Development of Statewide Freight Flows Assignment Using the Freight Analysis Framework (Faf³)

Arturo Bujanda^{1,*}, Juan Villa², Jon Williams³

¹Associate Research Specialist Texas Transportation Institute ²Program Manager Texas Transportation Institute ³Research Associate Texas Transportation Institute *Corresponding author: a-bujanda@tamu.edu

Received December 10, 2013; Revised May 30, 2014; Accepted June 02, 2014

Abstract This research presents a methodology to estimate freight flows along corridors serving international trade. A methodology to disaggregate regional flows from the Federal Highway Administration's Freight Analysis Framework (FAF³) to the state level was developed and applied to the State of Texas. To keep international trade moving in a timely and efficient manner, it is important to have accurate information identifying and anticipating capacity shortfalls and congestion nodes. As trade levels increase, the strain on existing infrastructure serving international trade will only get worse; therefore, this information is important for improving strategic investment decisions. This research presents findings from literature reviewed about the FAF³ structure and existing methodologies to estimate freight flows at statewide and regional levels. A methodology to disaggregate national FAF³ data and then assign and estimate the tons of international freight flows through statewide roadways and railroads was developed. Texas's international trade corridors are used as a case study to apply the methodology and estimate current and future freight demand. Results from the case study demonstrate encouraging findings about this methodology. Conclusions and recommendations to refine and improve this methodology and the FAF³ are provided.

Keywords: Freight Analysis Framework, Truck Traffic, freight flows, Statewide Traffic Assignment, international trade, texas, Truck Traffic Congestion, growth

Cite This Article: Arturo Bujanda, Juan Villa, and Jon Williams, "Development of Statewide Freight Flows Assignment Using the Freight Analysis Framework (Faf³)." *Journal of Behavioural Economics, Finance, Entrepreneurship, Accounting and Transport*, vol. 2, no. 2 (2014): 47-57. doi: 10.12691/jbe-2-2-3.

1. Introduction

International trade and timely freight movement is vital to the United States (U.S.) economy. According to Federal Highway Administration(FHWA) estimates, in 2008, the nation's transportation system moved more than 21 billion tons of goods worth almost \$17 trillion. The movement of freight in the country has more than doubled in the last 15 years, and it is expected to continue growing at an aggressive pace, with a projected level of 37 billion tons by 2035. This growth challenges the transportation infrastructure, resulting in congestion along corridors and nodes including maritime ports, surface ports of entry (POEs), truck and rail corridors, and airports.

To keep international trade timely and efficient, accurate information identifying and anticipating capacity shortfalls and congestion nodes would strategically improve infrastructure investment decisions. As trade levels are projected to increase in the coming years, primarily driven by the emerging economies (i.e., Brazil, India, and the Pacific Rim), the strain on existing infrastructure serving international trade will only get worse.

Canada and Mexico are the main trading partners for U.S. exports; nonetheless, China's emergent consumer

class is becoming a more prominent market for U.S. exports recently surpassing Japan. For U.S. imports, China has moved up as the main importer to the U.S. following Canada and Mexico. Nonetheless, high oil prices that increased supply-chain costs have made some companies rethink sourcing with "near-shoring" strategies. After having left to China, some manufacturing is now coming back to Mexico. A new element of the recovery is that international trade patterns are changing globally, and this could impact the U.S. transportation system including that of Texas. It is too early to determine what will be the ultimate structure of the new trade patterns. The picture of the new trade patterns will become more apparent once the establishment of the manufacturing base that will spur the expansion period of the next economic cycle takes place.

Another important element that will influence new trading patterns is the expansion of the Panama Canal. This \$5.2 billion expansion is expected to start operations in 2014, and will allow super-sized vessels to come through the canal and serve U.S. ports on the East Coast and the Gulf of Mexico. Transpacific trade between Asia and the U.S. East Coast accounts for more than half of the Canal's traffic. The expansion of the Panama Canal will alter trade patterns that currently use ports on the West Coast. The Port of Houston is one of the first U.S. ports on

route from the Panama Canal to U.S. customers. For ports near Houston, their fastest-growing market is East Asia, with total tonnage increasing more than 30 percent in the last three years. It is anticipated that growth will continue with the expansion of the Canal [1].

