

Multimodal Freight Distribution & Economic Development due to International Capacity Expansion

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Abstract This paper examines how international expansion may redistribute trade volumes across the intermodal system, including ports, waterways, railroads, and highways within the US Midwest and Southeast regions. The research includes a capacity analysis of existing transportation infrastructures to identify the possibility of capacity expansion. It also conducts economic development analysis to quantify the anticipated economic growth due to the increased freight movement in the potential sites. While developing the scenario based distribution model, this research focuses on the top six Asian countries that contribute 62 percent of current container imports. It also focuses on the top ten US ports, three more ports in the US that are critical to the study regions (Midwest and Southeast), and one Canadian port which is also critical to the Midwest and Southeast. Overall, there appears to be only minor economic impact on the Southeast and port states from the Panama Canal and the Port of Prince Rupert expansions. However, the Chicago-North area and other interior states experience significant impacts from the Panama Canal and the Port of Prince Rupert expansions under all three scenarios. This research provides 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.

Keywords Panama Canal, International Freight, Network Modeling

1. Introduction

The trade volume between the U.S. and Northeast Asia has continuously increased. The average freight volume growth rate from 2003 to 2012 is more than 4 percent; nevertheless the trade volume temporarily fell off due to the recent economic recession. Only five countries in Northeast Asia: China, Japan, South Korea, Taiwan and Hong Kong, handle roughly 53 percent of total container shipments to the U.S. [1]. Also, the U.S imports approximately 59 percent of containers from those five countries, and the volume has been consistently increasing. Due to the increasing freight volume from Northeast Asia, the Panama Canal Authority (PCA) [2] and the Port of Prince Rupert planned expansion projects, and the construction is underway. The Panama Canal expansion is expected to be finished in 2016, and the new canal will start to operate in 2016 [3]. The Port of Prince Rupert will initiate its operation in 2020.

There are three major routes for trade between Northeast Asia and East of the Mississippi regions: 1) using West coast ports and the U.S intermodal system for overland routes, 2) using East/Gulf coast ports via the Panama Canal, and 3)

using all water routes via the Suez Canal. Most recent information about shipping market share for routing from the Panama Canal Authority (PCA) shows that 61 percent of the trade volume from Asia to East Mississippi regions used the US intermodal system, and 38 percent of the freight was imported via the Panama Canal. The remaining 1 percent went through the Suez Canal [2].

The objective of this research is to perform freight assignment tasking for redistributed freight flow affected by the expansion of international trade capacity. Thus, it is important to estimate how much freight will be increased and how much freight will be distributed to the each shipping route. By priority, this paper reviews and adapts the expected freight volume from Asia to the US and its distribution, which is studied by University of Illinois, Chicago (UIC). UIC analyzed the imported freight volume by container distribution from Asia countries to the US Midwest regions. UIC collected the available data on, container shipment, the capacity of the major international ports in US, and the railways of the intermodal system. Also, additional information was collected to estimate the cost data. Based on the data, current distribution was analyzed. Then expected distributions in 2019 affected by the Panama Canal expansion and in 2020 affected by the Prince Rupert port expansion were estimated with an optimization process [4]. Secondly, network database information was collected and developed for the assignment of predicted freight flows

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affected by the expansion projects. During this step, generally accepted network databases were evaluated including: Highway Performance Monitoring System (HPMS), National Highway Planning Network (NHPN), and Freight Analysis Framework (FAF). Through this task, the most appropriate database was selected. The selected network was improved and used in the assignment step with the various scenarios. Lastly, the assignments of freight volume by truck and railroad are performed using the network database developed in the previous step. The zone system is appropriately adjusted on the network database and Origin-Destination trip tables (O/D tables) developed by UIC are adapted for the assignments.

