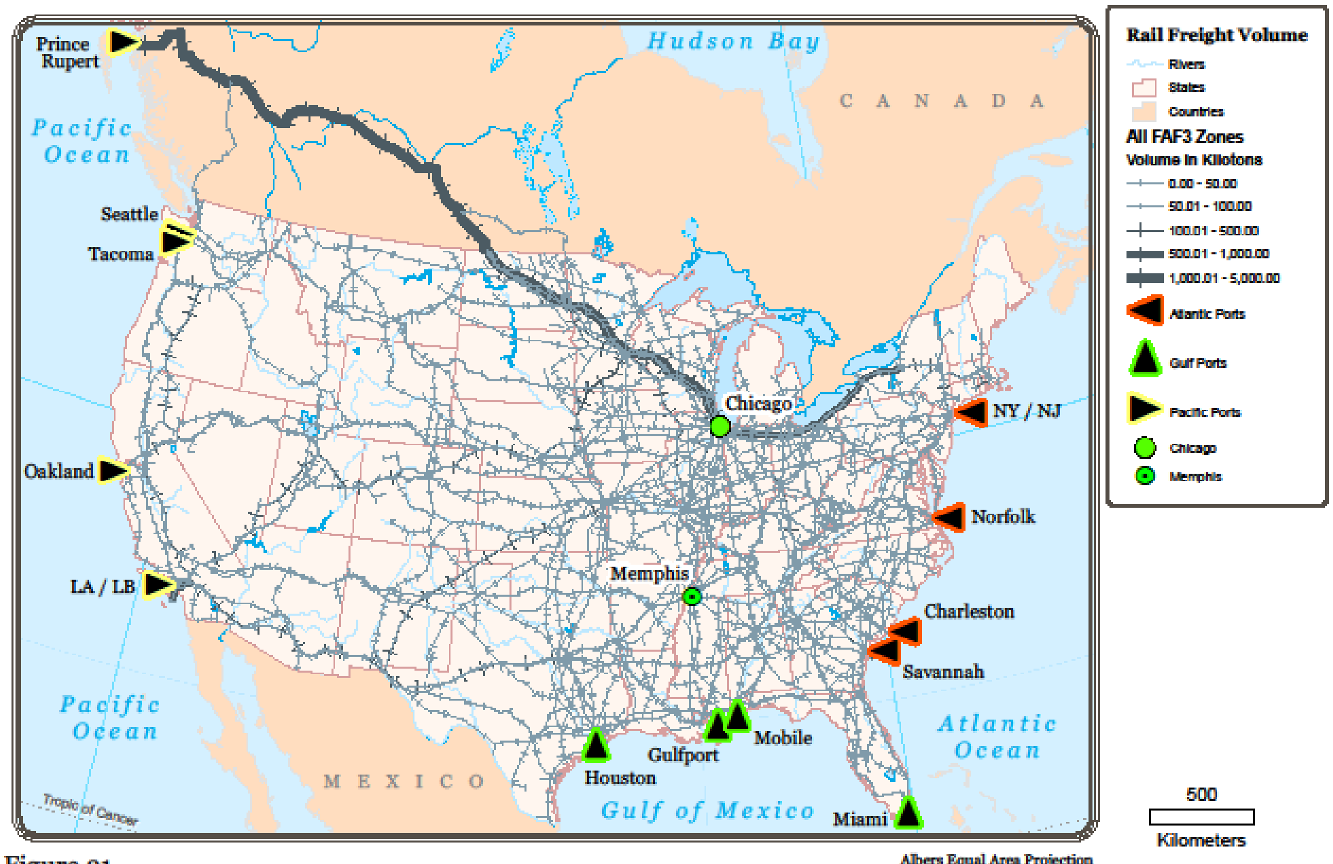


Figure 21
Results of Scenario 7: Freight Assignment (2012), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Numbers of FAF3 Zones in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – The Complete U.S. – Population Proportion Per State – Rail

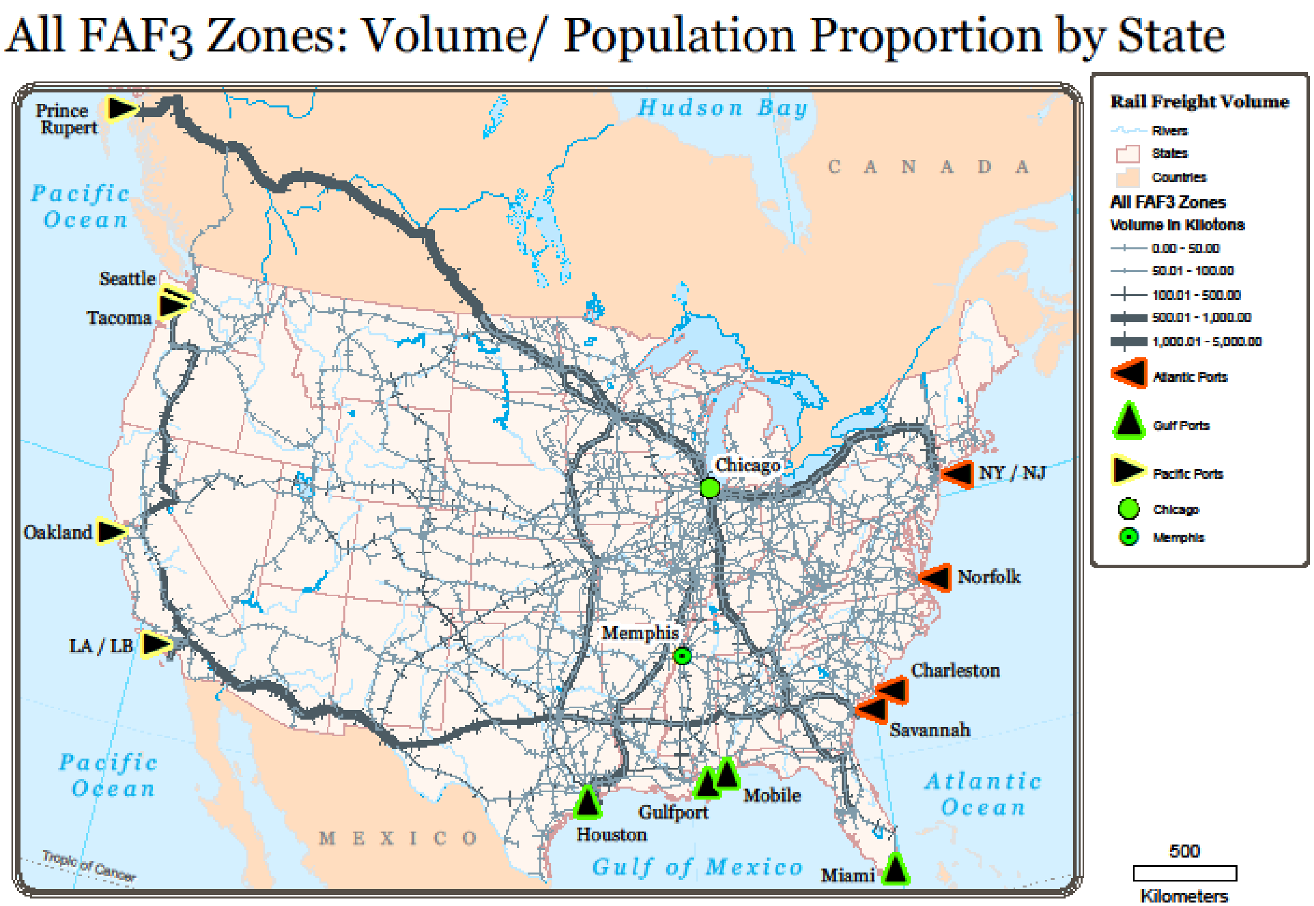


Figure 22
Results of Scenario 8: Freight Assignment (2019), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – The Complete U.S. – Population Proportion Per State – Rail

