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FREIGHT DATA FUSION FROM MULTIPLE DATA SOURCES FOR FREIGHT PLANNING APPLICATIONS IN FLORIDA

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Disclaimer

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

Metric Conversion Chart

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

Technical Report

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16. Abstract

A major hurdle in freight demand modeling has always been a lack of adequate data on freight movements for different industry sectors for planning applications. Several data sources are available for freight planning purposes in the United States. Of these, the most commonly adopted sources include Freight Analysis Framework (FAF), Transearch (TS), American Trucking Research Institute (ATRI) truck GPS data, and Department of Transportation (DOT) weigh-in-motion (WIM) data. Of these, the two most commonly adopted commodity flow data sources are FAF and TS. We developed a fused database from FAF and TS to realize transportation network flows at a fine spatial resolution while accommodating the production and consumption behavioral trends (provided by TS). Towards this end, we formulated and estimated a joint econometric model framework embedded within a network flow approach and grounded in maximum likelihood technique to estimate county level commodity flows. Subsequently, we developed additional algorithms to disaggregate county levels flows to the statewide traffic analysis zone resolution. The second part of the project was focused on generating truck OD flows by different weight categories, including empty truck flows. The estimated empty flows (where truck load is less than a threshold) were disaggregated into finer granularity to get better understanding about the patterns associated with empty flows.

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Executive Summary

Freight movement is a defining aspect of a region's economic viability and livability. A region's economy substantially benefits from increased intra- and inter-regional freight flows between different trading partners and intermodal centers (e.g., ports, intermodal logistics centers). Implementation of strategies that support efficient freight movement is therefore essential not only for attracting new industries to move freight within, into, and out of the region but also for addressing the needs of existing businesses. The strategies should also take into account the fact that increased movements bring challenges associated with added stress on already congested transportation networks and negative impacts to air quality. To address these challenges, detailed data on freight movements would provide a greater understanding of freight patterns and its impacts on the transportation network.

A major hurdle in freight demand modeling has always been a lack of adequate data on freight movements for different industry sectors for planning applications. Several data sources are available for freight planning purposes in the United States. Of these, the most commonly adopted sources include Freight Analysis Framework (FAF), Transearch (TS), American Trucking Research Institute (ATRI) truck GPS data, and Department of Transportation (DOT) weigh-in-motion (WIM) data. Of these, the two most commonly adopted commodity flow sources are Freight Analysis Framework (FAF) and Transearch (TS). FAF (freely available) and TS (proprietary) databases contain annualized commodity flow data that can be used in long-range freight forecasting. Although both FAF and Transearch provide annual commodity flows in the United States, several differences exist between these sources, including in the data collection mechanism, and in the spatial and commodity resolution. The coarser spatial resolution in FAF makes it challenging to generate reliable network flow estimates. While TS provides data at a fine spatial resolution, the supply-demand nature of the database does not represent the actual transportation network path flows and requires additional analysis to realize transportation network flows. The primary objective of the first part of the research project was to develop a fused database to realize transportation network flows at a fine spatial resolution while accommodating production and consumption behavioral trends.

To achieve the goal, we undertook disaggregation of FAF flows while augmenting with production consumption-based TS flows. Towards this end, we formulated and estimated a joint econometric model framework grounded in the maximum likelihood approach to estimate county level commodity flows. The algorithm was implemented for the commodity flow information from 2012 FAF data for five FAF zones and 2011 TS databases for 67 counties in Florida. The fused flows were further disaggregated at the Statewide Traffic Analysis Zone (SWTAZ) level using a proportional allocation framework. The fusion algorithm can be applied to obtain fused flows for future years, obviating the need to purchase the expensive TS dataset. We also developed a procedure to disaggregate FAF export/import flows. Using the payload factor, the total tonnages were converted to truck flows.

The second part of the project was focused on generating truck Origin-Destination (OD) flows by different weight categories, including empty truck flows using data that are readily available with the transportation agencies such as link level truck flows by weight from Weigh-in-Motion (WIM) sites, total link level truck flows from Telemetered Traffic Monitoring (TTM) sites, OD matrix of truck flows in a region, OD matrix of commodity flows in a region, and finally the path flows for the truck traffic from the assignment stage in a four-step demand model. Assuming the conservation of commodity and truck flows in a region, the optimization model minimized an objective function with sum of squared errors to estimate truck flows with multiple truck-weight categories. The procedure attempted to estimate the truck flows for specific truck-weight categories between OD pairs in such a manner that the resulting traffic counts at different links, commodity flows between OD pairs, and truck flows between OD pairs closely match with those in the observed data, at a county level resolution. Furthermore, the estimated empty flows (where truck load is less than a threshold) were disaggregated into finer granularity to get better understanding about the empty flows. The validation results were satisfactory and highlighted the efficacy of the proposed method.

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Abbreviations and Acronyms

AADTT	Average Annual Daily Truck Traffic
ADTT	Annual Daily Truck Traffic
ASM	Annual Survey of Manufacturers
ATRI	American Transportation Research Institute
BEA	Business Economic Area
CBP	County Business Patterns
CDD	Cargo Density Database
CSA Data	Compliance, Safety, Accountability Data
FAA	Federal Aviation Administration
FAF	Freight Analysis Framework
FCC	Florida Commodity Classification
FDOT	Florida Department Of Transportation
FGDL	Florida Geographic Data Library
FHWA	Federal Highway Administration
FISHFM	Florida Intermodal Statewide Highway Freight Model
FLSWM	Florida State Wide Model
GIS	Geographic Information System
GPS	Global Positioning System
MAEM	Mean of Absolute Error to Mean
NHCRP	National Cooperative Highway Research Program
NHFN	National Highway Freight Network
OD	Origin-Destination
ODME	Origin-Destination Matrix Estimation
SCTG	Standard Classification of Transported Goods
SIC	Standard Industrial Classification
SIS	Strategic Intermodal System
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Classification
SWTAZ	StateWide Traffic Analysis Zone
TAZ	Traffic Analysis Zone
TCF	Truck Conversion Factor

TS	TranSearch
TTMS	Telemetered Traffic Monitoring Sites
USA	United States of America
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Miles Travelled
WIM	Weigh-In-Motion

CHAPTER I: INTRODUCTION

1.1 INTRODUCTION

Freight movement is a defining aspect of a region's economic viability and livability. A region's economy substantially benefits from increased intra- and inter-regional freight flows between different trading partners and intermodal centers (e.g., ports, intermodal logistics centers). Implementation of strategies that support efficient freight movement is therefore essential not only for attracting new industries to move freight within, into, and out of the region but also for addressing the needs of existing businesses. The strategies should also take into account the fact that increased movements bring challenges associated with added stress on already congested transportation networks and negative impacts to air quality. To address these challenges, detailed data on freight movements would provide a greater understanding of freight patterns and its impacts on the transportation network.