Aiming to identify and anticipate current and new trading patterns and total volumes of freight moved into, out of, and within the U.S., the Federal Highway Administration (FHWA) released its third version of the Analysis Framework (FAF³)-the Freight most comprehensive publicly available dataset of freight movements. FAF³ estimates commodity movements by truck and the volume of long distance trucks over specific highways including data for 2007 and 2040. FAF³ relies on the use of models to disaggregate interregional flows from the commodity origin-destination (O-D) database into flows among localities and assign the detailed flows to individual highways [2]. These models are based on the geographic distribution of economic activities rather than a detailed understanding of local conditions.

While FAF^3 provides reasonable estimates for national and multi-state corridor analyses, FAF^3 estimates do not have the sufficient level of disaggregation to support local, regional, or state planning and project development. Even with recent advances in freight travel demand modeling, the development of practical tools to estimate current and future freight flows has been limited. Multiple characteristics of freight demand, such as volumes, weights, empty containers and trucks, proprietary nature of the data, etc. contribute to the complexity of freight demand modeling.

2. Research Approach

This research presents a methodology to estimate statewide freight flows on corridors serving international trade routes, based on the Federal Highway Administration's Freight Analysis Framework (FAF³). This approach includes findings from literature reviewed on FAF³ and existing methodologies to estimate freight flows at statewide and regional levels. The methodology was developed to disaggregate FAF³ data from a national to a state level, assign, and estimate the tons of international freight flows through roadways and railroads. Texas's international trade corridors are used as a case study to apply the methodology and estimate current and future demand.

3. Literature Review

Freight transportation systems, databases. and architectures are well documented in the U.S. Literature revealed several studies conducted within the U.S. related to the disaggregation and modeling of freight flows at state, regional, and local levels. Moreover, the most common finding was the need to probe the accuracy of available freight-related data; however, very few studies suggest how to do it. The application of O-D surveys to truck-drivers was reported as flawed and gives limited data. Most of the studies revised were based on the second version of the FAF (FAF²). Even though FAF³ is the most comprehensive publicly available dataset of freight movement, revised studies recognize the need to account

for different geographic levels (i.e., national, state, regional, and local levels).

An assessment of the database structure of FAF^3 revealed that it uses the same geographic zone structure as the 2007 U.S. Commodity Flow Survey (CFS), and its road network includes interstate highways, other FHWA designated national highways, as well as rural and urban principal arterials. The FAF³ includes improved estimates of the allocation of imports and exports to the U.S. domestic zones. Revised methodologies to estimate transborder freight flows between the U.S. Bureau of Transportation Statistics (BTS) with available O-D data primarily from surveys applied to truckers.

3.1. Methodologies to Develop Statewide Freight Flows

The Kansas Department of Transportation (KDOT) funded the development of the Kansas Freight Analysis Framework (KFAF) to support local planning efforts for the greater Kansas City Area [3]. This research integrated data from a variety of sources based on weight, value, and mode (i.e., highway, rail, water, air) in an online commodity-destination database. When converting commodity tonnage to truck volumes, this methodology applied a formula based on the average payload by commodities(in pounds) and assumed that eighteen wheelers transport all commodities, which significantly differs from reality. Conclusions from this research include the need to probe the accuracy of available data. The authors recognize that through-truck calculations could be improved with a more accurate way of choosing in-and-out locations.

To generate freight at a county level, distribute it between counties, and assign it to expected roadways in Alabama, a procedure based on the FAF² was developed by the University Transportation Center for Alabama [4]. The procedure included the development of an interface to link two preexisting statewide freight modeling tools: (i) the Alabama Transportation Infrastructure Model (ATIM), a discrete-event model; and (ii) a statewide multimodal network in TRANPLAN. This procedure applied a series of filters to disaggregate FAF² data into freight analysis zones (FAZ) by mode; then, such zones served as input to a gravity distribution model in TRANPLAN, and subsequently were combined with the ATIM. Conclusions from this research include the creation of a modeling tool that allows scenario development and the identification of key congestion chokepoint locations.

The Iowa Center for Transportation Research and Education presents a modeling procedure that identified commodity tonnage produced or attracted to predefined FAZs [5]. Freight routes were constructed in a statewide multimodal network. Cost minimization was the main modeling parameter to assign the freight flows. The last step of their approach was to calibrate and validate the resulting traffic assignment with the use of truck surveys and external databases. Conclusions from this work include the need to further refine the model (e.g., incorporating travel time into the link cost, improve the accuracy of commodity flows data). Modeling of policy changes in transport cost, production-consumption, and infrastructure can effectively be reflected by this methodology. Tsamboulas and Panayota present a methodological framework for the development of an intermodal international transportation corridor involving rail and ship [6]. Their method calculates freight volumes for a particular corridor, which overcomes issues such as limited availability of data; a case study corridor connecting ports in the Mediterranean tested their method.