This research also includes economic development analysis to quantify the economic impact expected from the increased freight movement and handling. The economic development analysis quantifies the economic growth due to the modeled change in freight 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. It is forecast that there will be minor economic impact on Memphis-South and Port States regions from the Panama Canal and the Prince Rupert port expansions. This research finds 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 finds that many areas will experience limited development opportunities while some other areas will see significant increases in freight traffic and are prime targets for intermodal development. The cities likely to benefit include 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. These communities are expected to see significant increases in freight volume so are potential locations for intermodal facility development. The following sections discuss freight distribution scenario analysis, transportation infrastructure database development, network modeling and economic modeling.

2. Literature Review

For the analysis of route selection and optimization, active research and results have been discussed recently. Leachman [5] 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. [6] 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. [7] used a genetic algorithm-based heuristic to solve the Knapsack problem in terms of calling sequences at ports.

Lei Fan et al. [8] 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 [9] 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 [10].

DeVuyst et al. [11] evaluated congestion with delay cost functions with a spatial optimization model for grain shipments on the Mississippi River. Lei Fan et al. [12] 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 [13] 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. Freight Distribution Scenario Analysis

The purpose of this step is to briefly introduce and to adapt the estimated container cargo distribution by UIC for this research. The research from UIC is used to analyze the imported container flow from seven Asian countries: China, Japan, Korea, Taiwan, Hong Kong, Mongolia and Macao to continental US regions [4]. The goal of this analysis is to estimate the container cargo distribution from seven Asian countries to the U.S. ports, and from the ports to the forty-eight states in the U.S. (in this research, Alaska and Hawaii are excluded).

This study first investigated available data of containerized freight flow between the US and its trade partners. The available trade information was collected from the World Institute for Strategic Economic Research Trade (WISERTrade). WISERTrade provides comprehensive worldwide trade information including the amount of US freight flow by individual port. By comparing WISERTrade

data to FAF3 data, mode choice ratio was computed. FAF3 data is based on the Commodity Flow Survey results and it is regarded as proper information for mode choice. The study also collected 13 major international trade ports' capacities, as well as the expected Panama Canal capacity and the Prince Rupert port capacity after the expansion. Lastly, the cost information of ocean, rail, and truck transit for optimization process was gathered.

Based on the data, the containerized cargo flow optimization was performed and the Origin-Destination distributions (O/D distribution) which satisfied minimum shipping cost were estimated. The estimated O/D distributions consist of freight volume of all of the commodities from seven Asia countries to U.S. continental regions via thirteen U.S. international ports. Total three scenarios were prepared. The first scenario is the base scenario considering current capacity conditions without any expansion projects in 2012. The Panama Canal expansion will be finished in 2015, so the second scenario considers the increased capacity of the Panama Canal in 2019. The third scenario was developed by considering the expected capacity of the Prince Rupert Port Authority in Canada in 2020. The estimated O/D distributions indicate total freight flow from major U.S. international ports to the states of US. In other words, each cell of the table indicates the imported cargo flow from each port to each state.

4. Transportation Infrastructure Database Development

The network database is the one of the most important elements in transportation demand modelling, and the network represents flow of people or goods between origins and destinations [14]. In particular, a network database covering the US is required in this project are necessary, as well as various attributes such as link speed, capacity, number of lanes, and traffic counts.

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

4.1. Highway Network Database Preparation

Network development represents the flow of people or goods between origins and destinations [15]. There are three principal types of network databases covering the US territory: Highway Performance Monitoring System (HPMS) [16], National Highway Planning Network (NHPN) [17], and Freight Analysis Framework (FAF3) [18].

The three network databases are compared to determine which is best suited for the project (see Table 1). All the databases are provided by Federal Highway Administration (FHWA) as GIS shapefiles. They also cover the whole US. 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 [14]. Also, since it is not practical to collect traffic counts on the whole roadway system, Annual Average Daily Traffic (AADT) information is necessary to perform this project. Additionally, only the interstate network is considered as a major subject in this research.

HPMS and NHPN contain numbers of through lanes that can be used to calculate link capacity. FAF3 networks include 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, it can be computed by using the assigned speed [14]. FAF3 attributes contain computed speed but HPMS and NHPN do not have 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 provided by Governors Highway Safety Association [19] on each link using the state's FIPS codes.