Florida is currently the third largest state by population in the United States with 19 million residents. According to Viswanathan et al. (2008), between 2001 and 2030, population and employment in the state of Florida is predicted to increase by 46.5% and 110%, respectively. Understandably, freight transportation will also grow over time with the expansion of population and economic activity within the state. Hence, the issue of efficient freight movement is gaining increasing importance at all levels of government in the state. Towards better understanding the freight flows in Florida, the Florida Department of Transportation (FDOT) has been at the forefront of acquiring and investigating new data sources for freight planning applications. However, movement data comes in many different forms, from many different sources (public or proprietary), with varying temporal and spatial resolutions, and with substantial differences in the sampling and/or data collection methods. To be sure, each data source contains a wealth of information, but each has its own sets of strengths and weaknesses. Therefore, instead of relying on a single source of data for modeling and other applications, a smarter approach would be to take advantage of data fusion techniques to create a fused dataset with a expanded scope of information and then use it for planning and forecasting purposes.

1.1.1 Research Context

Freight Analysis Framework (FAF) developed by Federal Highway Administration (FHWA) is a publicly available freight demand dataset. It is free and provides a snapshot of commodity flows that are shipped to (imports), from (exports), and within (domestic) the United States. FAF data report flows to and from eight international regions: Canada; Mexico; Rest of Americas (Virgin Island and Puerto Rico); Europe; Africa; South, West, and Central Asia; Eastern Asia; and Southeast Asia and Oceania. The data from Commodity Flow Survey (CFS) form an integral component of Freight Analysis Framework (FAF). The FAF data use a variety of data and models to estimate shipments that are out of scope for the CFS, such as imports, crude petroleum by pipeline, and shipments from farms. The commodity flow data are sufficient for understanding mesoscale freight flows for policy studies. Unfortunately, the dataset does not provide adequate data about local (since the movement information is mostly aggregated to the state and region level) or temporal trends in freight flows.

Transearch (TS) developed by IHS Global Insight is another commodity flow survey. It is a proprietary data source that includes rich information on commodity flows in the form of annual tonnage, containers (for intermodal), carloads (for rail) as well as the dollar value shipped. It reports flows to and from three foreign regions only: Canada, Mexico and Rest of Americas (Virgin Island and Puerto Rico). The data has greater level of detail than FAF - finer granularity of geography and more detailed characterization of commodities, useful to examine logistics and modal trends. However, it is expensive to acquire. It will be beneficial to develop a disaggregation procedure to convert FAF data available from FHWA into a Transearch format (i.e., to disaggregate to a finer geographical resolution) for future years (for example, see Beagan et al., 2018).

In addition to the commodity flow surveys, there is a massive GPS (ping) truck database collected and maintained by the American Transportation Research Institute (ATRI). While ATRI data is an excellent source of information on truck trip flows (i.e., where freight tucks are coming from, where they are going, how many of them, and highway routes/corridors used), the data does not include information on the commodities carried or the purpose of the trips (pickup/delivery, drayage, full truck load, or less than truck load, or empty hauls). Therefore, fusing the derived ATRI products from a recently completed research project (BDK84-977-20) with Transearch commodity flow data (and Transearch format data for future years) will help in deriving Origin-Destination matrices for different industries or commodities. In this project, our goal is to link different Florida specific freight movement data sources using appropriate matching criteria to gain an in-depth insight on the full continuum of freight movement issues in the state.

CHAPTER II: ACQUISITION AND REVIEW OF DATASETS

2.1 REVIEW OF DATASETS

The first step in our research involves a rigorous individual exploration of the candidate datasets for fusion. The exploration enables us to ascertain the patterns in each of the databases and identify the commonalities and dissimilarities. The data sources acquired are:

- Freight Analysis Framework (FAF) data
- Transearch data
- American Transportation Research Institute (ATRI) data
- Weigh-in-motion data
- Vehicle class data
- Parcel level land use data (with industry codes)

2.1.1 Dataset 1: Freight Analysis Framework (FAF)

For the project, we obtained Version 4 of the FAF database (FAF^4) and then data specific to the state of Florida was extracted and prepared for analysis. FAF^4 provides freight flow information for tonnage, value, and domestic ton-miles by region of origin and destination, commodity type, and mode. The baseline year is 2012 and forecasts on freight flows until 2045 are available in 2013, 2014, 2015 and then at five-year intervals.

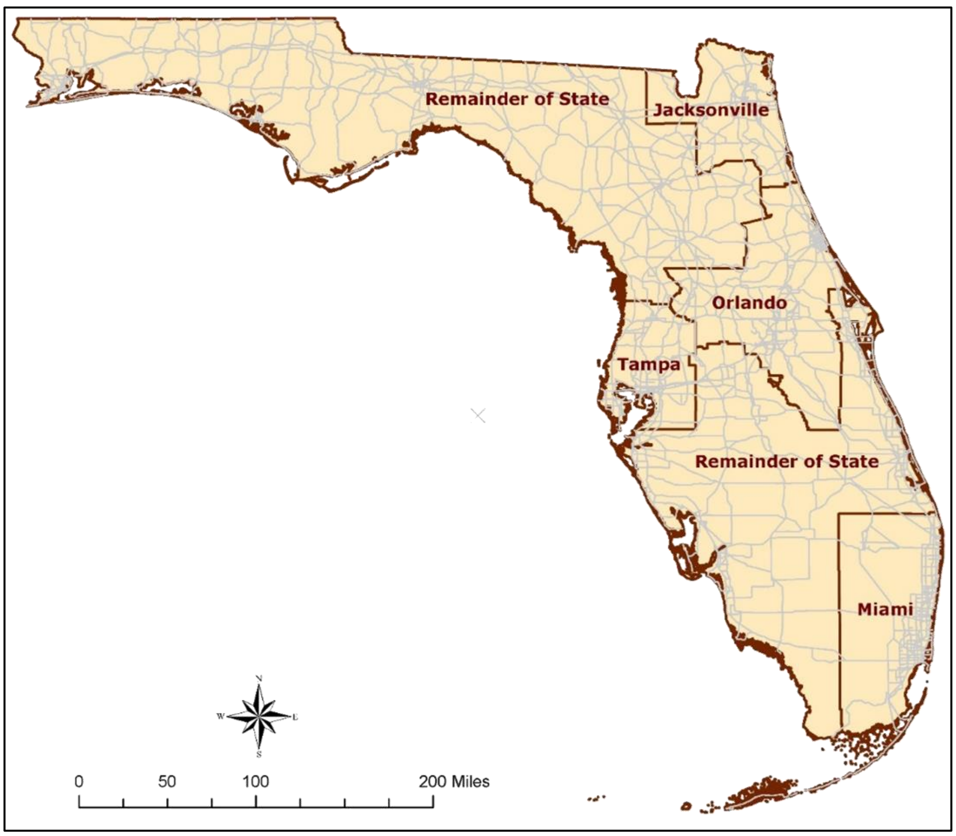


Figure 2-1: GIS Map of FAF Regions

In terms of the geographic dimension, FAF[4] provides freight trading information between 132 domestic zones and 8 foreign zones (Canada, Mexico, Rest of Americas (Virgin Island and Puerto Rico), Europe, Africa, South West and Central Asia, Eastern Asia, and South East Asia and Oceania); five of which are in Florida: Jacksonville (121), Miami (122), Orlando (123), Tampa (124), and remainder of Florida (129) (see Figure 2-1). In terms of commodity classification, FAF[4] reports freight flows using the same 43 2-digit Standard Classification of Transported Goods (SCTG) classes, as reported by the Commodity Flow Survey (CFS).