All FAF3 Zones: Volume/ Population Proportion by State

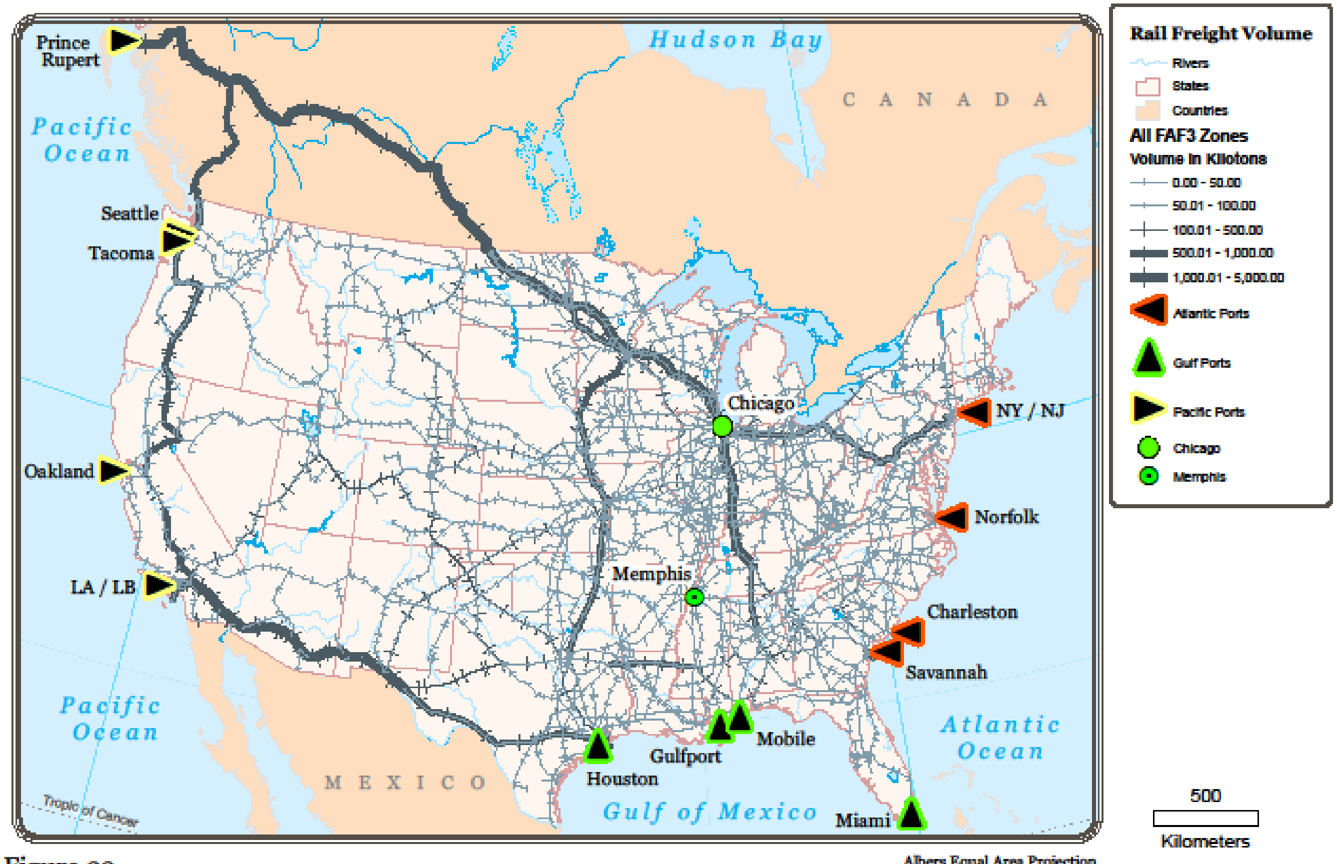


Figure 23
Results of Scenario 9: Freight Assignment (2020), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

Midwest FAF3 Zones: Volume/ Population Proportion by State

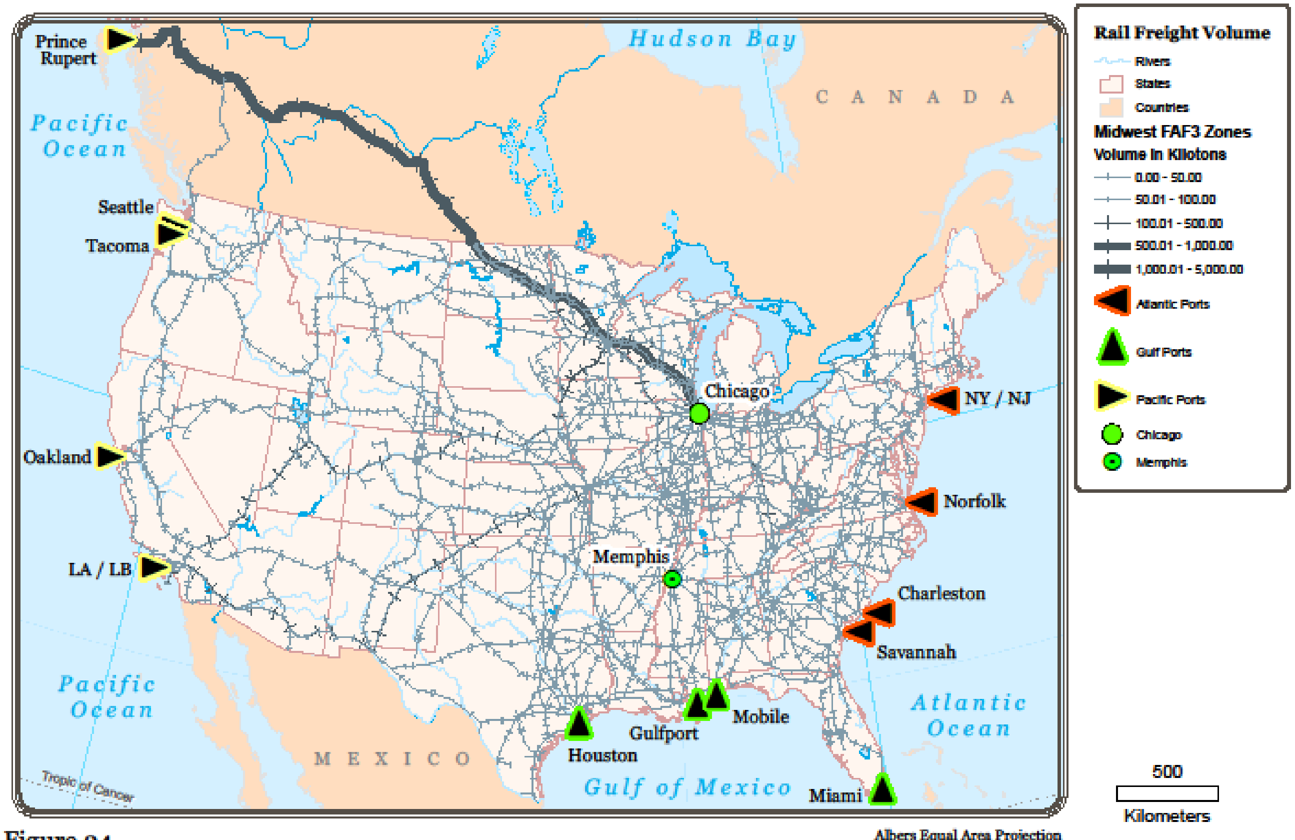


Figure 24
Results of Scenario 10: Freight Assignment (2012), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling before Panama Canal expansion and before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2019 After Panama Canal Expansion Before Prince Rupert – Midwest Region – Population Proportion Per State – Rail