NCHRP Report 606: Forecasting Statewide Freight Toolkit recognizes five classes of models to estimate freight flows: (i) flow factoring methods, (ii) O-D factoring methods, (iii) truck models, (iv) four-step commodity models, and (v) economic activity models [7]. In addition to a revision of the FAF² structure, this report presents eight case-studies to forecast the movement of freight; most of these cases focus on forecasting the movement of trucks on roads, either as part of comprehensive travel demand models (TDM) (i.e., passenger and trucks), or as standalone truck-only TDMs. The NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making presents an evaluation of possible improvements in freight TDMs and other analysis tools [8]. This report also provides a framework for categorizing existing models and a good comparison of model development and implementation. Based on interviews and surveys, valuable conclusions from this research include the decision-makers' satisfaction with methods available to support freight planning, but concerns with the quality of available data; moreover, public-sector freight analysis most critical needs include freight information about existing routings, costs and benefits, and flows per facility. The NCFRP 9: Guidance for Report Developing Freight Architecture **Transportation** Data presents the requirements and specifications to link existing datasets, including FAF, ina national freight data architecture [9].

Finally, literature regarding methodologies to estimate transborder U.S.-México freight O-D matrices was revised. Mendoza et al. developed a two-step procedure to combine information of transborder crossings from BTS with 15 years of O-D data collected in Mexico [10]; see also [11]. Similarly, in a study to analyze locations for a new surface POE, O-D surveys were applied to truck-drivers to determine the POE's location and expected demand [12]. This research argues that surveys of these drivers are flawed and give limited data.

3.2. FAF³ Database Structure

The FAF³ provides estimates of annual total volumes, tonnage and dollar valued flows of freight moved into, out of, and within the U.S. between individual states and major metropolitan areas. Freight O-D movements are estimated for calendar year 2007 out to 2040. The FAF³ examines four main transportation modes: (i) highway, (ii) railroad, (iii) water, and (iv) air. The principal dimensions of these FAF³ freight flow matrices are:

1. shipment origination region (O),

- 2. shipment destination region (D),
- 3. class of commodity being transported (C), and
- 4. mode of transportation used (M).

The structure of the FAF³ consists of 123 CFS regions or FAZ divided in the following subsets: seventy-four metropolitan area determined regions, thirty-three regions representing a state's territory outside metropolitan regions, and sixteen regions identified as entire states, within which no FAF³ metropolitan regions exist(see Figure 1). Metropolitan regions do not cross state boundaries. There are eight international trade regions to model U.S. exports and imports. The FAF³ freight flows matrix is made up of 131 origin \times 131 destination \times 43 commodity class \times 8 modal category data cells, for each of two reporting metrics, annual tons and annual dollar values.

The road network used in the FAF³ is comprised by data from the Highway Performance Monitoring System (HPMS), which includes interstate highways; other FHWA designated national highways; as well as rural and urban principal arterials. The FAF³ network database now includes the flow assignment for 2007 and 2040. Each link in the network includes attributes, most from the HPMS, such as: annual average daily traffic (AADT), average daily truck-traffic (AADTT), capacity, delay, speed and others for 2007 and 2040. Based on the use of PIERS data (international trade data available to subscribers), FAF³ includes improved estimates of the allocation of imports and exports to the U.S. domestic zones (domestic origination zones for exports, and destinations zones for U.S. imports) [2].

Each of the O-D pairs among each of the 123 CFS regions in the FAF^3 includes, in addition to a unique ID, the following attributes:

Foreign Origin. U.S. imports that originated in one of the eight international trade regions (Canada, Mexico, Rest of Americas, Europe, Africa, Southern, Central, and Western Asia, Eastern Asia, South-Eastern Asia and Oceania).

Domestic Origin. U.S. imports into, or freight originated, within one of the seventy-four metropolitan CFS regions.

Domestic Destination. U.S. exports to, or with final destination, within one of the seventy-four metropolitan CFS regions.