For analysis purpose, we defined those flows as domestic flow that originated and terminated within Florida, that originated in Florida but destined to regions outside Florida within the U.S., and that originated in regions outside Florida within the U.S. but destined to Florida. Export refers to the freight volume traveling to foreign regions outside the U.S. from Florida while import refers to inbound flow of freight from foreign regions outside of the USA to Florida.

2.1.1.1 Tonnage Share Analysis

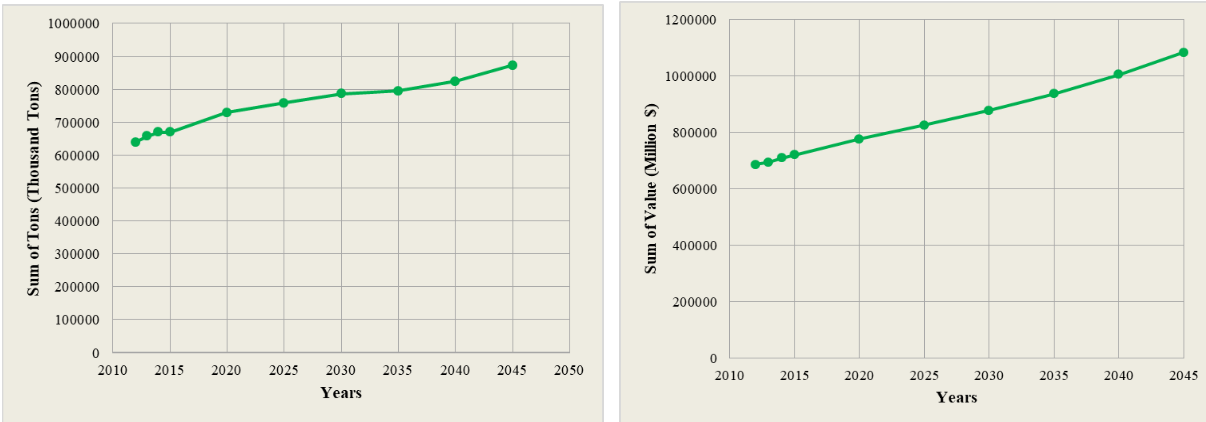
In 2012, approximately 706 million tons of freight valued at approximately $903 billion moved into, out of, within the Florida region via its roads, railroads, waterways, and air freight facilities. Table 2-1 displays freight flows by weight, value and direction for 2012. The following observations can be made from the Table.

- Domestic freight accounted for 639 million tons or nearly 91 percent of the total tonnage valued at $686 billion. More than 39 million tons (2.73%) were exported while 40 million tons (5.59%) were imported to and from the foreign regions. The total value of the exported ($69.56 billion) tonnage was higher than the imported tonnage ($71.99 billion).
- Intrastate volumes (Florida-Florida) represented the largest group in terms of total tonnage shipped (approximately 469 million tons) followed by inbound volumes from the rest of USA (approximately 124 million tons).

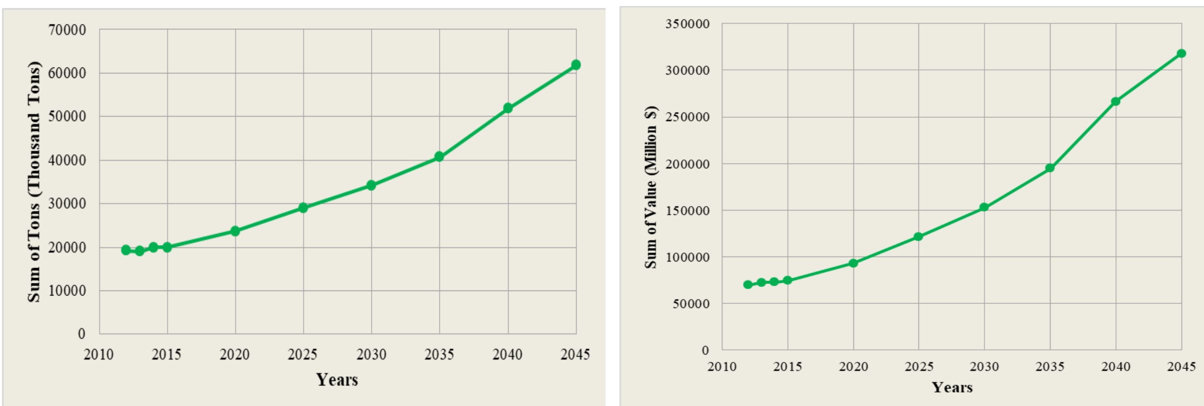
Table 2-1: Total Tonnage by Direction

Direction	Origin	Destination	Total Weight (million tons)	%	Total Value ($ billion)	%
Domestic	Florida	Florida	468.55	66.34	296.37	32.79
	Florida	Rest of the U.S.	46.94	6.65	136.95	15.15
	Rest of the U.S.	Florida	123.70	17.51	253.13	28.01
Import	Foreign	Florida	39.49	5.59	71.99	7.97
Export	Florida	Foreign	19.27	2.73	69.56	7.70
Through	Outside of FL	Outside of FL	8.37	1.18	75.81	8.39
Total	---	---	**706.31**	**100**	**903.81**	**100**

Domestic



Import



Export

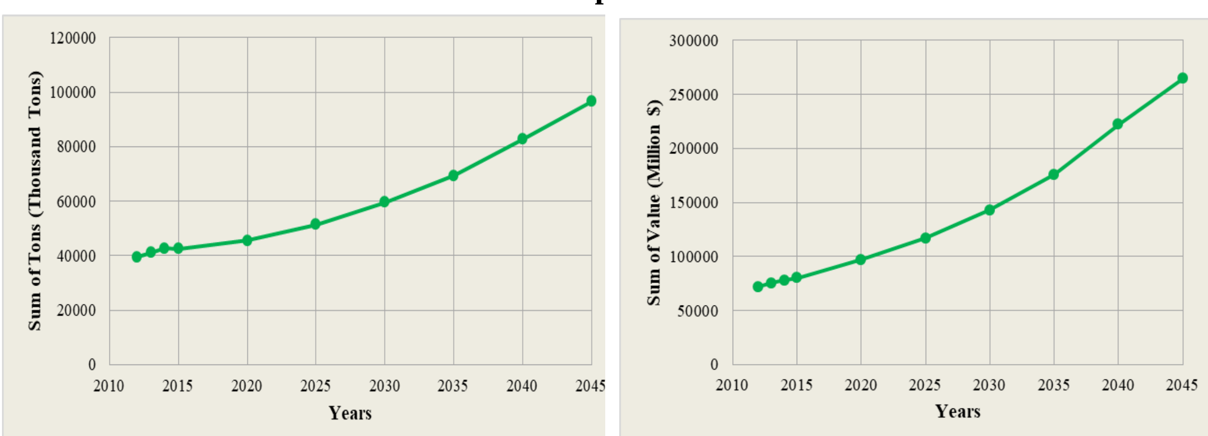


Figure 2-2: Predicted Tonnage (Left) and Value (Right) for Domestic Freight Traffic (top), Imports (middle), and Exports (bottom)

