Heuristic Path-Enumeration Approach for Container Trip Generation and Assignment

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A commonly ignored key ingredient in large-scale container network assignment is an impedance-driven geovisualization of optimal routes. In this study, we propose linear optimization models for both trip generation and trip assignment using dynamic programming on a GIS platform, which includes maps and data that are used to develop and generate trips. The proposed models are applied to intermodal railroad routes mostly in the United States. Dendritic optimal networks are figures visually depicting all optimal branches for the network.

INTRODUCTION

Growth of container markets and contracts between ocean and rail carriers has contributed to difficulty in tracking containers from one geographic region to another. Shipping containers have achieved economies of scale, a fact driven primarily by long-haul domestic demand, needing efficient freight operations (Muller 1999). Containerized cargoes have been transported through railway and highway networks connected to seaports in the United States. The average growth rate of the number of containers in North America was 9.44% from 1999 to 2006. The number of imported containers decreased slightly by 0.5% in 2007, but decreased by 8.2% and 14.5% in 2008 and 2009, respectively (U.S. Maritime Administration 2010; U.S. Maritime Administration 2011). The majority of imported containers to the United States came from China from 1997 to 2009, representing approximately 48% of the all imported 20-foot equivalent units (TEUs) (AAPA 2011). Fifty-six percent of import container traffic came through the Pacific areas (20 ports); the Atlantic areas (21 ports) accounted for 39.8% of TEUs and the Gulf areas (11 ports) accounted for 4% of TEUs. According to the intermodal industry statistics of the Intermodal Association of North America, 86.3% of total container traffic was moved by rail in 2009 (IANA 2011). Class I railroads[1] transported 8.2 million of 10 million containers transported in 2009 (IANA 2011, AAR 2010). The 2007 Commodity Flow Survey (CFS) found that the average distance for mixed freight[2] is 160 miles by truck and 1,182 miles by rail (U.S. Census Bureau 2010).

Several studies have been conducted to highlight the importance of container route optimization (Miller and Storm 1996, Luo 2002, Luo and Grigalunous 2003, Leachman et al. 2005, Leachman 2008, Leachman 2010, Levin et al. 2009a, Fan et al. 2009). Luo and Grigalunous (2003) analyzed import and export container markets by optimizing the routes and simulating hypothetical ports as alternative entry locales through Canada to mainland U.S. markets. They also applied a shortest path algorithm to minimize transportation cost, based on an assumption of shipper's behavior, for allocating network volume. They also simulated a hypothetical port in Canada to compete with U.S. ports along the Atlantic Coast of the two countries. In addition, the authors studied the Panama Canal's impact on route choice behavior.

Leachman et al. (2005) and Leachman (2008, 2010) studied the import container markets in the United States by optimizing the routes through assigning an origin trade partner and destination in U.S. inland markets. In these studies, markets were grouped into 21 regions based on regional distribution centers. Levin et al. (2009a) estimated the origin and destination (O-D) for U.S. imports of maritime containerization from the Port Import Export Reporting Services (PIERS) database and the 2003 STB Public Waybill sample database. The growth rate variation of railway shipping from ports to 48 inland markets was based on Bureau of Economic Analysis zones (BEAs) in their study. The estimation focused on the Trans-Pacific mainlane (between Asia and the United States) incorporating maritime, rail, and truck networks. Levin et al. also estimated container flows between origin and destination for U.S. exports of waterborne containerized freight in a series. Levin et al., Fan et al., and Fan used the 2006 STB Public Waybill sample to estimate the volume of containers for imports from the west coast of the United States and Canada. They optimized efficient routes from Asia to U.S. markets through the ports in the Pacific region via railways.

A rapid increase in the number of containers during the last several decades has created capacity, safety, and environmental issues in the port areas. The import containers to the United States are transported through U.S. entry ports, in addition to Canadian and Mexican entry ports. Hughes (2006) proposed and emphasized the importance of visualization to define spatial and temporal attributes of freight movements. The visualization of the trip assignment would be beneficial for analyzing the temporal trends and geographical patterns of imported freight flow. The analysis can be merged into different commodities for the railroad industry and multimodal choice patterns for the large-scale international trade patterns. In this study, we are proposing a way to visualize the container flow to aid in understanding container flows.

Mapping and visualizing feasible routes and estimating number of containers from foreign origins to U.S. inland markets through the North American ports and terminals would provide a better understanding of the freight flow pattern and a systematic view of imported container flow. Several studies provide estimated container flow for international trade (Levin et al. 2009a, Levin et al. 2009b, Leachman 2010, Fan et al. 2010). These studies present discrete flow based on O-D pairs instead of providing detailed segments for possible flow directions. However, the previous studies in the literature do not describe visualization of the output in detail for public communication. This study provides extensive and detailed procedures not found in the previous studies in the literature. Thus, this study focuses on traffic routes from coastal ports to inland markets based on Bureau of Economic Analysis (BEA) zones through established railway networks to generate and distribute trips. The routes can then be assigned an estimated volume on network links based on the number of estimated TEUs, which is called the process of trip assignment. Ultimately, utilizing the developed linear programs for choosing feasible routes, the optimal routes are geovisually displayed in a GIS map. Port authorities, intermodal terminals, and railroads could use the information in this paper as an input to infrastructure investment decisions.