Foreign Destination. U.S. exports that have its final destination in one of the eight international trade regions (Canada, Mexico, Rest of Americas, Europe, Africa, Southern, Central, and Western Asia, Eastern Asia, South-Eastern Asia and Oceania).

Commodity. FAF³ uses the Standard Classification of Transported Goods (SCTG) developed by statistics agencies in the U.S. and Canada.

Domestic mode. Includes the transport mode used by imports and exports within the U.S. (i.e., truck, rail, or air).

Inbound mode. Includes imports that enter the U.S. by either truck, rail, water, air, multiple modes and mail, pipeline, other and unknown.

Outbound mode. Includes exports that exit the U.S. by either truck, rail, water, air, multiple modes and mail, pipeline, other and unknown.

Trade type. This field identifies if the shipment is an import, export, or domestic.

Weight (thousand tons) for 2007, 2009 and 2015-2040 in five years increments.

Value (million U.S. dollars, \$) in constant dollars for the same years as above.

For this study, only import and export trade types were considered. Domestic freight was excluded, only data for 2007 and 2040 were considered given that 2009 was still preliminary information.



Figure 1. FAF³ Zone Structure (U.S. Commodity Flows Survey Regions). *Source:* Developed by TTI with data from the FHWA's Framework for Freight Analysis (FAF³). 2011

4. Methodology to Assign Statewide Freight Flows

A methodology to disaggregate national FAF³ data, assign it, and estimate the tons of international freight flows through statewide roadways and railroads was developed. Texas's international trade corridors are used as a case-study to apply the methodology and estimate current and future demand. Such methodology was developed keeping in mind the facilitation of future scenario development; however, no scenarios were explored. The data disaggregation procedure is based on data from the FAF³ database, and it consists of the following steps: 1). Database preparation, 2). Disaggregation filters, 3).State in-and-out freight control points, 4). Shortest path, 5). Freight flow assignment using ArcGIS, and 6). Transborder freight flow calibration. Each step's sequence is illustrated in Figure 2 with red circles, and explained in detail afterwards.



Figure 2. Data Disaggregation Procedure to Estimate Statewide Freight Flows. Source: Developed by Texas Transportation Institute. 2011

Three national databases in ESRI's geographic information system software (ArcGIS) format were downloaded from the FAF³ website [13]: (i)the national highway network (links), (ii) the national CFS zones (polygons), and (iii) FAF' soutput, which includes commodity O-D tables. These three databases were combined in ArcGIS. Since the goal of this project was to evaluate only international freight flows at a statewide level, with particular emphasis on flows at land ports of

entry (POEs)on the Texas/Mexico border, a Texas-only O-D matrix was developed as described in the next section.

4.2. Disaggregation Filters

Using the FAF³ database in ArcGIS, multiple queries were performed to select and export only the O-D pairs with either an origin or destination within each of the CFS zones in Texas (Figure 3). The Texas-only O-D pairs included the unique ID and all the original attributes in the FAF³ database (described in the previous section).



Figure 3. Texas-only Freight Analysis Zones. Source: Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF³). 2011



Figure 4. Desire Lines used to identifyTexas Freight Domestic O-D Pairs. *Source:* Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF³). 2011

In the FAF³ database, the "TX Remaining-489" FAZ represents the state's territory outside metropolitan regions. However, this represents a major drawback to assign statewide freight flows particularly for states close to international borders. For example, if measured by gross-domestic product (GDP), some FAZs that might not be significant at a national level aggregated into an overall "Remaining" FAZ in the FAF³, are indeed significant at a state level. A similar situation is presented at major POEs allocated to the "Remaining" FAZ, and such POEs merit special treatment and calibration, as will be explained in the *Transborder freight flows* section.

Once the O-D pairs for Texas-only where identified, a series of data disaggregation filters were applied in Ms. Excel. Such filters included the separation of O-D pairs by trade type (i.e., imports, exports, and removing domestic), by domestic mode (i.e., truck and rail only), and finally by 2007 and 2040 tons. Additionally, international freight that originated or terminated in one of the eight trade regions was international separated from international freight that originated or terminated in one of the seventy-four metropolitan CFS regions (i.e., foreign O-D pairs were filtered from domestic O-D pairs). Once the number of tons was identified by O-D pairs per transportation mode, O-D matrices were prepared and imported into Trans CAD to map O-D desire lines and identify the most relevant domestic O-D pairs (see Figure 4). Given that neither the road network used in the FAF³ nor the one used for Texas' international trade corridors differentiated directionality, individual databases of O-D pairs were added together to estimate total bidirectional flows. Subsequently, bidirectional foreign O-D pairs to and from one of the eight international trade regions were added to the domestic bidirectional flows.