Figure 2-2 graphically shows the total tonnages and values of goods projected until 2045. We can see that in 2045, total tonnage and value of goods are expected to increase to 873 million tons (36.55%) worth nearly $1,084 billion for domestic shipments. For import, the total tonnage is expected to increase to approximately 97 million tons which is worth almost $265 billion. In case of export, the total tonnage is expected to increase to 62 million worth nearly $318 billion.

2.1.1.2 Import (Inbound Freight)

Figure 2-3 graphically represents, by region, the distribution of total inbound tonnage from foreign origins. Among the five regions, Miami is the top region receiving freight shipments (15 million tons), accounting for almost 38 percent of all imported tonnage in Florida. Tampa is next accounting for more than 22 percent (8.8 million tons) followed by remainder of the state (17.18%), Jacksonville (16.12%), and Orlando (6.24%).

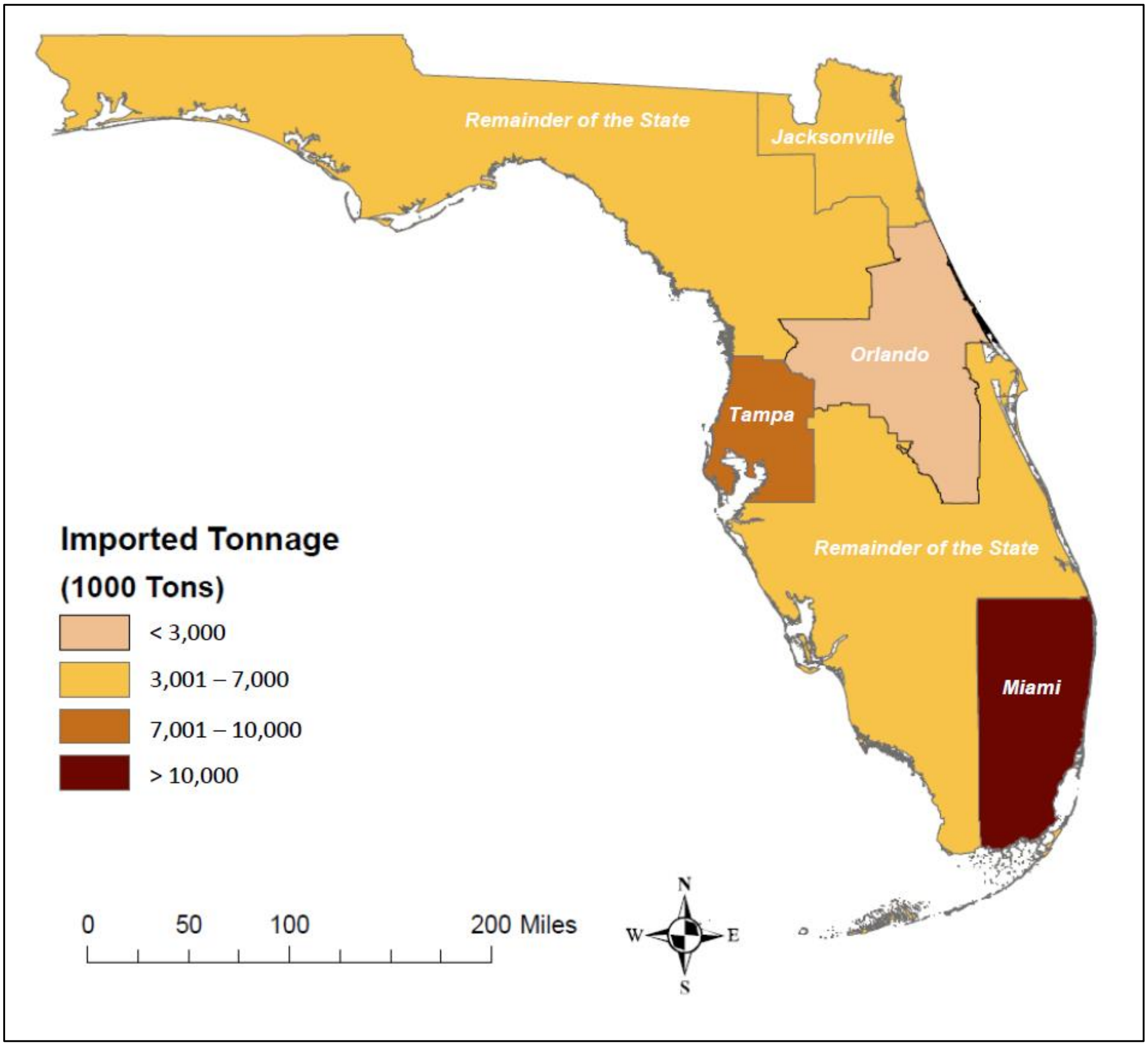


Figure 2-3: GIS Map of Terminating Regions

2.1.1.3 Export (Outbound Freight)

Figure 2-4 graphically represents, by region, the distribution of total outbound tonnage from Florida to foreign regions. Of the five FAF regions, Miami accounted for 41 percent (7.9 million tons) of the total exported freight tonnages. The second highest is Tampa which exported almost 30 percent (5.8 million tons) of the total exported tonnage. Orlando, Jacksonville, and remainder of the state each exported 5 to 15 percent (1 to 3 millions).