MODEL DEVELOPMENT

Assumptions

International Standard Organization (ISO) containers are 20-foot, 40-foot and 45-foot boxes that represent approximately 52.3% of the total container movements, including inland traffic (IANA 2011). The most common box lengths are 20-foot and 40-foot for international trade (Leachman 2008). All other lengths are 24-foot, 35-foot, 48-foot, and 53-foot containers handled through Pacific maritime ports. In 2007, Pacific Maritime Association (PMA) reported that for 20-foot containers, the shipping volume was 22.1%; for 40-foot containers the volume was 71.3%; all other lengths were 6.6% in the Pacific region (PMA 2009). Thus, throughput in this study is measured in TEUs for maritime and railway shipping. TEU is used for international trade and domestic distribution for container transit from ports (origin), via railways, and eventually to markets (destination). The ports in the study area were aggregated into BEA zones for analysis (Table 1). To represent a BEA zone, major cities were selected as destinations, and a major seaport in the BEA as the origin in the conceptual model. The number of containers originated from the arrival seaports was aggregated into a BEA level since the STB public waybill data are sampled based on BEA zones using 1997 BEA codes. Several intermodal marine ports in a BEA region are aggregated in a BEA code (U.S. Bureau of Transportation Statistics 2010). One or more Class I railroad companies provide intermodal services to the intermodal marine ports (Table 1).

Table 1: Intermodal Service Ports in the Bureau of Economic Zones via Class I Railroad Facilities

Regions	Coastal Bureau of Economic Zone (BEA)	BEA Code	Marine Ports	Class I Railroad for Intermodal Facility						
				BNSF	UP	CSX	NS	KCS	CN	CP
Pacific	Seattle-Tacoma-Bremerton (WA)	170	Seattle	V	V					
			Tacoma	V	V					
			Vancouver	V	V					
	Portland-Salem (OR)	167	Portland	V	V					
	San Francisco-Oakland-San Jose (CA)	163	Oakland	V	V					
			San Francisco	V	V					
	Los Angeles-Riverside-Orange County (CA-AZ)	160	Los Angeles	V	V					
			Long Beach	V	V					
			Hueneme							
	San Diego (CA)	161	San Diego							
Atlantic	Boston-Worcester-Lawrence-Lowell-Brockton (MA-NH-RI-VT)	3	Boston			V				
	New York –No. New Jersey – Long Island (NY- NJ- CT-PA-MA-VT)	10	New York / New Jersey			V	V			
	Philadelphia-Wilmington-Atlanta City (PA-ND-DE-MD)	12	Philadelphia			V	V			
			Wilmington			V	V			
	Washington-Baltimore (DC-MD-VA-WV-PA)	13	Baltimore			V	V			
	Richmond-Petersburg (VA)	15	Richmond							
	Wilmington (NC-SC)	25	Wilmington							
	Norfolk-Virginia Beach-Newport News (VA-NC)	20	Hampton Roads			V	V			
	Charleston-North Charleston (SC)	26	Charleston			V	V			
	Savannah (GA-SC)	28	Savannah			V	V			
	Jacksonville (FL-GA)	29	Jacksonville			V	V			
			Fernandina							
	Miami-Fort Lauderdale (FL)	31	Everglades			V				
			Miami			V	V			
			Palm Beach			V				
Gulf	New Orleans (LA-MS)	83	New Orleans	V	V	V	V		V	
	Houston-Galveston-Brazoria (TX)	131	Houston	V	V					
			Freeport	V	V					
	Tampa-St. Petersburg-Clearwater (FL)	34	Tampa			V				
	Tallahassee(FL-GA)	35	Panama City							
	Mobile (AL)	80	Mobile	V	V				V	
	Biloxi-Gulfport-Pascagoula (MS)	82	Gulfport						V	

Note: BEA represents Bureau of Economic Analysis (BEA) zone developed in 1997. The Class I railroad does not always connect to the ports directly, but in the BEAs instead.

Sources: National Transportation Atlas Databases 2010, U.S. Department of Transportation; Class I railroad company intermodal service maps; Fan (2010).