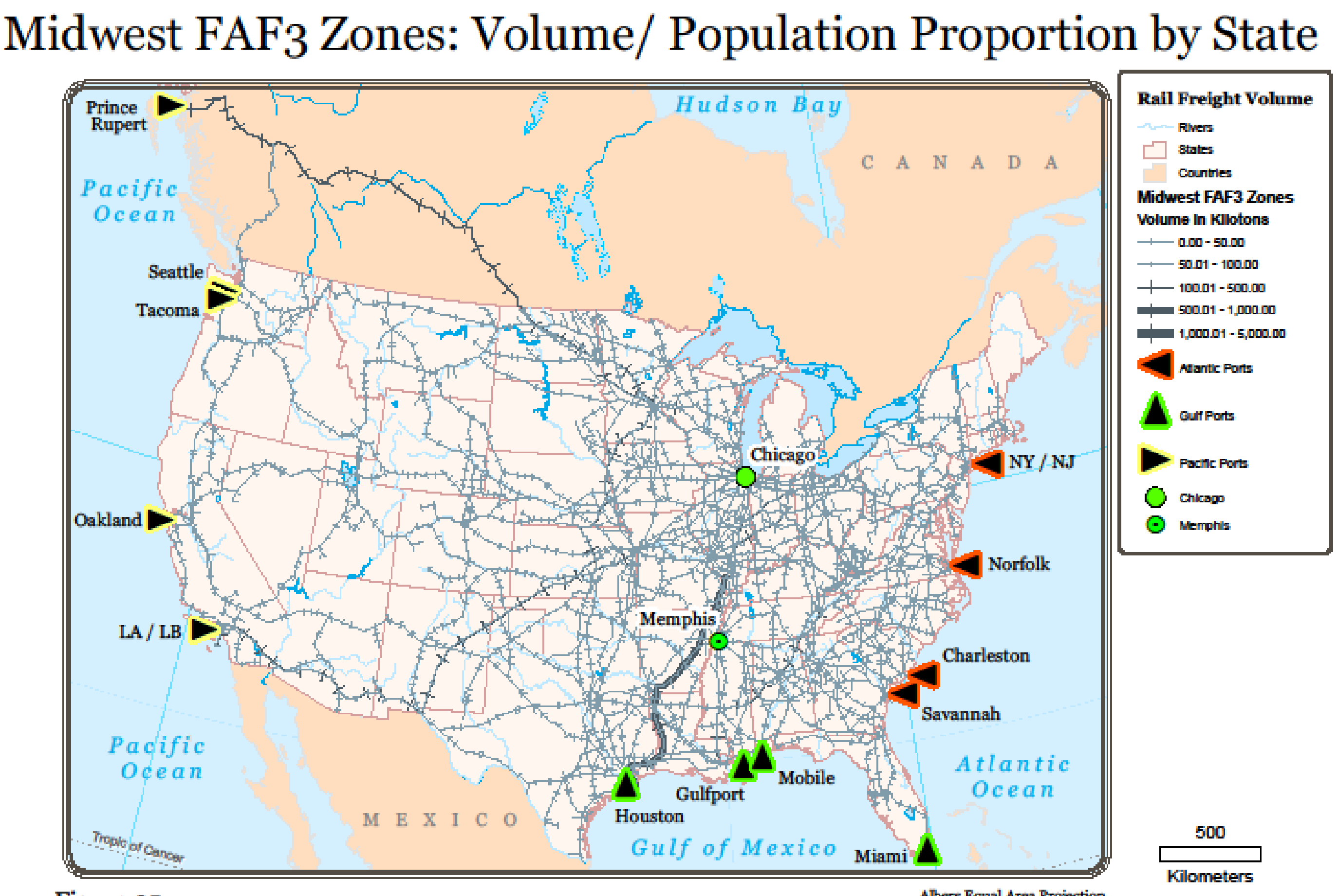


Figure 25
Results of Scenario 11: Freight Assignment (2019), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion but before Prince Rupert expansion.

U.S. Interior Optimized Scenarios – 2020 After Panama Canal Expansion and Prince Rupert – Midwest Region – Population Proportion Per State – Rail

Midwest FAF3 Zones: Volume/ Population Proportion by State

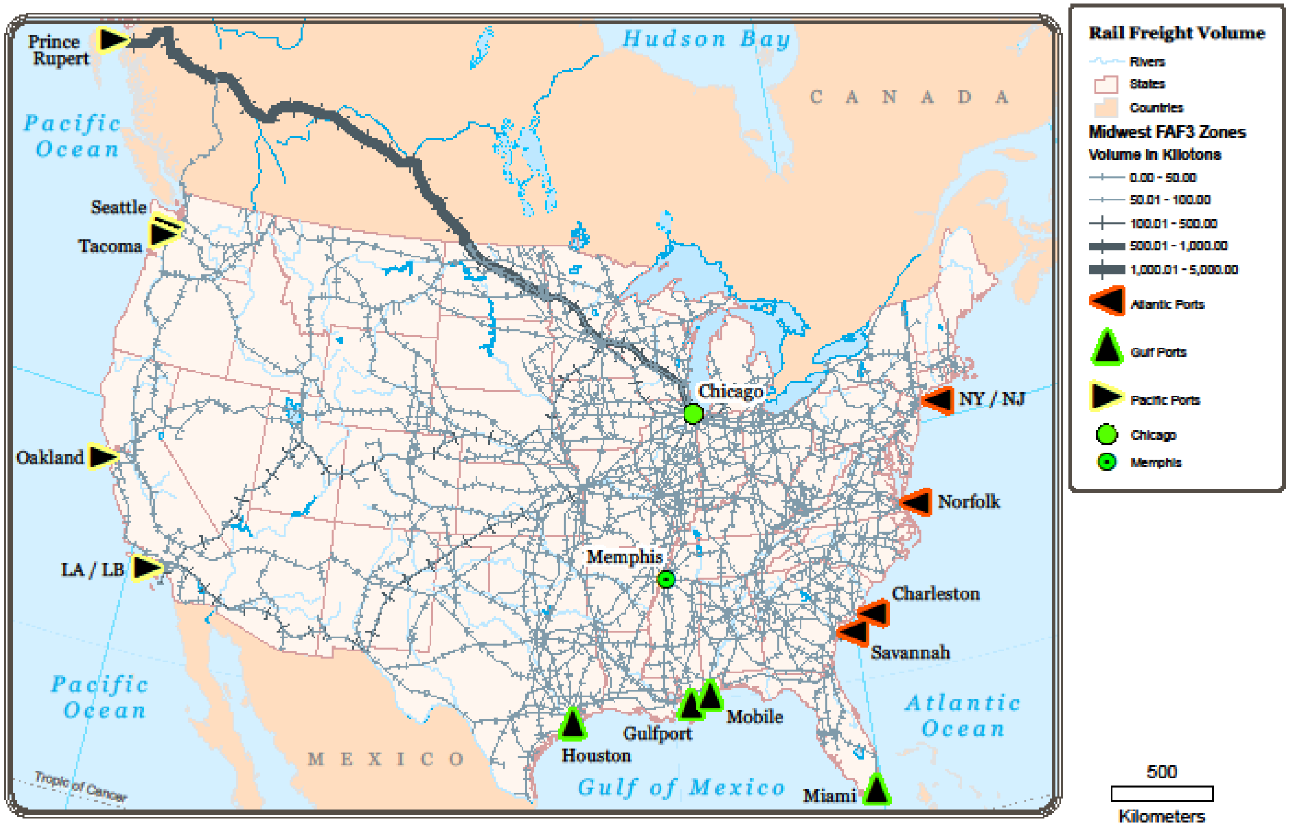


Figure 26
Results of Scenario 12: Freight Assignment (2020), MidwestFreight Analysis Framework 3 [FAF3] Zones with Proportion of State Freight Volume by Population Proportion in each State. Modeling after Panama Canal expansion and after Prince Rupert expansion.