The NHPN was chosen as best network database for this project and the necessary steps for preparation involved adding the speed to each roadway using ArcGIS.

Table 1. Comparing Characteristics of the Databases

	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

4.2. Railroad Network Preparation

The railroad network provided by nationatlas.gov was used in this research. The network contained polylines and attributes, but basic information such as speed and link length we added using ArcGIS. The network database consists of all of the railroads such as linehaul and Amtrak. We focus on linehaul railroad, especially, Class I railroads. The Class I railroad network was extracted from the shapefile. According to the Class I railroad statistics, classification are 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) [19]

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) [20]. Also, Soo Line is wholly owned subsidiary of Canadian Pacific (CP) [20]. So the Class I railroads are classified as BNSF, CSX, KCS, NS, CN, CP, and UP.

5. Transportation Network Impact Modeling

The assignment of freight volume by truck and railroad uses the networks developed and origin/destination trip tables. 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 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.

5.1. Construction of the Zone System

FAF3 consists of a total of 123 CFS regions and 8 international trade zones. This project focuses on the continental US 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. These 13 international ports signed the Memorandum of Understanding to increase capacity. The O/D matrix prepared in the previous chapter consists of 13 additional zones representing international trade ports for origin and 48 states 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 into 120 FAF3 zones.

5.2. Origin/Destination Table

The first step is to prepare a proper Origin/Destination matrix (O/D matrix) for freight assignment. The estimated O/D distributions, which are conducted by UIC, provide freight flows from thirteen international ports to forty-nine states in the US mainland as the destination zones. The O/D distributions mentioned before, consists of total freight tonnage by all modes between origin and destination. So, it is necessary to divide the total freight O/D distribution to freight by each mode O/D matrix. Also, we assume that all of the freight from the Port of Prince Rupert, Canada would use railway only. Each mode O/D matrix is rebuilt by using the mode ratio matrix (see Table 4 and 5).

The next step is to divide zone system of the state level

into the FAF3 zone system. Firstly, we assume two conditions to rebuild O/D matrix. The first condition is that each zone in the same state attracts same proportion of freight volume. The second condition is that each zone in the same state attracts different proportion of freight volume depending on the population. We build the new O/D matrices on these assumptions.

Secondly, the total freight volume in the each state is evenly divided by number of FAF3 zones in the each state in accordance with the first assumption. The reason why freight volumes are divided by the number of FAF3 zones is that it is necessary to compare between various scenarios. In the next step, we will rebuild O/D matrices under the second assumption based on the other criteria. For example, the freight volume in 2019 from the Los Angeles/Long Beach seaport (LA/LB) 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.

Lastly, each state's volume is divided by population proportion. Generally, employment is the most frequently used variable to calculate consumed commodities by industries, and population is the most frequently used variable to estimate consumer goods. Therefore, population was selected as the main variable to rebuild the zone system because the distribution of population and employment are not significantly different due to FAF3 zone system, which is comprised of large size zones. The United States consists of a total of 3,143 counties including the District of Columbia. The county level of population data is collected from US Census data [21]. 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 2), 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 2. 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

Table 4. Truck O/D Table in 2020 (kiloton)