Input Data and Data Sources

The number of containers in a TEU was acquired from the Maritime Administration Database (MARAD). The MARAD Trade Statistics summarizes the PIERS data, and therefore does not include specific overseas routes, the overseas ports of origin, and the through ports in North America (see also U.S. Maritime Administration 2010). The American Association of Port Authorities and MARAD use the PIERS database for statistics since MARAD provides aggregate traffic information from PIERS. Rail traffic information was derived from the pubic waybill sample used by the Surface Transportation Board (STB) Waybill, and Railroad Fact Sheet published by the American Association of Railroads (2008). The ports throughput was aggregated into a 1997 BEA zone, which the STB waybill uses for determining railroad statistics. Only ports with import data were selected as origin BEA zones. Railway networks were derived from the Oak Ridge National Laboratory (ORNL) database (Center for Transportation Analysis 2009), an online geodatabase for North American railway network information (Peterson 2000). In addition to the base network, this study utilized the impedance developed by ORNL in order to present modal route selection based on the 2003 Commodity Flow Survey, even if route choice is affected by congestion, travel time, market power, and price at origin and destination. The impedance is the generalized cost of different enroute activities (Southworth and Peterson 2000, Thill and Lim 2010). The normalized impedance represents the normalized shipping distance between multiple modes for each commodity. This study reclassifies the impedance into two groups: 1) Transportation impedance that is related to the traversable line-haul links, and 2) Inventory impedance that is terminal access links and logical terminal links (Thill and Lim 2010). This paper also regrouped them into relative and absolute impedance. The relative impedance will increase travel resistance on the links analogous to generating obstacles to slow traffic down; however, the links are still traversable, while the absolute impedance assigns a very large penalty in order to block the roads.

MODEL APPROACH

We can assign a total logistics cost that consists of haulage cost (*CH*), inventory cost (*CI*), and terminal cost (*FT*) for a fixed-charge location problem as follows

$$(1)\quad Min \sum_{i}^{I}\sum_{j}^{J}\sum_{k}^{K}\sum_{m}^{M}\sum_{t}^{T} Q_{ijkmt}(CH_{ijkmt} + CI_{ijkmt} + HS_{kt}CHS_{kt}^{v}) + \sum_{k}^{K} CHS_{kt}^{f} HS_{kt}$$

By redefining, CH_{ijkmt}, as haulage cost from origin *i* to destination *j* through terminal *k* for a container by mode *m* during period *t* which can be equated as the multiplication of the total travel time between origin and destination and the time cost for each mode from the relation; $CH_{ijkmt} = T_{ijkmt} \times CC_{ijkmt} \times W_{ijkmt}$, where CC_{ijkmt} is transportation cost per container/mile, W_{ijkmt} is the percent of traffic from origin *i* to destination *j* by mode *m* through intermodal terminal *k* during period *t*. T_{ijkmt} is a distance variable between locations using mode *m* during period *t*. CHS_{kt}^{v} is a variable cost per unit required to handle movement of a product at terminal *k* during period *t*, while CHS_{kt}^{f} is a fixed cost for keeping terminal *k* operable during period *t*.

Decision variables, for example Q_{ijkmt}, incorporate the number of containers moving from origin *i* to destination *j* by mode *m* in period *t* and an operable terminal, which will serve the demand as represented by binary values:

$$(2)\quad HS_{kt} \quad \left\{ \begin{array}{l} 1 \text{ if a terminal } k \text{ serves the BEA zone during a period } t \\ 0 \text{ otherwise} \end{array} \right\}.$$

A balancing constraint can be issued for the quantity of supply and demand. The number of outbound containers from all origins ($\sum_i^I Q_{ijt}$) may not always be equilibrated with the number of inbound containers at all destinations ($\sum_i^I Q_{jit}$) due to work-in-process in the delivery system, that is, $\sum_i^I Q_{ijt} \neq \sum_j^J Q_{ijt}$. Nevertheless, the total number of outbound containers from origin i to a destination j during a period t should be the same as the supply, as $\sum_i^I Q_{ijt} = \sum_i^I S_{it}$, where Sit indicates the number of outbound containers from port suppliers. On the other hand, the total number of inbound containers to destination j should equal the demand quantity, that is, $\sum_j^J Q_{ijt} = D_{jt}$, where D_{jt} represents demand at destination j during period t. For mode combination, the number of through terminals cannot exceed the total demand between origin i and destination j, $\sum_i^I Q_{ijm\bullet} \geq \sum_k^K Q_{ijm\bullet}$, $\sum_i^I Q_{ijmt} \geq \sum_k^K Q_{ijkmt}$ but the total demand is not sufficient for the condition due to the time lag. In the case of interrupted routes (a_{ijkmt} = 0) such as rail segment abandonment and bridge collapse, the value should be zero for the specific segment from origin i to destination j, while incurring large costs, that is Q_{ijkmt} = 0 when a_{ijkmt} = 0. The relation, a_{ijkmt} = 0, indicates blocked routes of a segment from origin i to destination j through terminal k by a transportation mode m during period t. The number of containers from origin i to destination j cannot be assigned a negative number, as $Q_{ijkmt} \geq 0$.