APPENDIX C – SENSITIVITY ANALYSIS SCENARIOS

RI-6 Sensitivity Analysis Scenarios – 100% of 2012 Volume – Truck

Truck Scenario 1

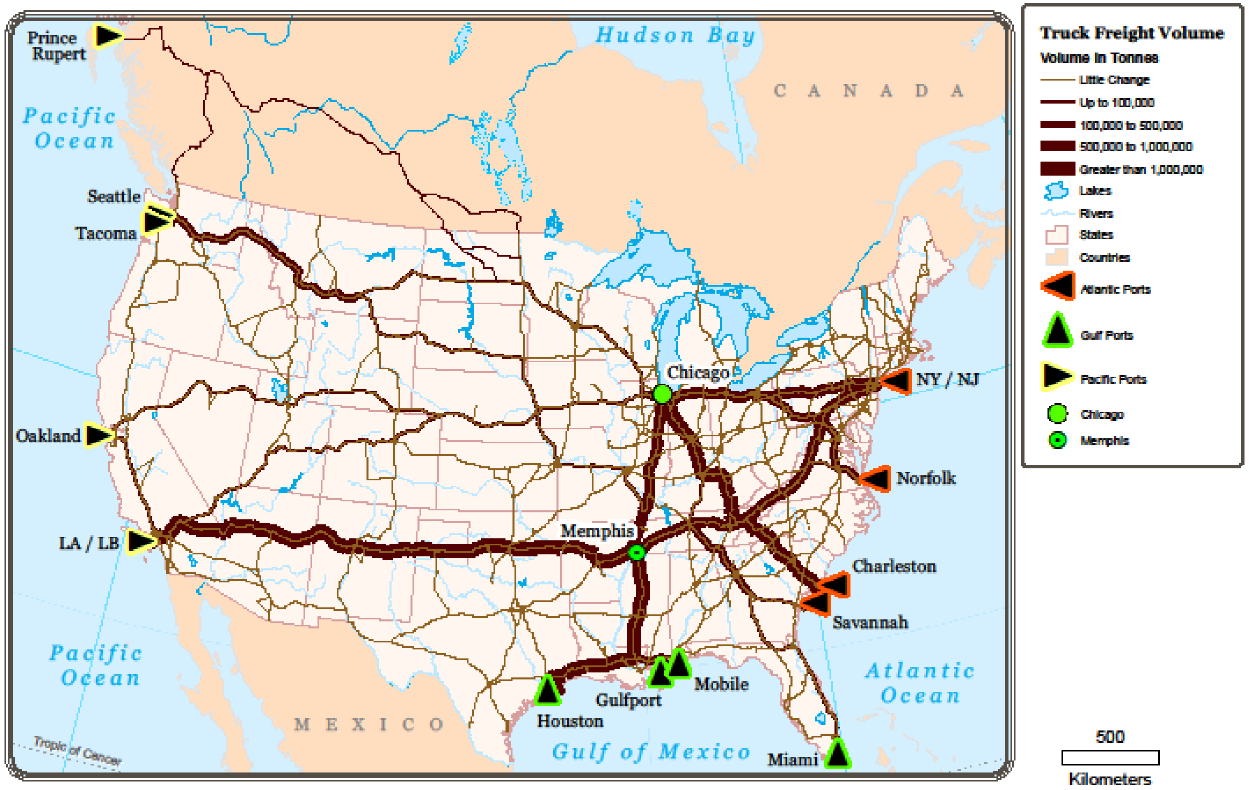


Figure 1
Scenario 1: 2012 container freight flows from 13 US ports to Memphis and Chicago markets via trucks

RI-6 Sensitivity Analysis Scenarios – 70% of 2020 Forecast Volume – Truck

Truck Scenario 2

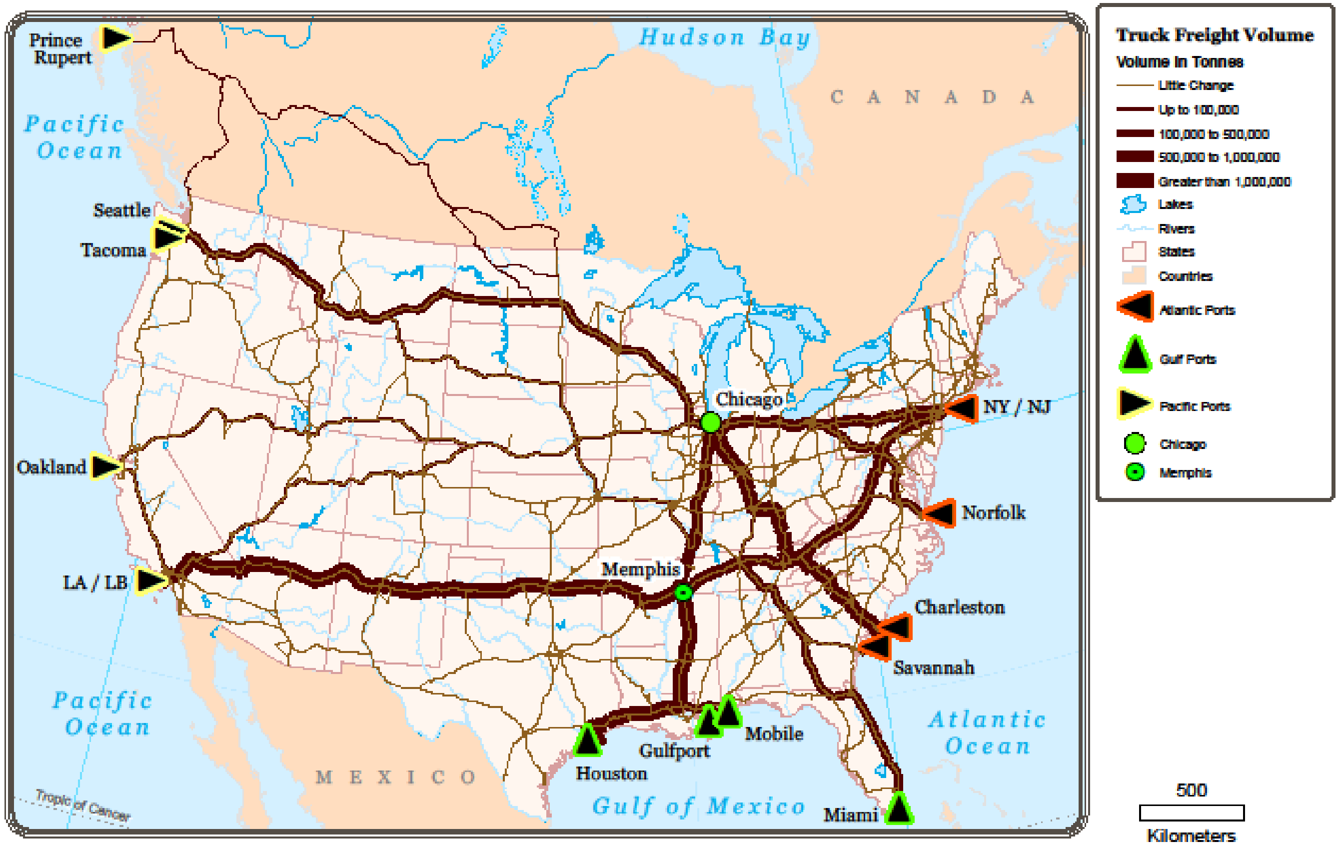


Figure 2
Scenario 2: 70% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via trucks [Forecasted container fright flows for 2020 was received from individual port studies].

RI-6 Sensitivity Analysis Scenarios – 85% of 2020 Forecast Volume – Truck

Truck Scenario 3

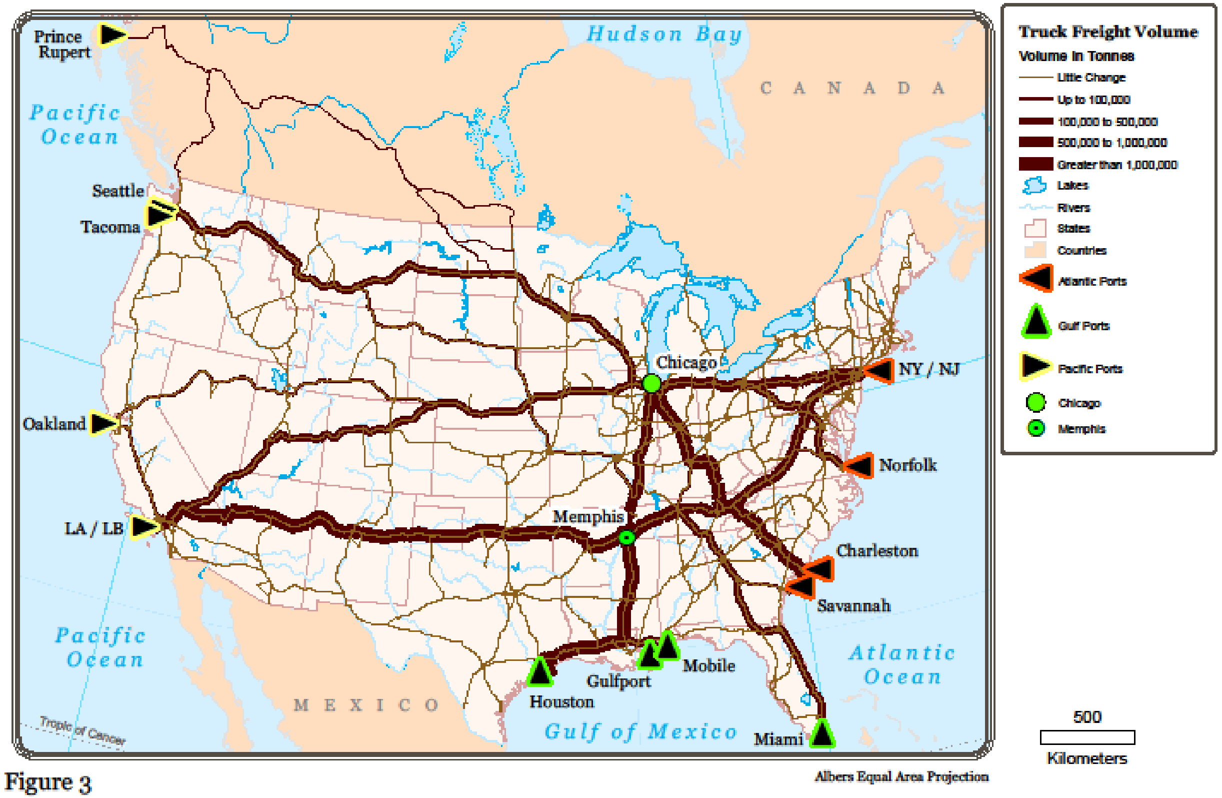


Figure 3
Scenario 3: 85% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via trucks [Forecasted container fright flows for 2020 was received from individual port studies].