D/O	LA/LB	Oakland	Seattle	Tacoma	Prince Rupert	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfport
Alabama	158.09	2.37	13.69			18.29		49.44			143.96		
Arizona	80.88	5.14	84.32	25.53		52.92			29.57				
Arkansas	222.31	0.63	41.22			16.06	3.10	12.89			7.61		
California	6333.87	357.27	227.40	18.05		588.20	916.59	205.40	2605.93	2603.81			
Colorado	149.33	0.47	112.27	1.88		26.63	1.45	0.12	3.53			2.43	
Connecticut	156.68	2.84	67.18			76.90	3.31	10.04				14.94	
Delaware		0.22				2.35				0.40			
Washington DC	1.86	6.92	19.84	15.41		9.42		0.20				2.53	
Florida	732.78	13.61	136.35			369.54						75.88	
Georgia	1260.19	78.72	4.11			352.00	142.69	10.88			186.40		
Idaho	19.19	1.66	9.35			2.94		3.00	1.27				
Illinois	1100.99	46.44	3.52	23.94		156.85	216.37	2.02	595.14			98.68	
Indiana	379.63	16.18	5.85	12.23		38.00	62.52	24.61	463.40			29.23	
Iowa	93.95	3.25	1.87	14.78		6.21	2.03	11.27	4.15			14.58	
Kansas	234.08	0.33	99.43			15.61			8.95			3.65	
Kentucky	254.01	31.60	6.38			31.22	33.33	6.38					
Louisiana		82.50	87.08			89.66		4.26			11.74		
Maine	12.99			5.33		4.55	1.04	0.65				0.01	
Maryland	204.57	9.75	165.73	10.04		67.70		19.40				23.66	
Massachusetts		6.17				638.13							
Michigan	316.33	34.96	3.34	7.27		45.17	51.41	36.67				179.12	
Minnesota	1373.53	5.00	6.36			45.38	51.80	2.48	16.44				
Mississippi	152.97	2.44	16.58			30.32	16.03	3.37			78.48		
Missouri	382.63	6.30	12.00	1.74		43.68	43.03	18.41	17.56			11.44	
Montana	22.09	0.18	10.18			0.84		0.98					
Nebraska	122.87		13.38			32.85		4.38	7.94			1.01	
Nevada	113.84	2.93	107.95			25.63		1.05	5.04				
New Hampshire	52.95	0.12				2.70	7.93	3.67	0.72			0.72	
New Jersey	944.10	174.79	326.15	31.88		606.24	116.60	27.77				56.12	
New Mexico	18.48	0.25	8.97	1.35		0.58			3.80				
New York	1140.76	89.94	380.32			1297.43	215.76	18.41				163.78	
North Carolina	55.04	16.16	1019.54			99.62		146.68			112.65		
North Dakota	115.90	0.46	1.29			0.62						4.66	
Ohio	577.20	84.30	2.79	20.47		77.90	71.37	1.06	502.43			122.60	
Oklahoma	116.65	2.61	84.34	53.70		10.87	7.53	10.34	0.84				
Oregon	168.46	10.62	29.58				27.22	0.70	48.36	35.47		86.92	
Pennsylvania	101.20	40.29		1630.10		174.29							
Rhode Island	91.57	0.10				8.69	6.51	3.35				4.35	
South Carolina	541.85	28.55	4.39			59.87	67.05	66.91			46.68		
South Dakota	14.72		5.85			0.54		0.82					
Tennessee	366.52	16.67	41.01			110.11	69.66				1139.46		
Texas	664.49	86.90	79.33			827.08	223.08	4.69		3467.98	178.54		
Utah	93.99	1.64	126.06	1.87		40.94	4.71		5.65				
Vermont	7.01	2.50				1.80	0.38	1.15				0.18	
Virginia	447.39	80.44	187.35	21.81		45.65		20.44				19.17	
Washington	671.41	24.84	4.12				67.57	611.73	139.03	448.76			
West Virginia		0.03	19.01	7.45		1.64	7.51	1.05					
Wisconsin	574.86	44.34	5.81	15.75		66.60	33.73	15.60				15.74	
Wyoming	12.09		2.23			0.94							

*The blank cell indicates 0.00 kiloton of freight volume.