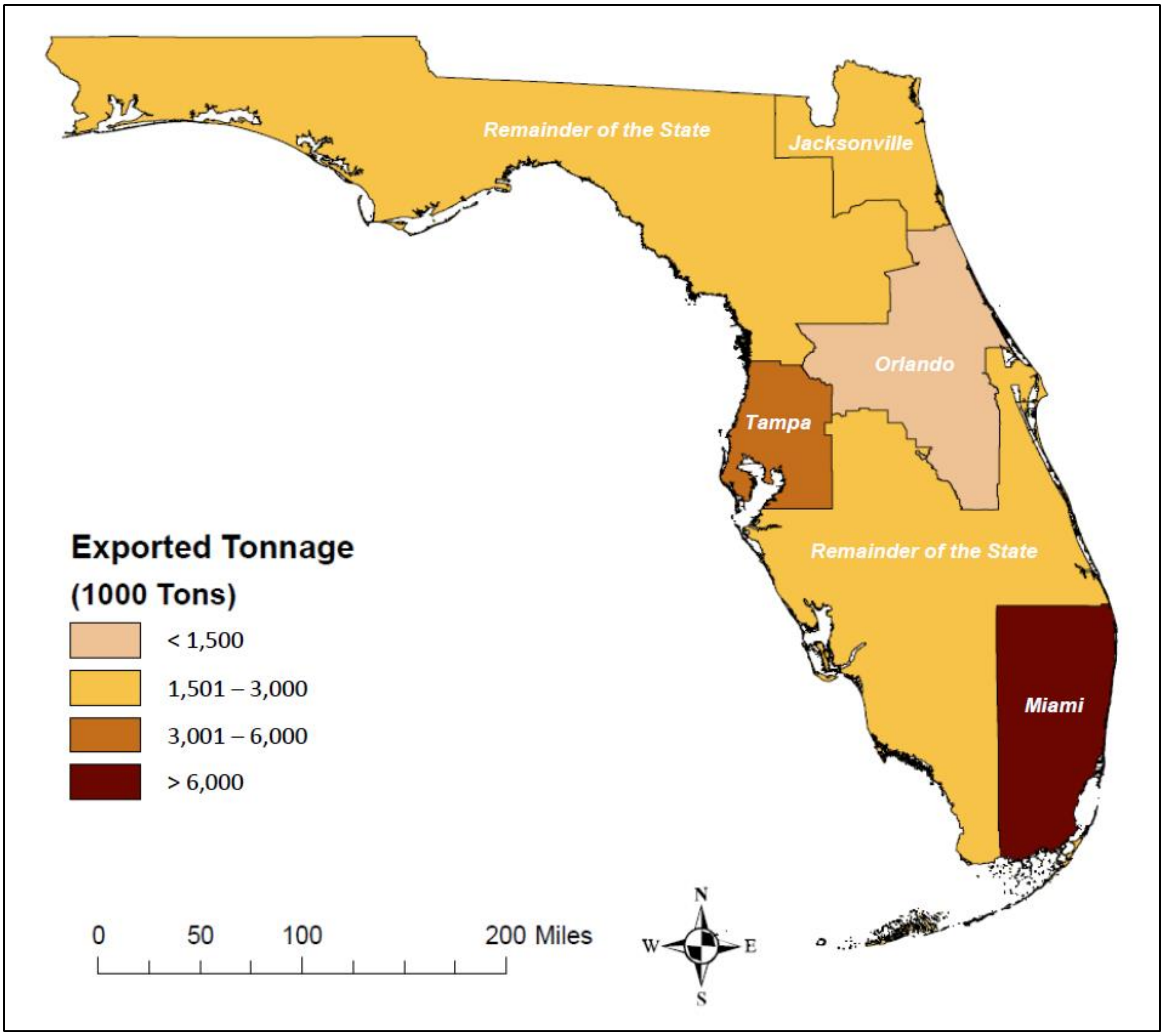


Figure 2-4: GIS Map of Originating Regions

2.1.1.4 Domestic (Intraregional)

Table 2-2 represents the intraregional flow by tonnage within Florida. Flow by tonnage was the highest inside Remainder of state and inside Miami which accounted for 26.26 percent (123 million tons) and 25.73 percent (121 million tons), respectively. The third and fourth highest flow by tonnage was between Tampa to Tampa (9.82%) and Orlando to Orlando (6.66). The least amount of flow by tonnage occurred between Jacksonville to Tampa which accounted for only 0.16 percent (0.76 million tons).

Table 2-2: Freight Movement between In-state Origin-Destination Pairs

Origin	Destination	Tons (in Thousand)	%
Remainder of Florida	Remainder of Florida	123,065.640	26.26
Miami	Miami	120,582.222	25.73
Tampa	Tampa	45,990.733	9.82
Orlando	Orlando	31,212.016	6.66
Remainder of Florida	Orlando	28,405.354	6.06
Remainder of Florida	Tampa	22,701.247	4.84
Jacksonville	Jacksonville	21,896.679	4.67
Remainder of Florida	Miami	11,477.235	2.45
Tampa	Remainder of Florida	10,022.240	2.14
Miami	Remainder of Florida	8,443.225	1.80
Orlando	Tampa	7,412.829	1.58
Miami	Tampa	5,595.335	1.19
Tampa	Orlando	5,220.543	1.11
Orlando	Remainder of Florida	5,142.095	1.10
Jacksonville	Remainder of Florida	4,070.739	0.87
Orlando	Miami	2,750.071	0.59
Remainder of Florida	Jacksonville	2,454.973	0.52
Tampa	Miami	2,335.695	0.50
Jacksonville	Orlando	1,956.209	0.42
Jacksonville	Miami	1,854.338	0.40
Tampa	Jacksonville	1,467.190	0.31
Miami	Orlando	1,459.614	0.31
Orlando	Jacksonville	1,391.375	0.30
Miami	Jacksonville	887.8911	0.19
Jacksonville	Tampa	758.7557	0.16
Total	**---**	**468,554.2535**	**100.00**

2.1.1.5 Mode Share Analysis

Figure 2-5 reflects the distribution of domestic freight tonnage moved within Florida by mode. The following observations were made in terms of intrastate mode share:

- In the state of Florida, truck is the dominant mode of freight transportation. In 2012, trucks carried 96 percent (448 million tons) of the total domestic tonnage shipped within Florida followed by rail (15 million tons). Shorter in-state travel distances make trucking more competitive and attractive than the other mode options.
- The share of truck tonnage is projected to increase by 37.7 percent in 2045. However, increase (55.7%) in the share of rail tonnage is expected to be higher than that of truck share.
- Approximately 1 percent of the domestic intraregional freight travelled by water, air, pipeline and other modes. It is understandable since shipping by air is costly if it's within state while water is more time consuming than other modes.