Equation (1) can be decomposed into smaller shortest path problems: the first term in Equation (3) is set for direct shipping bypassing any hub location, while the second term in Equation (3) is necessary to minimize the total cost.

$$(3)\quad Min \quad \sum_{(i,j)\in P} \sum_{m=\{highway\}} Q_{ij} w_{ijm} \left(CH_{ijm} + CI_{ijm}\right) + \sum_{(i,k)\in P} \sum_{(k,j)\in P} \sum_{k\in N_i} \sum_{m=\{rail\}} Q_{ijk} w_{ijkm} HS_k \left(CH_{ijkm} + CI_{ijkm} + CHS_k^v\right)$$

$$(4)\quad s.t. \quad \sum_{(i,j)\in P} w_{ijm} + \sum_{(i,k)\in P} \sum_{(j,j)\in P} w_{ijkm} = 1 \quad \forall i \in I, \forall j \in J$$

$$(5)\qquad HS_k = \{0,1\}$$

$$(6)\qquad \sum_{k\in N_i} HS_k = \begin{cases} 1 & \text{if } w_{ij} < 1 \\ 0 & \text{otherwise} \end{cases}$$

$$(7)\qquad HS_k - \sum_{k\in N_i} w_{ijk} \geq 0$$

$$(8)\qquad \sum_k Q_{ijk} w_{ijk} \leq MQ_k$$

where:

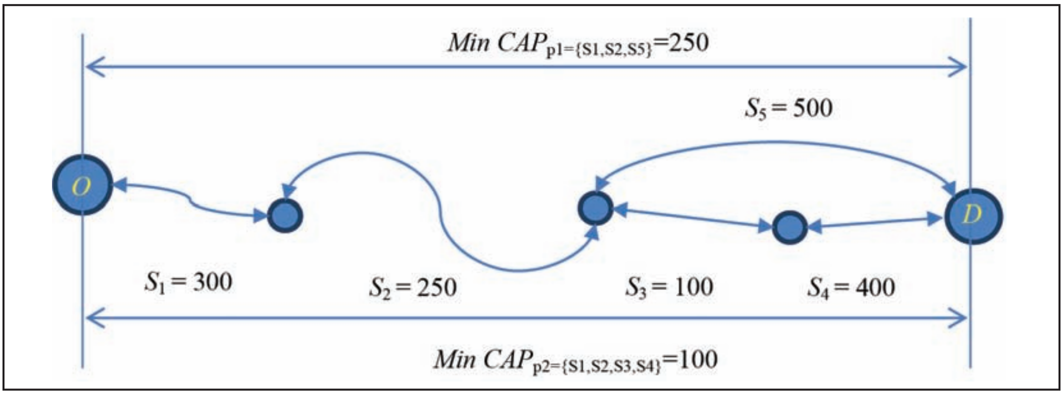
Q_{ij}	= number of containers from origin *i* to destination *j*
CH_{ijm}	= transportation impedance from origin *i* to destination *j* by mode *m*
CI_{ijm}	= inventory impedance from *i* to destination *j* by mode *m*
w_{ijm}	= trip assignment ratio to the path between origin *i* and destination *j* by mode *m*
Q_{ijk}	= number of containers from origin *i* to destination *j* through intermediary facility *k*
CH_{ijkm}	= transportation impedance from origin *i* to destination *j* through intermediary facility *k* by mode *m*
CI_{ijkm}	= inventory impedance from origin *i* to destination *j* through an intermediary facility *k* by mode *m*
HS_k	= binary variable; if select intermediary facility *k*, HS_k=1; otherwise, HS_k=0
CHS^v_k	= relative impedance caused by selecting intermediary facility *k*
w_{ijkm}	= trip assignment ratio to the path between origin *i* and destination *j* through intermediary facility *k* by mode *m*
M	= arbitrarily large number

The rewritten equation is a capacity-confined *path-based* model. The capacity of the path is determined by $\min\{CAP_{s\in P}\}$, when $CAP_{s\in P}$ is a capacity of a segment *s* for the selected path *P*. In other words, the minimum capacity of the selected path *P* is determined by the minimum capacity among the segments (S_1, S_2, S_3, and S_4) of the selected, alternative path (*P*) (see Figure 1). In Figure 1, the volume discount factor is not considered.

Q_{ij} in Equation (1) is replaced by $Q_{ij}w_{ijm}$ and Q_{ijk} by $Q_{ijk}w_{ijkm}$ in Equation (3). The total ratio of the trip assignment of an O-D pair transported by truck and rail cannot exceed one, which is 100% in Equation (4). The combined subroutes, from origin *i* to terminal *k* and the terminal *k* to destination *j*, would create a feasible path. When a trip demand, Q_{ijkm}, exceeds the capacity of a selected path, the trip information is dissected into two parts by a portion (w_{ijkm}) of the initial trip information. For example, when a trip to be assigned onto the selected path is 50 trips and the capacity of the selected path is 30 trips, only 30 trips (w_{ijkt} = 60%) would be feasible through the path and the other 20 trips will be assigned onto the next alternative route. In Figure 1, two feasible paths between origin (O) and destination (D) are found: P_1={S1,S2,S5} and P_2={S1,S2,S3,S4}. Suppose 200 containers need to be delivered between an O-D pair and the shortest path is the path P_2, a carrier would select P_2 and then assign the minimum capacity of the path calculated by $min\{Cap_{p2}\}$=100. The rest of the demand (100 containers) will be assigned to the next shortest path P_1. The $min\{Cap_{p1}\}$=250, which is the larger than the remaining demand. Therefore, the 100 containers would be assigned to the P_2. It is based on the greedy algorithm, by which the best route is selected *a priori*.