Truck Scenario 4

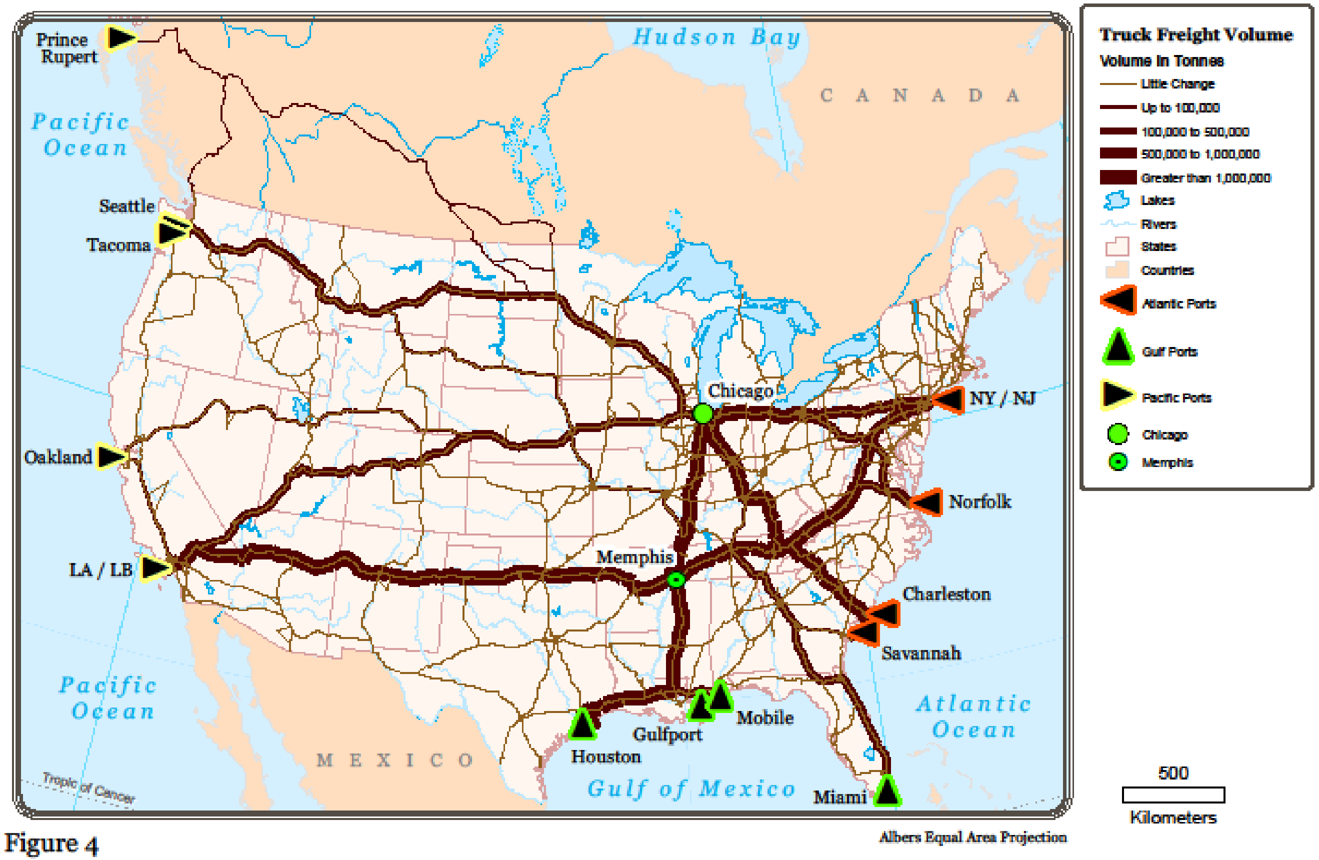


Figure 4
Scenario 4: 100% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via trucks [Forecasted container fright flows for 2020 was received from individual port studies].

Truck Scenario 5

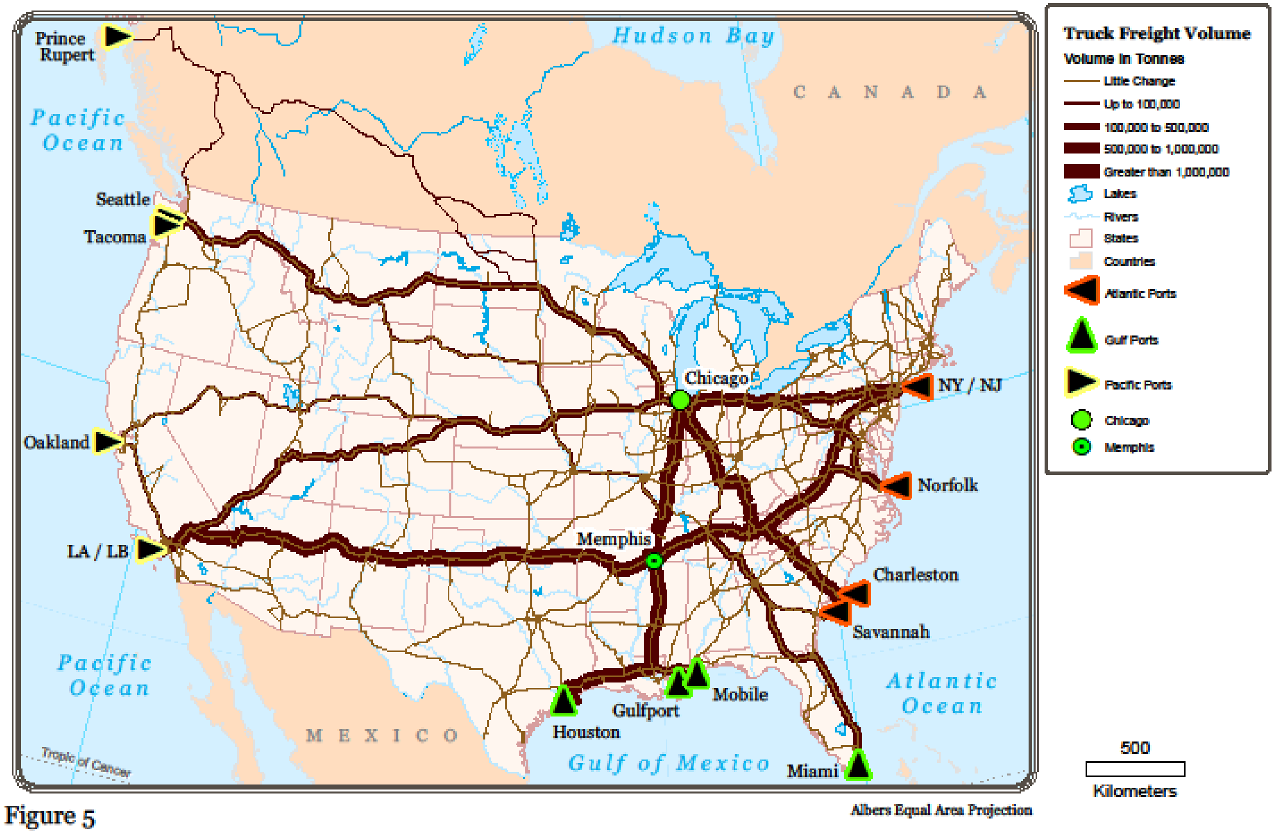


Figure 5
Scenario 5: 115% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via trucks [Forecasted container fright flows for 2020 was received from individual port studies].