4.3. State Inbound-and-Outbound Control Points

After identifying the O-D pairs for freight movement through Texas, control points were strategically located at freight in-and-out of the state locations (i.e., truck routes, surface and maritime POEs), see Table 1 and Figure 5. It was not possible to obtain 2007 data for the total amount of freight imported or exported through Texas' truck routes. However, 2002 volumes were used as a basis for comparison. Data for the total amount of freight imported or exported through surface POEs was obtained from the Bureau of Transportation and Statistics (BTS) for 2007 for trucks and rail [14]. Data for the imports and exports through maritime ports was obtained from the U.S. Army Corps of Engineers [15].

Interstate Highways (Truck Routes)	ID	Surface Ports of Entry	ID	Maritime Ports	ID
I-10 at El Paso TX to Los Angeles	1	El Paso	9	Houston	17
I-10 at Orange TX to Louisiana	2	Presidio	10	Corpus Christy	18
I-20 at Shavenport to Louisiana		Del Rio	11	Beaumont	19
I-30 at Texarkana TX to Arkansas	4	Eagle Pass	12	Texas City	20
US 75 at Denison TX to Oklahoma		Laredo	13	Galveston	21
I-35 at Gainsville TX to Oklahoma	6	Hidalgo	14		
I-40 East of Amarillo	7	Brownsville	15		
I-40 West of Amarillo	8	Progreso	16		

Table 1. Texas Inbound-and-Outbound Control Points

4.4. Shortest Path

For each domestic O-D pair, the shortest path was estimated using the "get directions" function in Google maps, and freight was assigned to paths crossing through one of the inbound and outbound control points. Subsequently, a unique identifier per control point was added to each O-D pair in Excel, and disaggregation filters were applied again to identify the total amount of freight by year and mode through each of the control points in Texas. For O-D pairs with an international FAZ either as an origin or destination, the shortest path was estimated as a function of the transportation Outbound mode(as previously described) and the nearest POE for trucks and rail. For example, an O-D pair from Dallas to Mexico by truck was assigned to the nearest POE, Laredo; or an O-D pair from Dallas to Europe by ship was assigned to the nearest maritime port, Houston. After estimating the shortest path for an O-D pair in Google maps, the same path was replicated in ArcGIS by creating a selection set for a particular O-D pair using the roadway and railroad networks respectively.

4.5. Freight Flows Assignment Using ArcGIS

Based on the FAF³ national road network, a simplified version was created using existing statewide truck routes for Texas in ArcGIS format (see Figure 5). The objective was to facilitate statewide network-based spatial analysis, such as routing, travel directions, determining closest control points, and to perform the freight traffic assignment-using the 2007 and 2040 number of tons. Furthermore, the freight flow assignment in ArcGIS was created keeping in mind the facilitation of the estimation of ton-miles per each of the international trade corridors in Texas and of future scenario developments. While estimating the shortest path for each O-D pair, the total tons of freight by mode were assigned by creating a selection set for a corridor, and then adding the number of tons for each O-D pair using that particular corridor. This incremental addition was performed using the field calculator function in ArcGIS until all O-D pairs aggregated through the control points (1048 for trucks and 502 for rail) were completed.



Figure 5. Texas Road Network used for the Assignment of Truck Freight Flows. Source: Developed by Texas Transportation Institute. 2011

4.6. Transborder Freight Flows

Transborder freight flows were constructed from diverse data sources depending on the mode of trade. FAF³ freight flows imported and exported from Texas to (or from) any of the eight international zones were used to develop the assignment of transborder freight flows in ArcGIS. Freight flows for each O-D pair were spatially disaggregated and assigned to an international POE, either surface or maritime depending on the O-D, based on the shortest path selection.

For the surface transborder freight flows, once the first iteration of the assignment was complete, truck and rail freight movements between the U.S. and Mexico were calibrated using data from BTS. A second iteration was conducted in ArcGIS until final flows matched those of all control points. For O-D pairs with a Mexican FAZ either as an origin or destination, the flows were re-assigned as a function of (i) the *Outbound mode*, (ii) the shortest path (for the nearest POEs) and (iii) proportions for each POE in Texas estimated using data from BTS for trucks and rail. For example, in the second iteration, an O-D pair from Dallas to Mexico by truck was assigned to Laredo, Hidalgo, Brownsville, and Eagle Pass according to the estimated proportions from BTS data respectively.