The assigned trips to the intermodal terminals are subject to the following constraints: the sum of O-D trips by intermodal transportation ($\sum_{k\in N_i} w_{ijk}$) cannot exceed the value of HS_k (Equation 7), where w_{ij} of the shipments are by truck, and $HS_k - \sum_{k\in N_i} w_{ijk}$ is a combination of multiple routes of intermodal transportation. The total trips of an O-D pair moving through an intermodal terminal cannot exceed the assigned trips on the terminal (Equation 8). Decision makers also must consider the fixed costs and variable costs for intermodal shipping. For example, while delivering products by roadways, truck drivers are charged tolls, which are not proportional to travel distance in the United States, unlike in other countries. Unexpected events during shipping are other possible sources of variable costs, such as road closures and detours caused by weather and natural disruptions. The events and activities occur on transportation networks with road links (segments) and intermodal terminals at origin and destination (nodes).

Figure 1: Capacity of a Path Based on Minimum Capacity of the Segments



The intermodal terminals are presented as points in GIS without connectivity to links, so dummy links can be created for the terminals with a set threshold distance needed to connect them to the nearest road links. Southworth and Peterson (2000) and Lee and Farahmand (2009) introduced an impedance intermodal network model with absolute and relative penalties, which can be expressed as the length of a road, or any disutility value depending on the decision maker's criteria.

The terminal nodes are converted into terminal links, which include the link impedance such as dummy miles (R_N), and a user-defined penalty in miles (X_N) for transferring commodities [see second term in Equation (9)]. Each network segment includes distance-based penalties: resistance (R_S), such as mode and road classification, and absolute penalty (X_S), such as bridge and tunnel clearance or road construction during a certain period. These nodes (N) and links (S) are a subset of an alternative path (P) from

(9) $$Min \sum_{S \in P} (R_S + X_S) + \sum_{N \in P} (R_N + X_N).$$

This study examines an intermodal route, so the different transportation modes from coastal port i to terminal k by rail and from terminal k to inland market j by truck are subdivided into separate network definitions. The two different networks are linked at intermodal terminals for connectivity:

(10) $$Min \sum_{S \in P_{HWY}} (R_S + X_S) + \sum_{S \in P_{RAIL}} (R_S + X_S) + \sum_{N \in P} (R_N + X_N).$$

The blocked route s would be assigned by the user-defined high penalty value (called reactance in this study) onto a segment (X_S) and a terminal (X_N). For the detailed information for the definition and setting of reactance, see Lee and Farahmand (2009). The terminal nodes are reshaped by dummy links, so we can rewrite Equation (11) as

(11) $$Min \sum_{S \in P_N \Leftrightarrow OD} (R_S + X_S) Q_{OD} w_{P_N},$$

when each route has a percent (w_{P_N}) of the assigned trip (Q_{OD}) to an O-D pair.

The quantity of a shipment on the alternative path is allocated by the portion of O-D trip data, which is the minimum capacity of the selected segments of the path. Equations (7) and (8) are included to measure the total system cost. However, the process will be preceded for finding individual trip's best route in the order of trip assignments for the O-D matrix. In this approach, each trip is selected based on the best alternative route using First-In-First-Out (FIFO) trip information from the O-D table in a given row. Instead of using optimization, this study uses a heuristic approach to generate the feasible routes between O-D. The route exchange method is combined with the FIFO greedy algorithm by enumerating all possible routes in the boundary of *s* (this process is called path enumeration). In other words, this study enumerates all feasible routes based on the heuristic approach, which is an experience-based geo-technique. Therefore, the holistic, systemic optimum would be the sum of all pairs of paths as

$$(12)\quad \sum_{\{OD\}} \min\left(\sum_{S \in P_N \Leftrightarrow OD} \left(R_S + X_S\right) Q_{OD} w_{P_N} \right)$$

RESULTS AND IMPLICATION

The U.S. container markets are located along the Mississippi River as well as in coastal metropolitan cities, such as New York, Miami, Los Angeles, and Houston (Figure 2). The STB public waybill sample indicates that 70% of the containers went through the Pacific BEA regions, while 21% of the containers were originated from the Atlantic BEA regions. Along the Gulf and Atlantic areas, truck routes are used more frequently than rail networks, while rail is used for container shipping more often than truck routes at the Seattle and Tacoma BEA zone in Washington. Based on the rail market share for the imported containers from the foreign origins, the markets are located along the east and west coasts of the United States and the Mississippi River Valley. The largest markets are Chicago, Memphis, and Dallas. Intermodal terminals (including COFC-TOFC [3] terminals) are also located around the markets. In addition to the Mississippi River Valley markets, Los Angeles is a large market for imported containers by rail shipping.