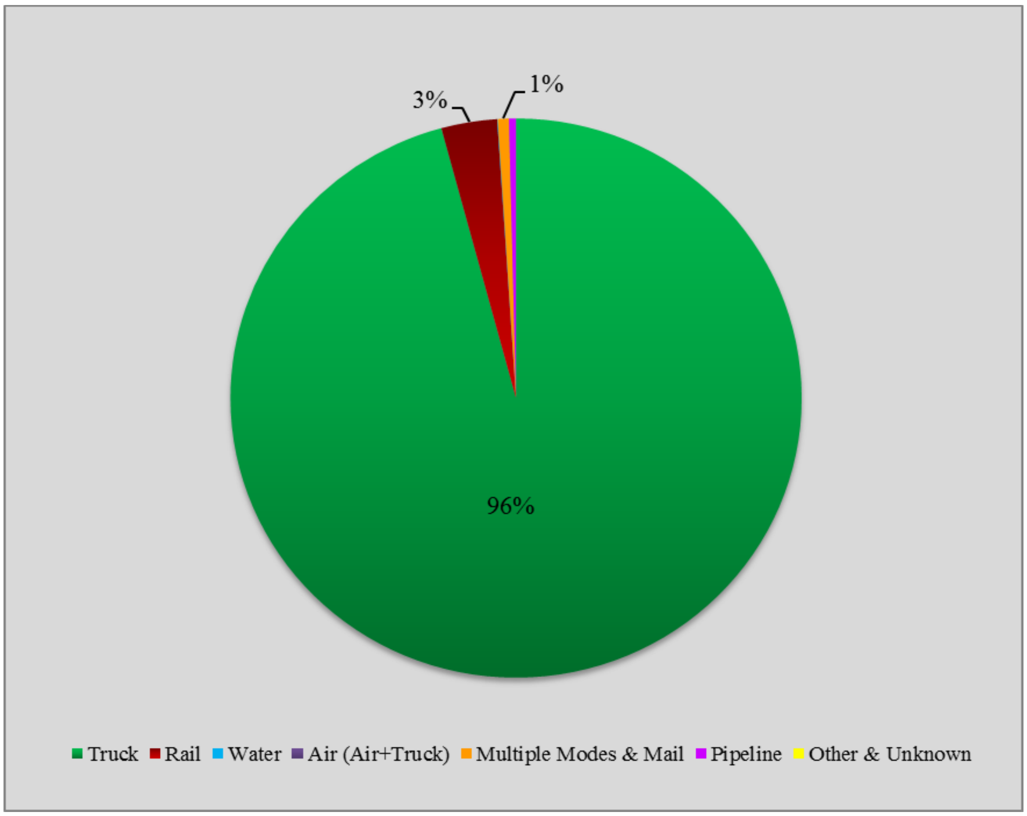


Figure 2-5: Mode Split by Tons – Intraregional Freight within Florida

Figure 2-6 reflects the distribution of domestic freight traveling inbound from other states of the U.S. to Florida by mode. The following observation was made for this type of domestic flow:

- Almost all types of modes have been used to bring freight from other states to Florida with truck (51 million tons), rail (27 million tons), pipeline (24 million tons), and water (14 million tons) being the dominant four modes.

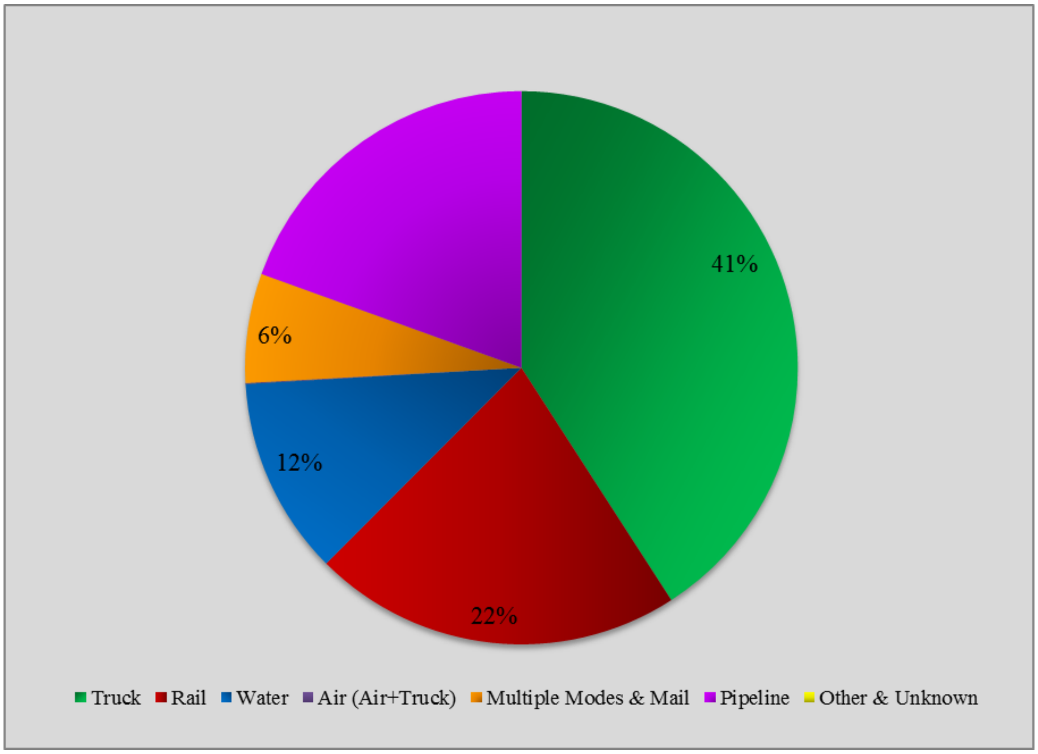


Figure 2-6: Mode Split by Tons – Inbound from Other States of the U.S. to Florida

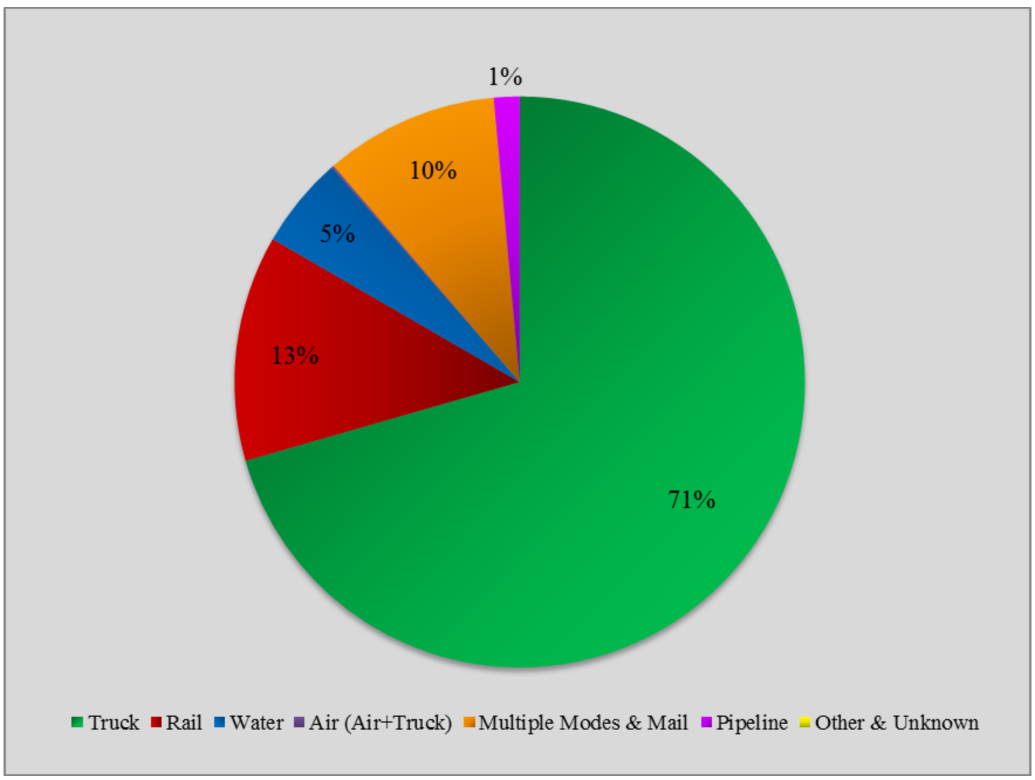


Figure 2-7: Mode Split by Tons – Outbound from Florida to Other States of the U.S.