As with the assignment for surface transborder freight flows, waterborne imports and exports were derived first using data from FAF^3 for international freight movements by ocean vessels. Once the first iteration for the assignment was complete, maritime freight movements between the U.S. and Europe, Africa, Southern, Central, and Western Asia, Eastern Asia, South-Eastern Asia and Oceania (all of them through Texas), were calibrated using data from the U.S. Army Corps of Engineers International Waterborne Commerce.

5. Texas International Trade Corridors Case Study

Table	2.	Texas	International	Trade	Corridors	tons	by	Trucks
(Impor	rts/l	Exports	, Millions)					

(FFF)					
	2007		2040		
Corridor	Tons	Ton- Miles	Tons	Ton- Miles	
I-35 Laredo & San Antonio	31.94	5,016	92.05	14,418	
I-35 San Antonio & Dallas	20.80	5,560	54.47	14,501	
I-10 Houston & Louisiana	32.32	3,668	77.67	8,626	
I-30 Dallas & Arkansas	8.68	1,478	24.88	4,226	
I-10 San Antonio & Houston	21.55	4,012	63.60	11,859	
I-10 El Paso & San Antonio	12.28	6,589	20,056	8,364	
I-45 Houston & Dallas	16.34	3,780	2,478	469	
US 59 Houston & Arkansas	3.10	869	37.67	36.44	
US 75 Dallas & Oklahoma	2.81	214	10.33	6.02	
US 59 US 77 & Houston	12.58	1,439	28.10	3,216	
US 77 I-37 & Victoria	8.87	684	18.10	1,395	
US 77 Brownsville & I-37	2.92	440	8.04	1,219	
I-35 Dallas & Oklahoma	5.22	309	15.03	818	
US 281 Texas Valley & I-37	9.00	1,415	24.25	3,809	
I-37 Corpus Christi & San Antonio	12.66	1,184	34.27	3,234	
I-20 El Paso & Dallas on to Louisiana	2.30	1,688	6.73	4,996	
I-40 Amarillo & Texas Panhandle	4.71	302	13.5	865	
US 287 Dallas & Amarillo	3.98	1,478	11.60	4,254	
Ports to Plains I-27/US 87/I- 10, Amarillo & North	0.85	403	2.43	1,125	
US 69 Beaumont & US 75	0.61	427	1.75	1,214	
US 83 Laredo & Texas Valley	0.06	104	0.07	122	

Source: Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF3). 2011

Based on the methodology developed and described in the previous section, freight flows for 2007 and 2040 were assigned to the network. Table 2 lists the Texas international trade corridors by volume moved through each corridor by truck for 2007 and projections for 2040. These commodity flows are calculated using the FAF3.

Ton-miles for 2007 and projections for 2040 are also illustrated.



Figure 6. International Trade Tons by Trucks 2007 (top) and 2040 (bottom) (Imports and Exports). *Source:* Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF3). 2011

Figure 6 (top) shows truck shipments by weight (metric tons) for the forecasted year 2007. Similarly, the bottom map illustrates the expected impact on Texas'

international trade corridors using the tons by truck for 2040 (figures showing 2007 and 2040 volumes share the same graphic classification scale to facilitate analysis).

Table 3 shows international trade moved through the corridors by rail. Similarly, the weight and ton-miles

projected for the year 2040 are shown.

Table 3. Texas In	nternational Trade	Corridors tons b	y Rail (Im	ports/Exports,	Millions)