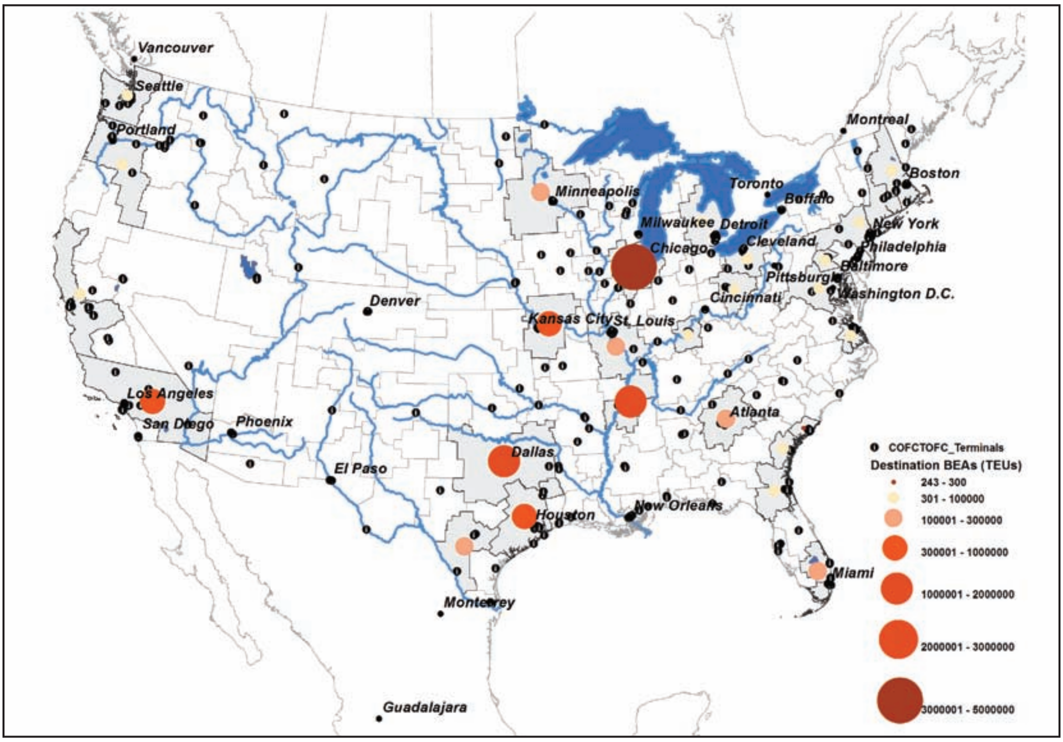
In line with the imported container markets and terminal locations, most of the rail containers originated from the west coast (Figure 3). The rail shipping lanes were estimated by the impedance network with the shortest path algorithm in GIS. The estimated lanes are grouped by selected regions, for example, Atlantic, Pacific, and Gulf of Mexico regions.

Figure 4 shows rail shipping lanes and the density on the segments of the lanes from the East Coast. The containers are loaded on rails from cities such as Boston, New York, Baltimore, Washington D.C., Norfolk, and Jacksonville. Most of the containers are shipped to the Mississippi River Valley and the west coast. In Figure 4, the rail shipping lanes are mixed along the East Coast. Some containers are destined for Vancouver and Quebec, Canada. Landbridge lanes are from the East Coast to Vancouver, Canada, and from Seattle and San Francisco-Oakland in the United States to the East Coast. We speculate that the containers originating from Europe and South America are destined for the East Coast.

Figure 5 shows a high density of the imported containers flowing from the West Coast. A very large number of containers are shipped from the Los Angeles and Long Beach BEA region to Chicago through Kansas City and to Memphis through Dallas. The Seattle-Tacoma BEA region is the next largest West Coast source for the imported containers transported by rail to U.S. inland markets. The containers flow to Chicago through Minneapolis. Some imported containers are shown moving from Portland and Sacramento and headed to Chicago, Minneapolis, and Kansas City. Small landbridge container volumes flow from Pacific ports to the East Coast, including East Coast cities like Boston, New York, Jacksonville, and Miami.

Figure 6 presents the rail shipping density for imported containers through the Gulf of Mexico. In the STB public waybill, one BEA zone, Houston, Texas, shows rail shipping from the Gulf of Mexico. Most of the rail traffic is headed to Los Angeles and northward to Portland and Seattle. The rest of the containers are shipped to New York, Washington D.C., Chicago, Memphis, and St. Louis.

Figure 2: Container Market Density by the STB Waybill Public Sample and Geographical Locations of Intermodal Terminal in 2007



CONCLUSION

One of the major objectives of the study was to geovisualize container flow based on developed linear programs. We implemented the GIS model integrating an impedance approach and investigated the flow of the imported containers in the United States. Using GIS to create visualization, U.S. import container traffic was determined. For the visualization, the STB waybill sample was used as trip information for railroad shipping from the portal BEA regions to inland container markets. Visualization of the freight information could be used for portal areas along the coastal cities to estimate segment density and evaluate container flow. Using geovisualization, it becomes possible to ascertain density and major shipping routes of the imported container traffic, with impedance, for each major direction from the Atlantic Ocean, Pacific Ocean, and Gulf of Mexico to inland markets.