Table 5. Railroad O/D Table in 2020 (kilotons)

D\O	LA/LB	Oakland	Seattle	Tacoma	Prince Rupert	NY/NJ	Norfolk	Charleston	Savannah	Houston	Mobile	Miami	Gulfport
Alabama		1.48	6.44		728.44			2.78			0.20		
Arizona	2.48	0.04	7.18		20.19	0.20							
Arkansas	3.95	0.51			21.09	0.04		8.58			4.72		
California	19.55	8.25	12.16	13.44	563.99	15.47	0.13	23.26	370.38	857.48			
Colorado	1.23	0.02	8.41	0.35	163.75				7.13				
Connecticut	0.02					0.02						0.87	
Delaware										1.48			
Washington DC													
Florida	2.40	0.03			108.12	0.14						0.35	
Georgia	30.58				662.82	0.02	0.48	0.42			0.37		
Idaho	0.01	0.01			1.34								
Illinois	84.36	18.17	0.21		425.15	1.83	0.12	0.02	36.11				
Indiana	8.18		0.29		56.13	0.46		0.11	39.66				
Iowa									1.03				
Kansas	0.35		1.21		46.63	1.49							
Kentucky	0.18					0.85							
Louisiana			0.71			1.09		1.42					
Maine												0.01	
Maryland	2.02	0.26	0.26			0.01							
Massachusetts						0.13							
Michigan	8.43	0.03	0.59		265.56	0.23	8.21	0.47				20.32	
Minnesota	163.80		0.16		20.48			0.11	35.12				
Mississippi	0.18		5.26					0.82			0.02		
Missouri	7.06	0.18	10.89					0.45					
Montana		0.02	0.12										
Nebraska	10.73												
Nevada	3.94				4.35	0.01							
New Hampshire								0.06	0.25				
New Jersey	54.36	14.76	1.13		742.71	10.42		6.04				17.69	
New Mexico			0.05		1.89								
New York	75.61	0.19	0.43		74.50	0.45	0.02	3.18				23.35	
North Carolina	4.75	17.79	0.06			0.09		10.87			111.62		
North Dakota			0.27										
Ohio	13.31	2.16	0.20		222.95			0.01	52.89			0.12	
Oklahoma			0.59			0.45							
Oregon	24.25	0.21			74.09			2.11		137.24			
Pennsylvania	1.09	0.26				1.22							
Rhode Island								2.58					
South Carolina								2.08					
South Dakota	0.04												
Tennessee	6.02		0.85				0.04						
Texas	71.05	1.60	12.70		1050.59	32.47	0.64	0.02		278.55	159.63		
Utah	0.10	0.01	0.92		4.52								
Vermont													
Virginia	10.43	48.71				0.11		1.22				12.16	
Washington	7.81	0.01	0.04		56.32					0.52			
West Virginia		0.04					0.28						
Wisconsin	7.33		0.02			0.24		7.85				0.11	
Wyoming	0.61												

*The blank cell indicates 0.00 kiloton of freight volume.

5.3. Scenario Preparation

We prepare O/D matrices for three years by using two different proportions. With these matrices, this study also classifies the research regions. This study specifically focuses on Midwest and Southeast as study regions. Therefore, the research regions are considered as two categories. The study categorizes all FAF3 zones and Midwest and U.S South regions for the assignment model. As a result of these processes a total of twelve scenarios are prepared for freight volume by truck assignment (see Table 3).

5.4. Assignment of Truck Freight Flows

For assignment, 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/Voyager. Then, based on the prepared network, the freight volume by truck is assigned using the computed link travel time. Example output of the freight assignments are illustrated as Figures 1 and 2. As mentioned above, the expected O/D distributions were estimated as volume of all of the commodities. The O/D distributions can be converted if each commodity would be estimated by using conversion factors. However, the available source is total commodity volume, thus the freight

volume is assigned on the network. It has limitations of the network calibration and validation because of the object of the network assignment. Therefore, the network calibration and validation work are not performed in this study.

Table 3. 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 and U.S South 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 And U.S South Regions	State Volume / Population Proportion
11	2019		
12	2020		



Figure 1. Result of Scenario 8: Truck Assignment (2019)



Figure 2. Result of Scenario 11: Truck Assignment (2019)

5.5. 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. We 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.