Figure 2-7 reflects the distribution of domestic freight traveling outbound from Florida to other states of the U.S. by mode. The following observations were made for this particular type of freight movement:

- Domestic outbound flows were mostly dependent on trucks. Seventy-one percent of total tonnage of the products was carried out of Florida to other states by Truck. Approximately 33 million outbound tonnages were carried by Truck. The other two most common modes were Rail (13%) and Multiple Modes and Mail (10%).

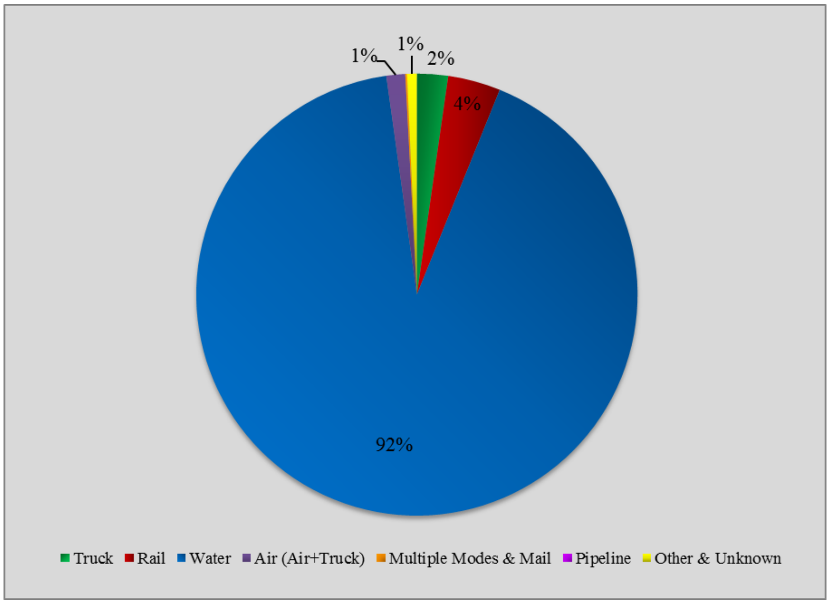


Figure 2-8: Mode Split by Tons – Freight Imported to Florida from Foreign Countries

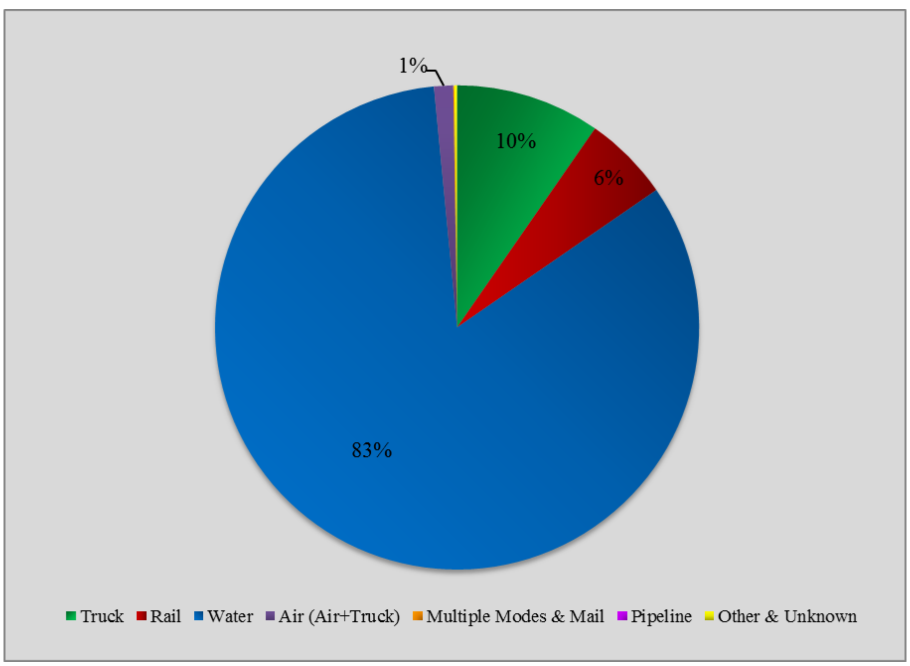


Figure 2-9: Mode Split by Tons – Freight Exported from Florida to Foreign Countries

Figure 2-8 clearly represents that the majority of the commodity by tonnage was imported to Florida from foreign countries by Water (92%) as Florida is surrounded by sea on three sides and has some major ports. Similar to import, the majority of the tonnages were exported to foreign countries by Water (83 percent, or 16 million tons) while Truck accounted for only 10 percent of total exported weight, as shown in Figure 2-9.

2.1.1.6 Tonnage Share by Commodity across Trade Types

Gravel and crushed stone (22.36%) have been found to be the highest transported commodity by tonnage within Florida (See Table 2-3). The second highest transported commodity is natural sands (18.31%). The lowest transported products by tons are precision instrument and apparatus, tobacco, coal, and transportation equipment, jointly accounting for only 0.04 percent of the total tonnage.

Table 2-3: Percentage of Weight by Commodity Type – Within Florida

Commodity Type	Tonnage (%)
Gravel and Crushed Stone (excludes Dolomite and Slate)	104766 (22.36)
Natural Sands	85795 (18.31)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	43498 (9.28)
Non-Metallic Mineral Products	40188 (8.58)
Waste and Scrap (excludes agriculture or food)	29193 (6.23)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	26405 (5.64)
Other Prepared Foodstuffs, Fats, and Oils	17612 (3.76)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	16255 (3.47)
Mixed Freight	14569 (3.11)
Other Non-Metallic Minerals not elsewhere classified	12604 (2.69)
Wood Products	11284 (2.41)
Logs and Other Wood in the Rough	8900 (1.90)
Cereal Grains (includes Seed)	7489 (1.60)
Alcoholic Beverages and Denatured Alcohol	5987 (1.28)
Basic Chemicals	5206 (1.11)

Measured by weight, Other Coal and Petroleum Products generated the most freight by tons in 2012 which are transported to Florida from other states of the U.S., accounting for over 31 percent of the total tonnage combined (See Table 2-4).