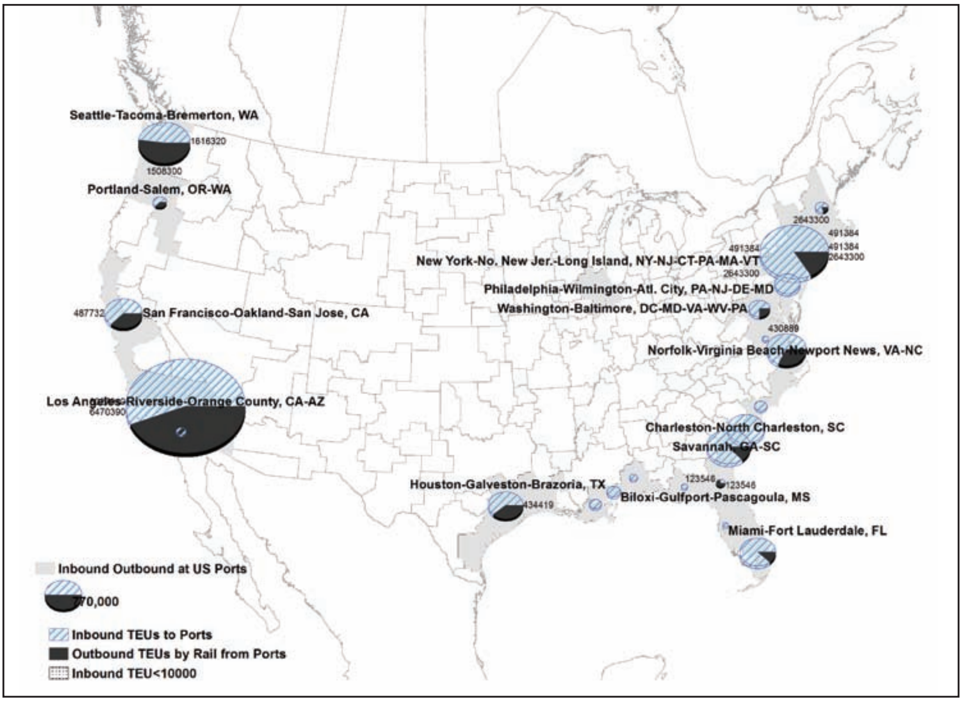
Endnotes

1. Class I railroads are Burlington Northern and Santa Fe Railway (BNSF), Union Pacific Railroad (UP), Norfolk Southern (NS), CSX Transportation (CSX), Kansas City Southern Railway (KCS), Canadian National Railway (CN), Canadian Pacific (CP), Ferrocarril Mexicano (Ferromex), and Kansas City Southern de Mexico (KCSM) as of 2010.

2. Standard Classification of Transported Goods (SCTG) Code is 43 for the mixed freight.

3. Container-on-Flat-Car (COFC) and Trailer-on-Flat-Car (TOFC)

Figure 3: Comparison Import Containers Inbound TEUs to Ports by Ocean Shipping to Outbound TEUs from Ports by Rail in 2007



Note: The same space of inbound TEUs to Ports (dashed) and the outbound TEUs by rail from Ports (in dark) means that all TEUs inbounded to a port are transported by rail from the port to inland markets.