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 the same as the truck mode analysis. In other words, the assignment uses travel time as a main factor to calculate equilibrium model. According to the Federal Railroad Administration, the operating speed limits vary with railroad conditions. However, most of railway conditions are not opened as public information. Therefore, assumption is made that the speed limit of the railroad network is sixty mile per hour. The output of the freight assignments are illustrated in Figure 3 and 4.

5.6. Model Strengths and Limitations

One of the key aspects of this research was to develop "Optimized Freight Distribution" Model. This model identified the routes, modes, and amount of freight

movements from 14 ports to primarily two markets (Memphis & South and Chicago & North). This distribution is ideal and minimizes the cost of freight distribution. For example, following table shows the optimum distribution of containers from selected West coast ports to two markets (Memphis & South and Chicago & North), port states and other states. In reality, shipping companies may choose to ship via different modes and different amounts based on their business models and hence pay more to do that.

Another outcome of this research was "Scenario-based Freight Distribution" Model. This model developed several scenarios (56 scenarios) based on individual port studies and identified the routes, modes, and amount of freight movements from 14 ports to primarily two markets (Memphis & South and Chicago & North). This distribution is a result of what-if scenario analysis. For example, figure 5 shows the current distribution of containers from 14 ports to two markets (Memphis & South and Chicago & North), via trucks. If both Panama Canal and Prince Rupert expansions are completed and individual port forecasting are realized at certain level (scenario 11), both markets will receive significantly increased containers and part of I-40, I-70, and I-59 will be over congested (see Figure 6). If both Panama Canal and Prince Rupert expansions are completed and individual port forecasting are realized at certain level (scenario 12), only Chicago & north markets will receive significantly increased containers and part of I-40, I-70, and I-75 will be over congested (see Figure 7).