RI-6 Sensitivity Analysis Scenarios – 130% of 2020 Forecast Volume – Truck

Truck Scenario 6

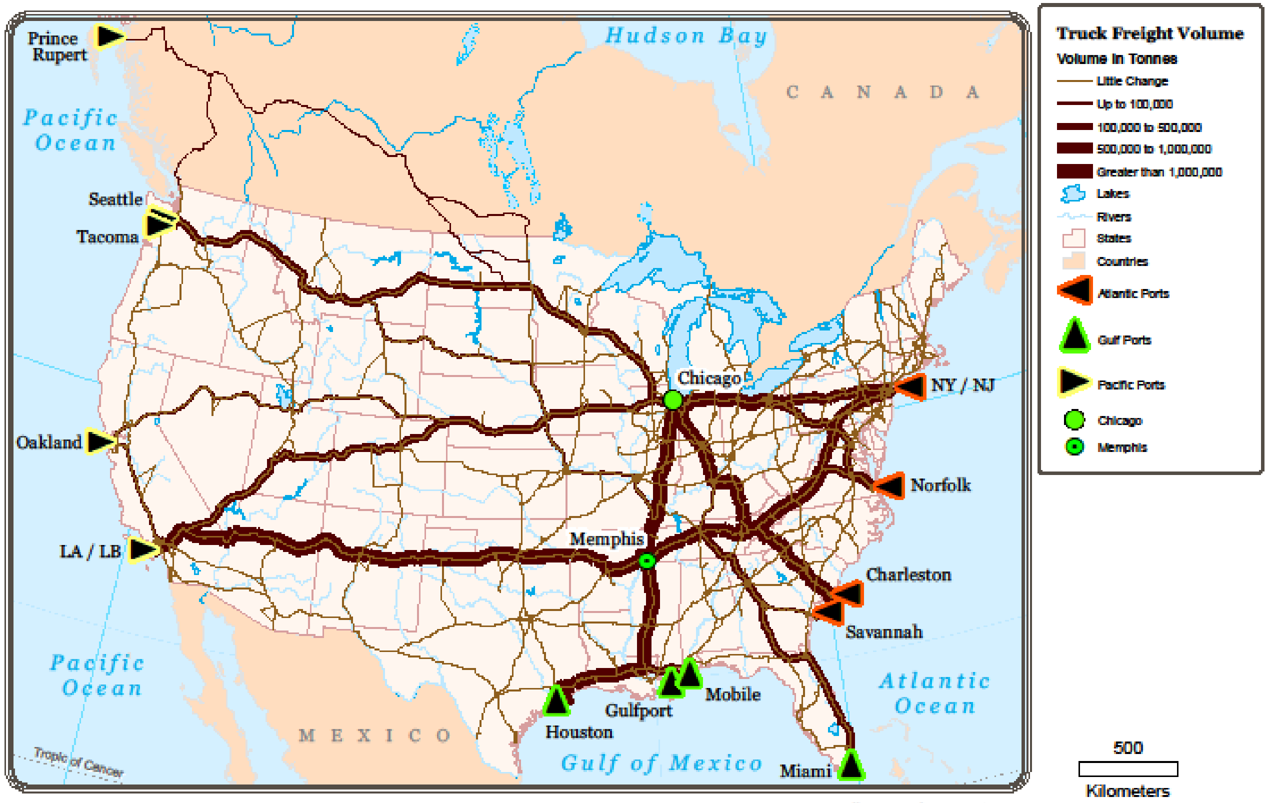


Figure 6
Scenario 6: 130% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via trucks [Forecasted container fright flows for 2020 was received from individual port studies].

RI-6 Sensitivity Analysis Scenarios – 100% of 2012 Volume – Rail

Rail Scenario 1

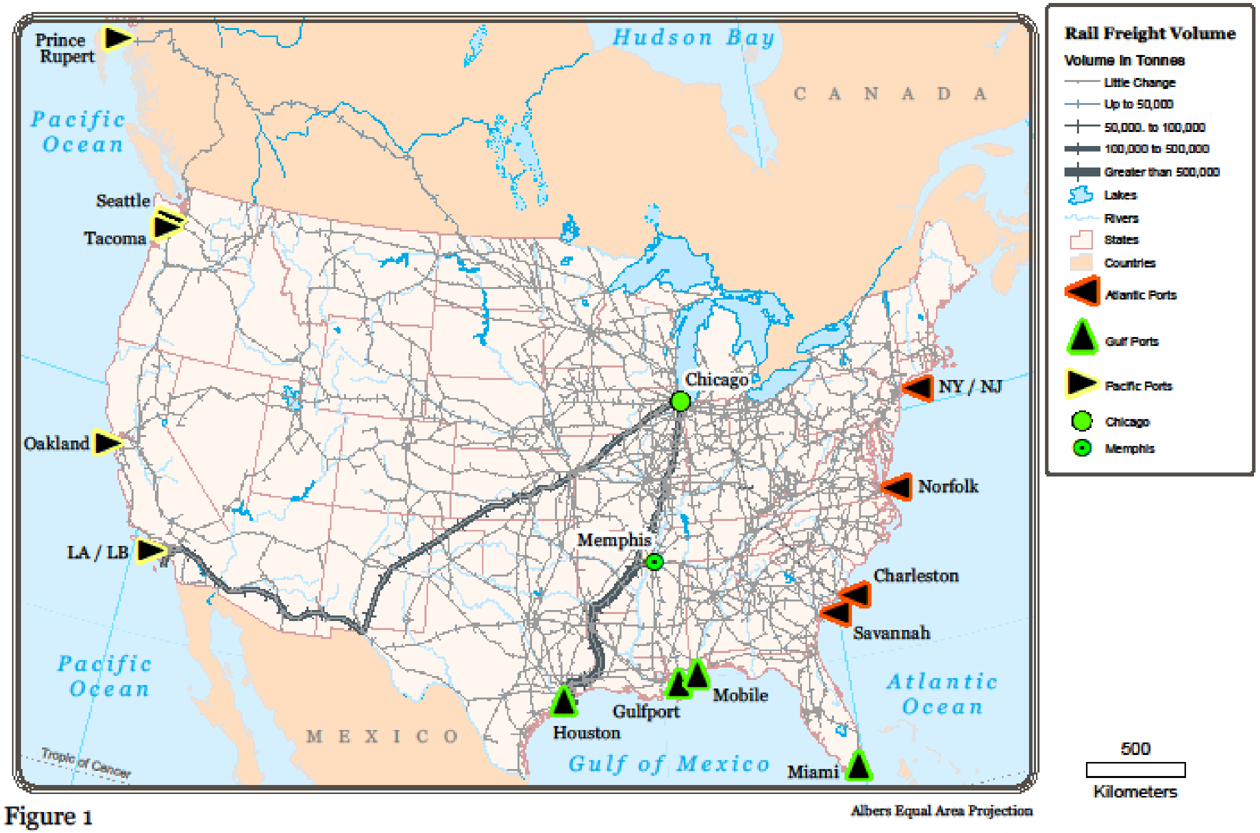


Figure 1
Scenario 1: 2012 container freight flows from 13 US ports to Memphis and Chicago markets via tracks