Figure 4: Container Flow from the Atlantic Ports

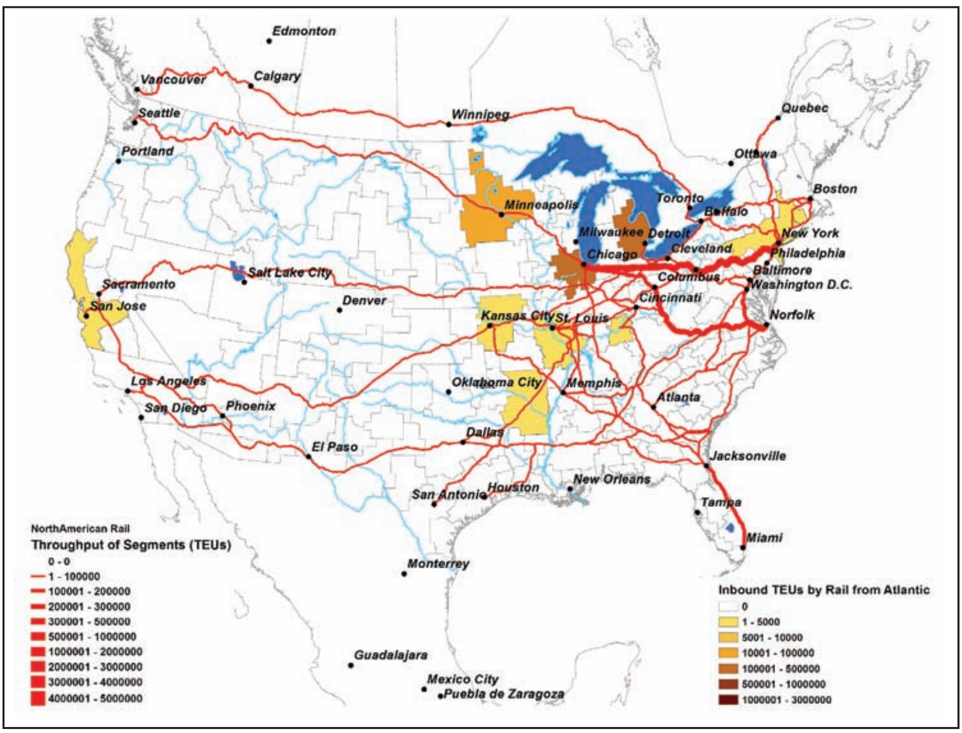


Figure 5: Container Flow from the Pacific Ports

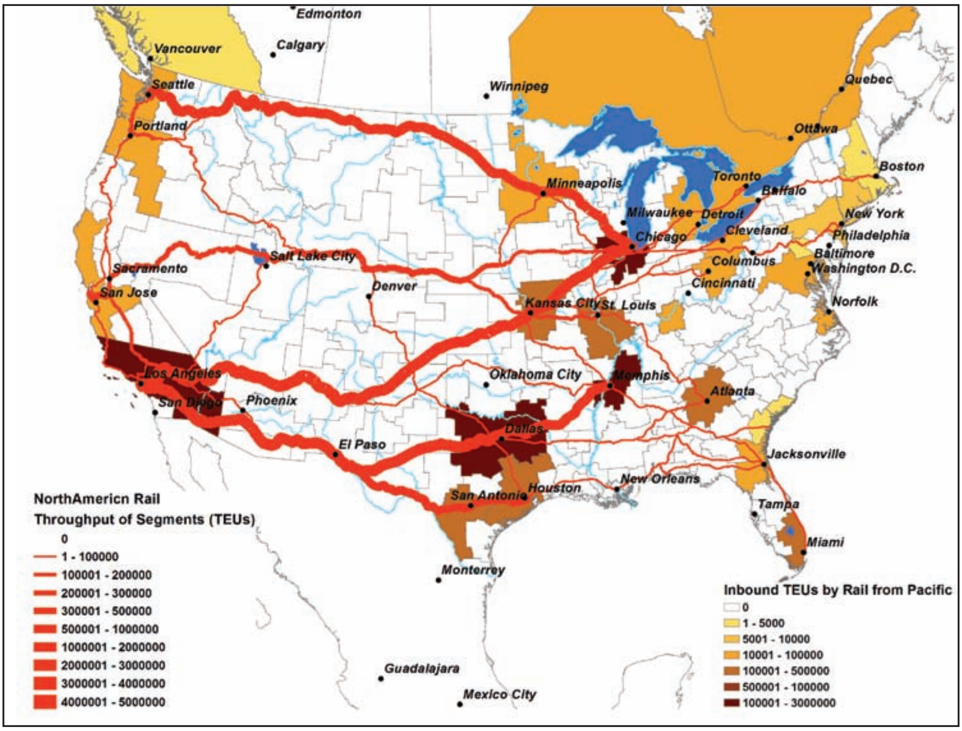
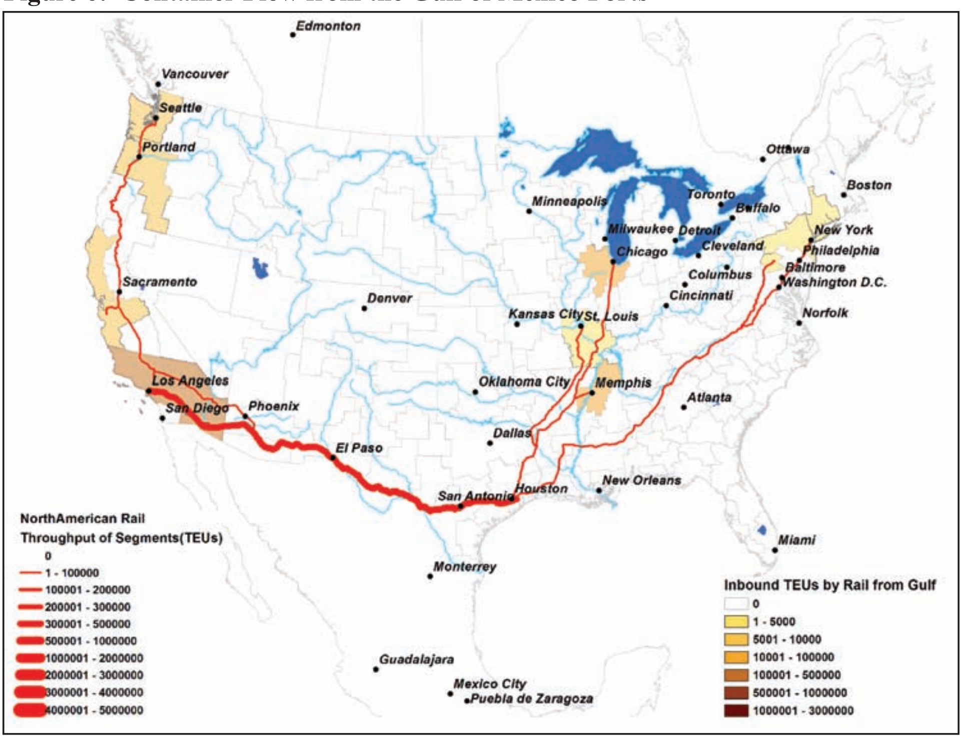


Figure 6: Container Flow from the Gulf of Mexico Ports



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