Corridor	2	.007	2040		
Collidoi	Tons	Ton-Miles	Tons	Ton-Miles	
I-35 Laredo & San Antonio	18.52	2,877	44.70	6,937	
I-35 San Antonio & Dallas	9.88	3,101	22.38	6,998	
I-30 Dallas & Arkansas	1.87	216	4.03	445	
I-35 Dallas & Oklahoma	5.92	385	12.83	824	
I-10 Houston & Louisiana	9.49	1,131	24.11	2,868	
US 75 Dallas & Oklahoma	1.69	136	3.27	261	
I-10 San Antonio & Houston	10.30	2,305	29.82	6,693	
US 59 Houston & Arkansas	7.09	2,385	16.53	5,574	
I-45 Houston & Dallas	4.88	1,217	10.66	2,645	
I-40 Amarillo & TX Panhandle	0.83	101	1.54	187	
I-10 El Paso & San Antonio	4.84	3,156	16.79	11,035	
I-37 Corpus Christi & San Antonio	1.96	233	4.94	605	
US 59 US 77 & Houston	1.89	167	4.16	366	
US 77 I-37 & Victoria	2.45	170	5.50	382	
US 77 Brownsville & I-37	1.43	236	3.74	616	
I-20 El Paso & Dallas to Louisiana	2.98	2,355	6.92	5,472	
US 287 Dallas & Amarillo	0.37	131	0.72	255	
US 83 Laredo & Texas Valley	0.00	0	0.00	0	

Source: Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF3). 2011



Figure 7. International Trade Tons by Rail 2007 (top) and 2040 (bottom) (Imports and Exports). Source: Developed by TTI with data from the FHWA, Framework for Freight Analysis (FAF3). 2011

Figure 7 (top) shows rail shipment tons by weight for the year 2007; similarly, the bottom map shows projected rail shipment tons by weight for the year 2040.

5.1. Major International Trade Corridors

5.1.1. I-35

The I-35 corridor continues to be the most prominent corridor for international trade via both rail and truck in Texas. The I-35 corridor links Laredo, the largest Texas port of entry, to San Antonio, Austin, Dallas, and north to Canada. The Union Pacific Railroad runs parallel to the Texas portion of I-35. Trade flows between Laredo and Dallas are expected to grow 65 percent between 2007 and 2040 for all modes. With this corridor's heavy use and continued growth, congestion can be expected to worsen if steps are not taken to address the transportation need.

5.1.2. I-10

The I-10 corridor connects El Paso, San Antonio, Houston and Beaumont. Of the total 73.6 million tons shipped by all modes for the Houston-Louisiana corridor, 51.4 million tons were shipped by pipelines. The remaining corridor segments of I-10 have trucks carrying more weight and dollars of goods than any other mode. Some shipments travel from Laredo along I-35 to San Antonio and then proceed to I-10 and travel east or west depending on their destinations.

5.1.3. I-45

The I-45 corridor connects the Port of Galveston to Houston and continues to Dallas. Much of the freight in this corridor is moved via pipelines that run parallel to I-45 from Houston to Dallas. The Port of Houston provides the majority of trade that is shipped via I-45. The I-45 corridor is expected to grow 55 percent from 2007 to 2040, which is much slower than the 67 percent Texas average for international trade corridors.

5.2. Other Corridors

The remaining corridors account for 20 percent of the weight and 29 percent of the value of international goods shipped through Texas by all modes. New industrial developments or major infrastructure changes, such as I-69, might affect future international trade movements through these corridors.

6. Conclusions and Further Research

The resulting methodology from this research demonstrates encouraging findings about the estimation of freight flows and their assignment to the transportation network. Using data from FAF³ to produce freight flows, and data from BTS and the U.S. Army Corps of Engineers to calibrate land POE and maritime port freight flows proved to be a successful combination of various data sources. The use of Trans CAD to map O-D desire lines and identify the most relevant O-D pairs was a practical way of establishing the control points for freight moving in and out of the state by transportation mode. Similarly, the application of ArcGIS was a practical way of conducting the routing, travel directions, determining the

closest control points, and performing the freight traffic assignment—using the current and future number volumes extracted from the FAF3 database. Furthermore, ArcGIS resulted to be of great value when performing the estimation of ton-miles for each of the international trade corridors in Texas.

As described in this paper, this methodology focused on the assignment of volumes of tons rather than trucks. Assigning truck volumes is far more complicated, as commodity to truck conversion factors would be needed, as well as an estimation of the number of empty vehicles on the state network. This would add errors that could be expanded during the forecasting process of estimating future flows. Further refinements are needed to improve the estimation of freight flows by truck and rail through Texas international trade corridors:

1. Account for various vehicle types and paid load characteristics and develop truck-trips estimates.

2. Conduct traffic counts at control points to improve calibration.

3. Consider planned freight generating centers such as manufacturing plants and intermodal and logistic zones along both sides of the U.S. – Mexico border.