RI-6 Sensitivity Analysis Scenarios – 70% of 2020 Forecast Volume – Rail

Rail Scenario 2

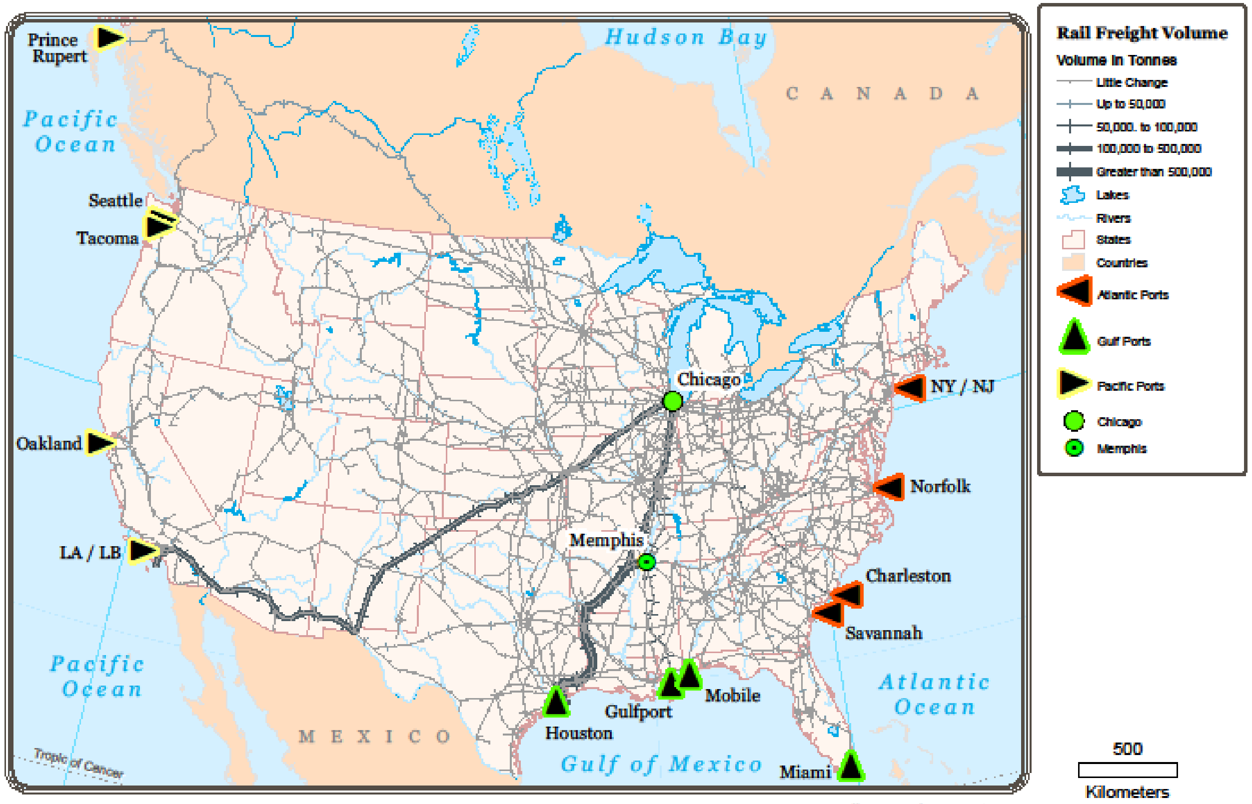


Figure 2
Scenario 2: 70% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via tracks [Forecasted container fright flows for 2020 was received from individual port studies].

Rail Scenario 3

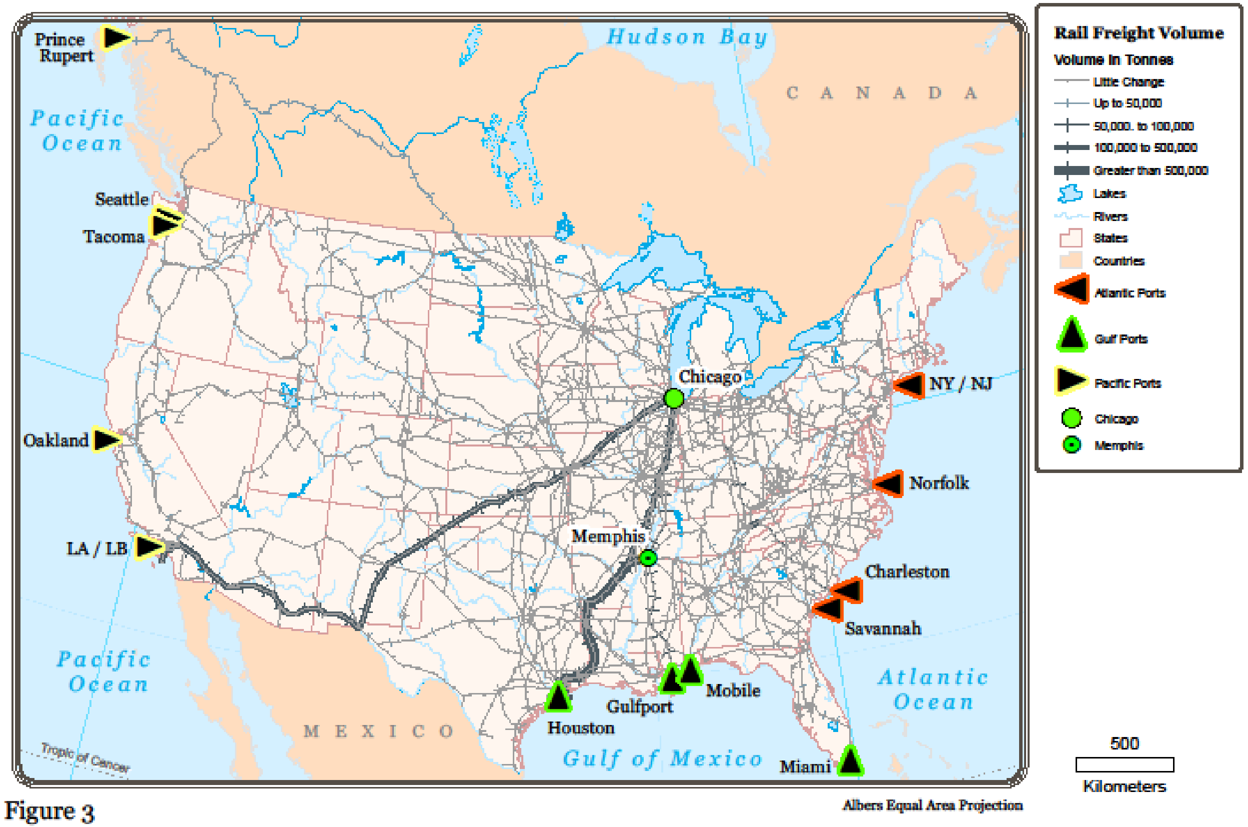


Figure 3
Scenario 3: 85% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via tracks [Forecasted container fright flows for 2020 was received from individual port studies].

RI-6 Sensitivity Analysis Scenarios – 100% of 2020 Forecast Volume – Rail

Rail Scenario 4

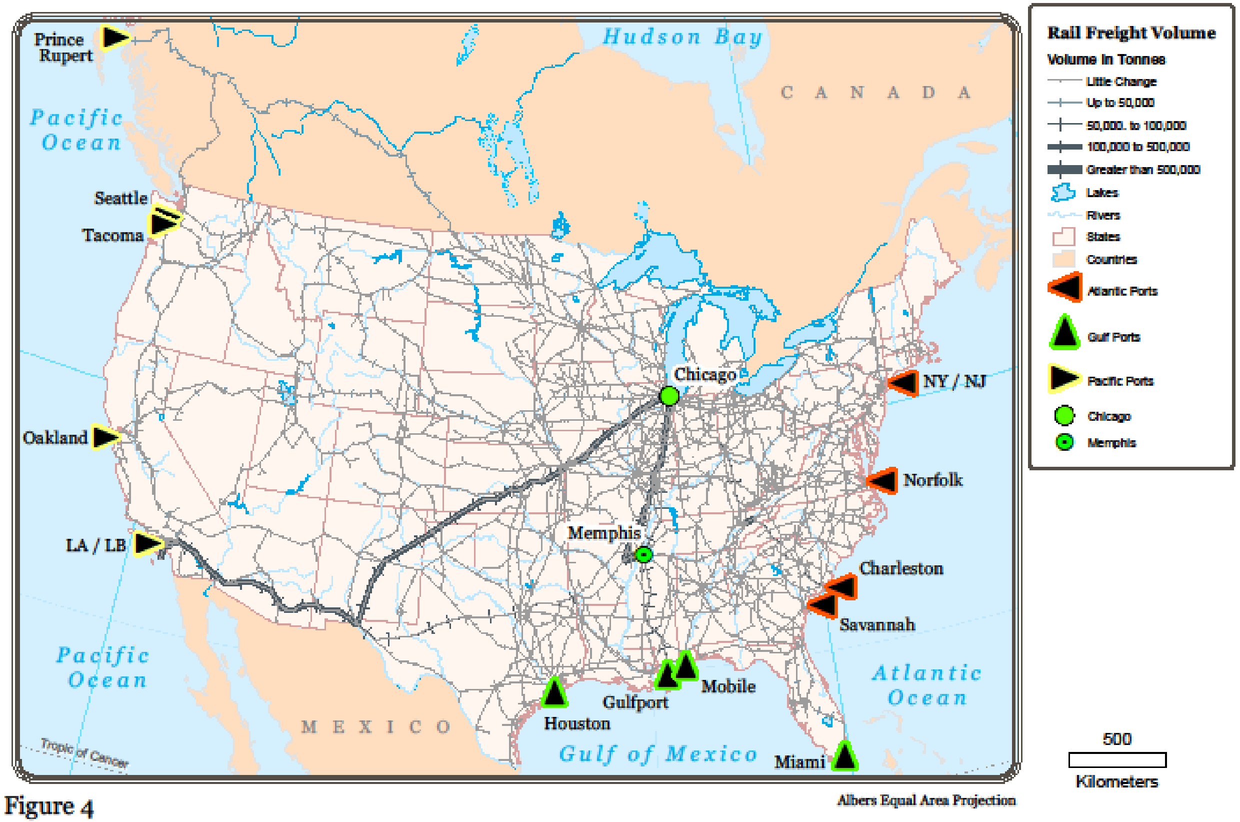


Figure 4
Scenario 4: 100% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via tracks [Forecasted container fright flows for 2020 was received from individual port studies].