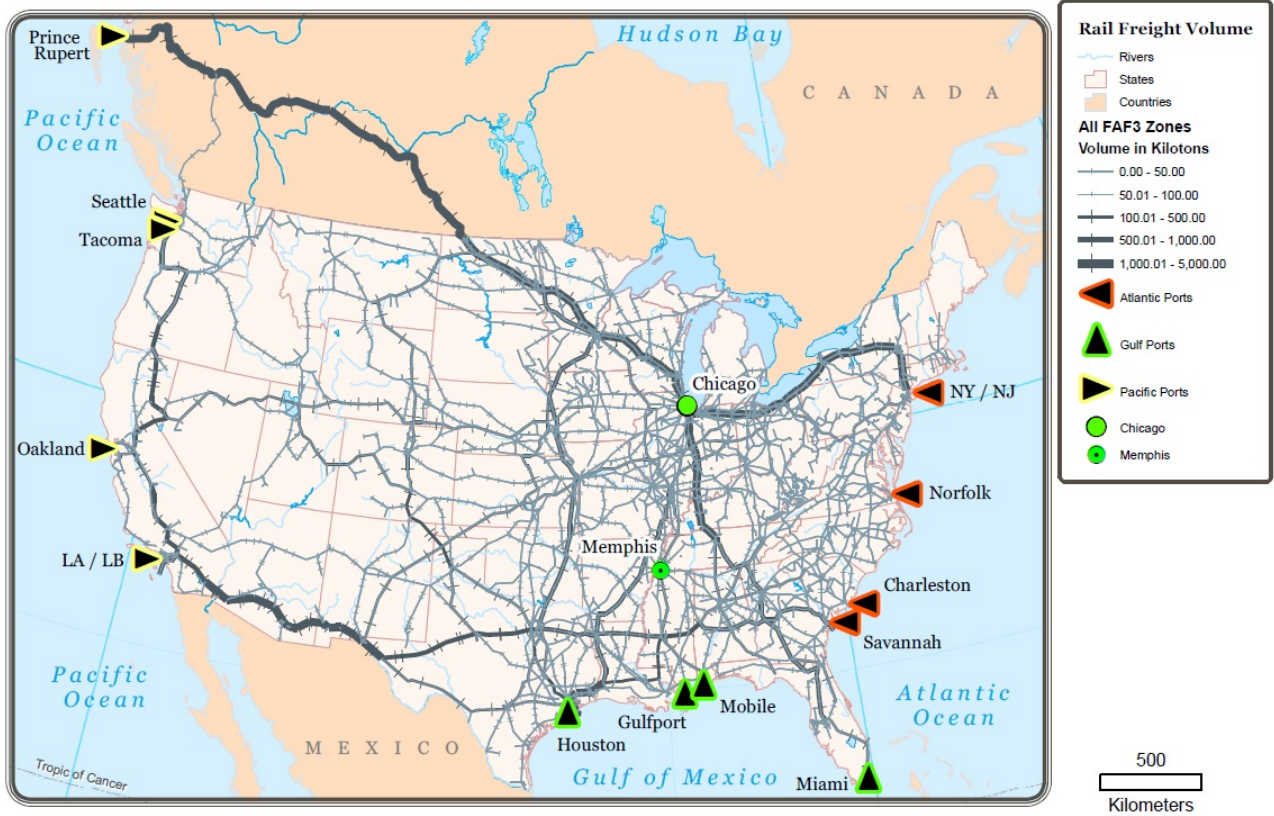


Figure 3. Results of Scenario 8: Railroad Assignment (2019)