4. Increase the granularity of the FAF³ "TX Remaining FAZ 489" as it includes several major freight generators.

Finally, there is a pressing need to study the potential impacts of projected demand (examined in this report) upon current and planned infrastructure (the supply side), such as capacity and infrastructure conditions on roadways and railroads, as well as on surface and maritime POEs and their connecting infrastructure.

Acknowledgements

Support for this research was provided by the Texas Department of Transportation. The authors thank Jack Foster P.E. at the Transportation Planning and Programming Division of the Texas Department of Transportation for his invaluable support in conducting this research.

References

- Port of Houston authority. Sustainability Report. [Online] 2009. http://www.portofhouston.com/pdf/AR09/PHA_Sustainabilty_Rep ort_09.pdf.
- [2] Southworth, Frank, et al., et al. The Freight Analysis Framework, Version 3: Overview of the FAF3 National Freight Flow Tables. Washington, DC: Office of Freight Management and Operations Federal Highway Administration, 2010.
- [3] Wurfel, Erin, et al., et al. Freight Analysis Framework for Major Metropolitan Areas in Kansas. Lawerence, Kansas: Kansas Department of Transportation and The University of Kansas, 2009. Final Report. K-TRAN: KU-08-4.
- [4] Harris, Gregory and Anderson, Michael.*Modeling Truck Traffic Volume Growth Congestion*. Tuscaloosa, AL: University Transportation Center for Alabama, The University of Alabama. 07304.
- [5] Preissig, David T and Souleyrette, Reginald R.Multimodal Statewide Freight Transportation Modeling Process. Schaumburg, IL: TranSystems Corporation and Center for Transportation Research and Education Iowa State University.
- [6] Methodology for Estimating Freight Volume Shift in an International Intermodal Corridor. Tsamboulas, Dimitrios and Moraitis, Panayota. 2008, Washington, D.C.: In Transportation Research Record: Journal of the Transportation Research Board, 2007. ISSN: 0361-1981.

- [7] NCHRP REPORT 606: Forecasting Statewide Freight Toolkit. Cohen, Harry, Horowitz, Alan and Pendyala, Ram. Washington, D.C.: National Cooperative Highway Research Program, 2008. ISBN: 978-0-309-09924-0.
- [8] Cambridge Systematics and Geostats.NCFRP Report 8: Freight-Demand Modeling to Support Public-Sector Decision Making. Washington, D.C.: Transportation Research Board, 2010. ISBN 978-0-309-15513-7.
- [9] Quiroga, Cesar, et al., et al.NCFRP Report 9: Guidance for Developing a Freight Transportation Data Architecture. Washingotn, D.C.: Transportation Research Board, 2011. ISBN 978-0-309-15523-6.
- [10] Methodology to Obtain a Mexico–U.S. Multiproduct Origin– Destination Matrix. Mendoza, Alberto, Perez, Emilio Abarca and Centeno, and Agustín G. Washington, D.C.: In Transportation Research Record: Journal of the Transportation Research Board, 2008, Vol. 2049, pp. 153-157.
- [11] Multiproduct Network Analysis of Freight Land Transport between Mexico and the United States. Mendoza, Alberto, Gil, Claudia Z. and Trejo, Juan M. Washington, D.C.: In Transportation Research Record, Journal of the Transportation Research Board, Vol. 1653.
- [12] Using Brokers to Determine North American Free Trade Agreement Truck Origins and Destinations at Texas–Mexico

Border. Harrison, Robert. Washington, D.C.: In Transportation Research Record: Journal of the Transportation Research Board, Vol. 1719, pp. 136-139.

- [13] U.S. Department of Transportation Federal Highway Administration. Freight Analysis Framework 3 Network Database and Flow Assignment: 2007 and 2040. Freight Management and Operations. [Online] June 6, 2011. [Cited: July 25, 2011.] http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/net wkdbflow/index.htm.
- U.S. Department of Transportation. North American Transborder Freight Data: Query Detailed Statistics. *Research and Innovative Technology Administration, Bureau of Transportation Statistics*.
 [Online] [Cited: July 28, 2011.] http://www.bts.gov/programs/international/transborder/TBDR_Q A.html
- [15] US Army Corps of Engineers. US Army Corps of Engineers Navigation Data Center. Waterborne Commerce Statistics. [Online] Waterborne Commerce Statistics Center. [Cited: July 28, 2011.] http://www.ndc.iwr.usace.army.mil//wcsc/wcsc.htm