Rail Scenario 5

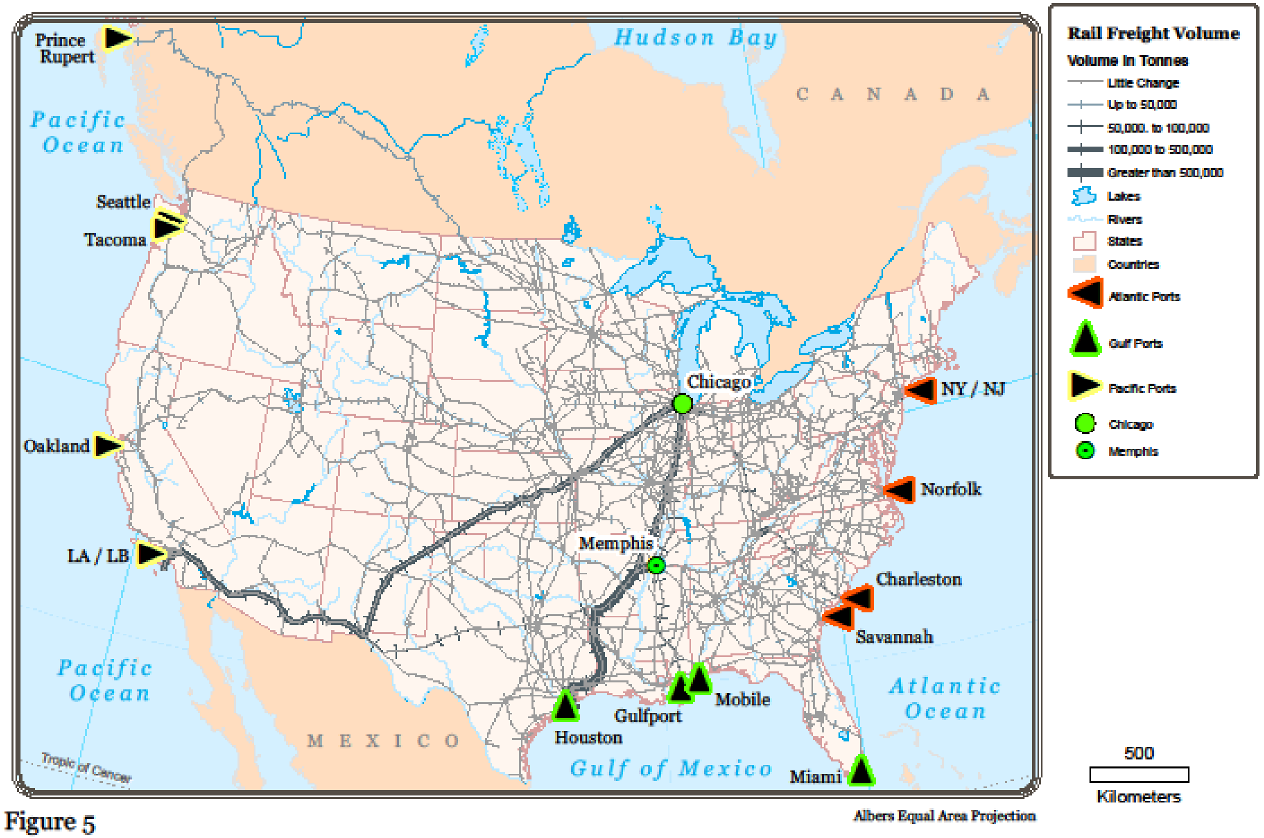


Figure 5
Scenario 5: 115% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via tracks [Forecasted container fright flows for 2020 was received from individual port studies].

Rail Scenario 6

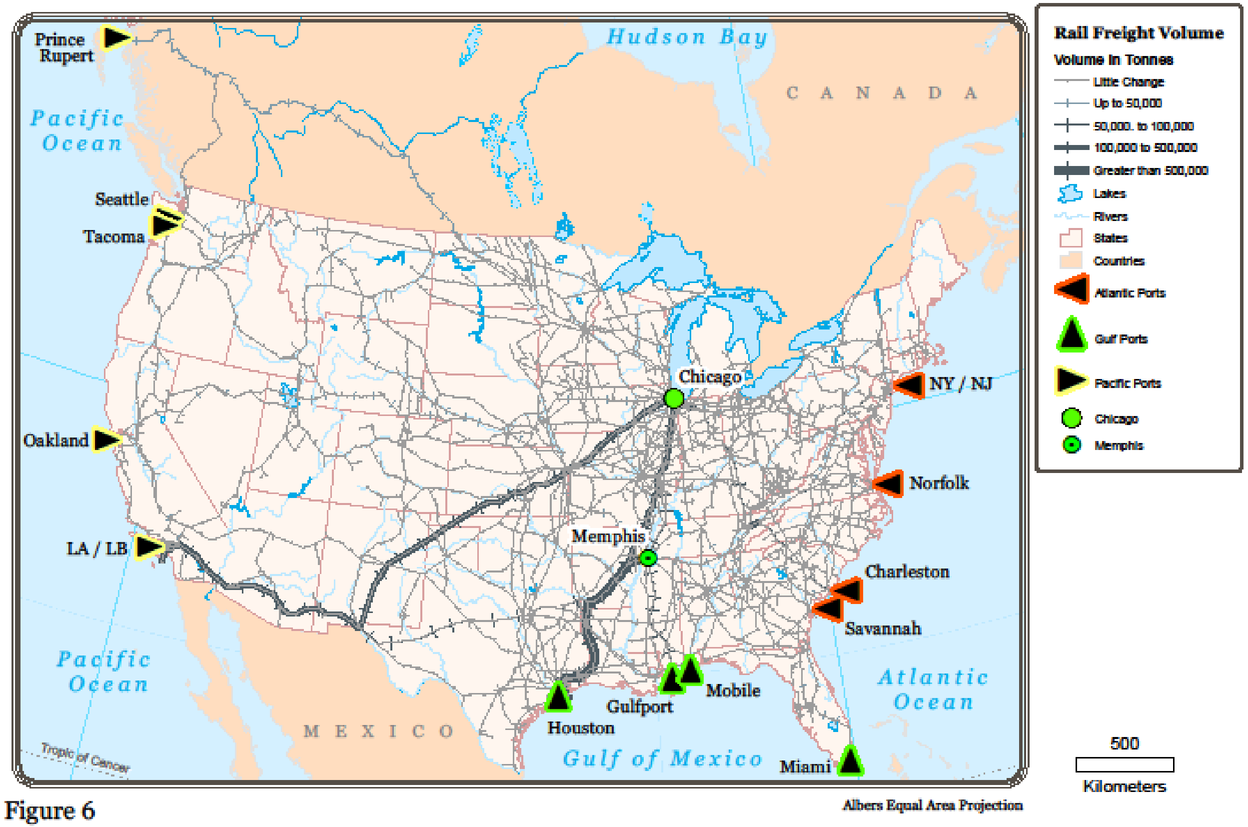


Figure 6
Scenario 6: 130% of forecasted container freight flows in 2020 from 13 US ports to Memphis and Chicago markets via tracks [Forecasted container fright flows for 2020 was received from individual port studies].