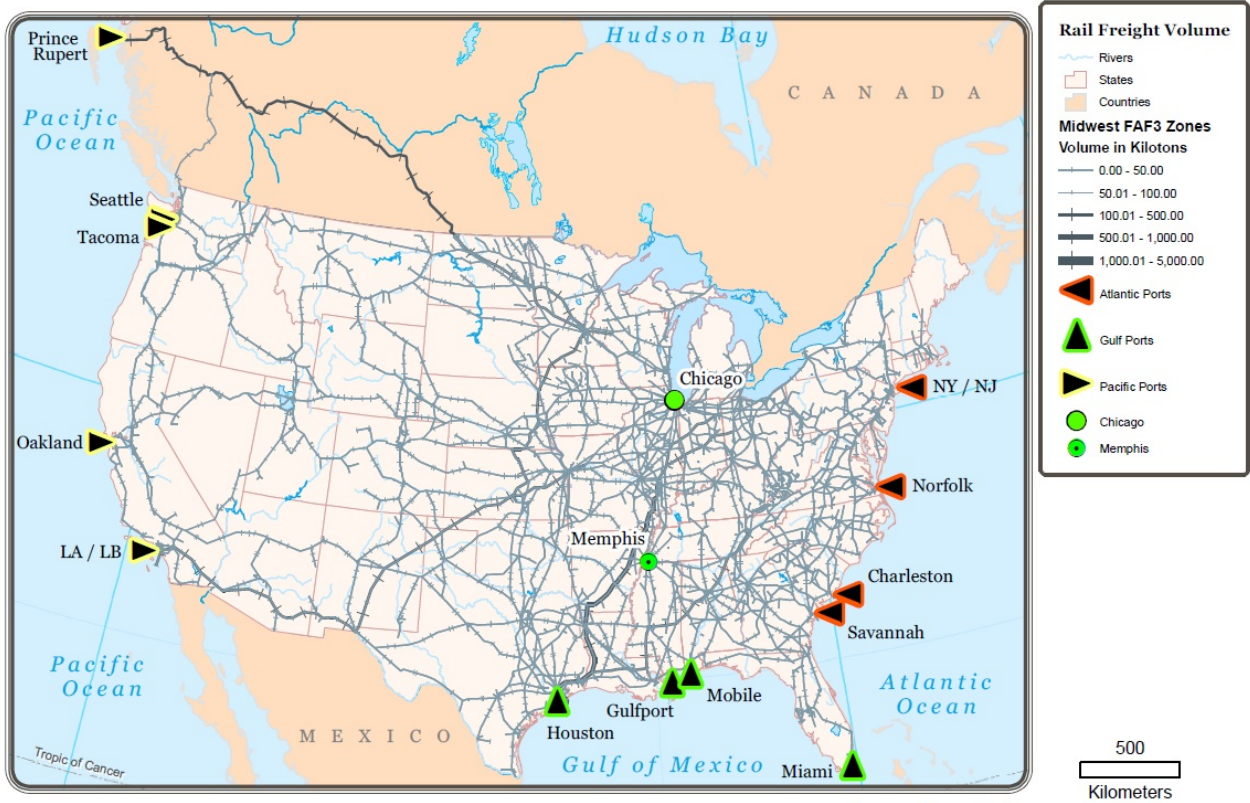


Figure 4. Results of Scenario 11: Railroad Assignment (2019)

Table 6. Estimated Container Freight Mode Choice from the West Coast Ports to the U.S. in 2019 (after the Panama Canal Expansion) based on optimized model

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



Figure 5. 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 6. 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 7. 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. Economic Development Analysis

Based on the models, potential communities for freight based-economic development were determined and expected regional competitiveness impacts projected. The 11 cities in Table 7 are expected to see the largest increase in traffic and

are prime targets for freight based-economic development. The reality is that they all technically have some kind of intermodal capability, but many are smaller facilities 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.

Site specific factors of the 11 potential intermodal development locations need to be considered. Table 7 provides the cities which are potential locations for intermodal facility development because they are expected to see significant increases in freight volume along with details of existing container intermodal transfer facilities near the identified cities along with major rail lines. According to a 2011 Transportation Research Board's report (Steele et al. 2011), the primary criteria for intermodal facility location selection are as follows 1) access to markets or customers, 2) availability of transportation networks, 3) availability of workforce, 4) total cost of operation, 5) proximity to ports 6) permitting and regulations, and 7) availability and cost of ability space. These factors will need to be considered at each location to see if increased capacity is warranted based on increased freight volume.

6.1. Economic Development Analysis Methodology for Regional Competitiveness

The second study objective of the economic development analysis in this study is 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 by state). Gross Domestic Product (GDP), formerly Gross

State Product, 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.

In order to model the projected impact of change in import tonnage on GDP by region, the historical statistical relationship of import tonnage to GDP by state in the region was determined. For containerized import tonnage by state, the WISERTrade database was used. WISERTrade 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.

A statistical correlation analysis was conducted for all fifty states by the University of Southern Alabama. The fit of the statistical model varied greatly from a R2 of 0.05 for Illinois to 0.93 for Alaska. The fit at the regional level used in this analysis was much better. The ranges were from 0.94 for the Chicago-North region to 0.83 for the port regions. Because of the large variation at the state level, only the regional analysis is presented.



Figure 8. Economic Analysis. All Freight Analysis Framework 3 (FAF3) zones with volume by number 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

Table 7. The Results of Statistical Correlation Analysis

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

Table 8. 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		

6.2. Statistical Correlation Analysis Findings

Several scenario analysis were run and consistently the Chicago-North region was most impacted. Table 8 presents a typical scenario and X represents freight in kilograms. This scenario modeled the impact of the expansions to the Panama Canal and the Port of Prince Rupert on imports through the Gulf Ports. Under this scenario, all the regions will experience an increase in tonnage of imports. The impact on regional economies of this increase in imports is more pronounced for Chicago-North and Other states regions. This same pattern was found in all the scenarios run.

7. Conclusions

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, Figures 1 through 4 show the results of the assignments for freight flow with regard to the expansion projects. Large amount of freight volume from Asia is forecast to be diverted from ports on the West Coast to East and Gulf Coast in 2019 after the Panama Canal expansion. In addition, the freight volume directly arriving in the US is expected to be diffused to Prince Rupert after its port expansion in 2020.

It is also expected that there will be little economic impact on Memphis-South and Port States regions. On the other hand, Chicago-North and other states regions will have significant impacts from the Panama Canal and the Prince Rupert expansions. Based on economic development models, the study finds eleven cities which are potential locations for the expansion of intermodal facilities.

As mentioned above, this research 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.

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