Table 2-4: Percentage of Weight by Commodity Type – Other States to Florida

Commodity Type	Tonnage (%)
Other Coal and Petroleum Products, n.e.c*	26375 (21.32)
Coal	12533 (10.13)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	12419 (10.04)
Gravel and Crushed Stone (excludes Dolomite and Slate)	11456 (9.26)
Waste and Scrap (excludes of agriculture or food, see 041xx)	7808 (6.31)
Other Prepared Foodstuffs, Fats and Oils	6325 (5.11)
Mixed Freight	3813 (3.08)
Basic Chemicals	3600 (2.91)
Wood Products	2808 (2.27)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	2725 (2.20)
Non-Metallic Mineral Products	2525 (2.04)
Plastics and Rubber	2403 (1.94)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	2397 (1.94)
Meat, Poultry, Fish, Seafood, and Their Preparations	2083 (1.68)
Alcoholic Beverages and Denatured Alcohol	1961 (1.59)

* n.e.c. = not elsewhere classified

Table 2-5 shows that Florida mostly exported fertilizers to other states of the U.S. (14.79%). The second highest exported commodity is other prepared foodstuffs, fats and oils, which accounts for 12.16 percent of total tonnage shipped.

Table 2-5: Percentage of Weight by Commodity Type – Florida to Other States of the U.S.

Commodity Type	Tonnage (%)
Fertilizers	6943 (14.79)
Other Prepared Foodstuffs, Fats and Oils	5708 (12.16)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	5329 (11.35)
Crude Petroleum	3682 (7.84)
Waste and Scrap (excludes of agriculture or food)	3066 (6.53)
Pulp, Newsprint, Paper, and Paperboard	2278 (4.85)
Basic Chemicals	1991 (4.24)
Wood Products	1921 (4.09)
Non-Metallic Mineral Products	1857 (3.96)
Other Chemical Products and Preparations	1499 (3.19)
Mixed Freight	1423 (3.03)
Plastics and Rubber	1096 (2.34)
Alcoholic Beverages and Denatured Alcohol	889 (1.89)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	813 (1.73)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	796 (1.70)

Table 2-6 shows that by tonnage, gasoline, aviation turbine fuel and ethanol is the major imported commodity (18.22%) followed by fertilizers which accounts for 13.48 percent of the total tons imported to Florida. The third highest imported commodity by tons is gravel and crushed stones (11%).

Table 2-6: Percentage of Weight by Commodity Type – Imported to Florida

Commodity Type	**Tonnage (%)**
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	7196 (18.22)
Fertilizers	5324 (13.48)
Gravel and Crushed Stone (excludes Dolomite and Slate)	4498 (11.39)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	2840 (7.19)
Coal	2749 (6.96)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	2215 (5.61)
Pulp, Newsprint, Paper, and Paperboard	1898 (4.81)
Other Non-Metallic Minerals not elsewhere classified	1771 (4.49)
Non-Metallic Mineral Products	1559 (3.95)
Other Prepared Foodstuffs, Fats and Oils	1077 (2.73)
Plastics and Rubber	810 (2.05)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	652 (1.65)
Wood Products	628 (1.59)
Textiles, Leather, and Articles of Textiles or Leather	602 (1.53)
Basic Chemicals	583 (1.48)

Table 2-7 shows that fertilizers is the major exported commodity from Florida to foreign countries by tonnage (30%). The second highest exported product is waste and scarp which is almost 19 percent lesser than fertilizers.

Table 2-7: Weight by Commodity Type – Exported from Florida

Commodity Type	**Tonnage (%)**
Fertilizers	5863 (30.43)
Waste and Scrap (excludes of agriculture or food, see 041xx)	2205 (11.44)
Pulp, Newsprint, Paper, and Paperboard	1386 (7.20)
Other Prepared Foodstuffs, Fats and Oils	1239 (6.43)
Wood Products	796 (4.13)
Non-Metallic Mineral Products	735 (3.81)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	673 (3.49)
Basic Chemicals	629 (3.26)
Motorized and Other Vehicles (includes parts)	567 (2.94)
Machinery	550 (2.85)
Plastics and Rubber	514 (2.67)
Other Chemical Products and Preparations	403 (2.09)
Metallic Ores and Concentrates	401 (2.08)
Meat, Poultry, Fish, Seafood, and Their Preparations	385 (2.00)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	364 (1.89)

2.1.1.7 Tonnage share by commodity across regions

In addition to the tonnage analysis by commodity across trade types, tonnage analysis by commodity across FAF regions within Florida is also conducted. The highest movement in terms of tonnage is observed for Gasoline, aviation turbine fuel and ethanol products (22.43%) followed by natural sands which accounted for 15.62 percent of total tonnage (see Table 2-8).

Table 2-8: Percentage of Weight by Commodity Type (Within Region 121)

Commodity Type	Tonnage (%)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	4912 (22.43)
Natural Sands	3420 (15.62)
Gravel and Crushed Stone (excludes Dolomite and Slate)	2710 (12.37)
Waste and Scrap (excludes of agriculture or food, see 041xx)	2194 (10.02)
Non-Metallic Mineral Products	1528 (6.98)
Other Prepared Foodstuffs, Fats and Oils	1250 (5.71)
Logs and Other Wood in the Rough	1238 (5.66)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	1192 (5.44)
Wood Products	569 (2.60)
Alcoholic Beverages and Denatured Alcohol	482 (2.20)
Other Coal and Petroleum Products, not elsewhere classified	340 (1.55)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	293 (1.34)
Mixed Freight	275 (1.26)
Pulp, Newsprint, Paper, and Paperboard	252 (1.15)
Articles of Base Metal	165 (0.75)

Top two commodities in terms of tonnage exported from Jacksonville to other FAF regions are gasoline, aviation turbine fuel and ethanol (18.37%) and agricultural products (16%) (see Table 2-9).

Table 2-9: Weight by Commodity Type (from Region 121 to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	1587 (18.37)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	1405 (16.26)
Non-Metallic Mineral Products	988 (11.43)
Mixed Freight	820 (9.49)
Wood Products	761 (8.81)
Alcoholic Beverages and Denatured Alcohol	706 (8.17)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	513 (5.94)
Other Prepared Foodstuffs, Fats and Oils	497 (5.75)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	368 (4.26)
Articles of Base Metal	172 (1.99)
Motorized and Other Vehicles (includes parts)	117 (1.36)
Meat, Poultry, Fish, Seafood, and Their Preparations	84 (0.97)
Other Coal and Petroleum Products, not elsewhere classified	78 (0.90)
Other Chemical Products and Preparations	70 (0.81)
Pulp, Newsprint, Paper, and Paperboard	67 (0.78)

Top 3 commodities coming to Jacksonville from other FAF regions within Florida are: basic chemicals (15.70%), mixed freight (12.22%), and wood products (11.93%) (see Table 2-10).

Table 2-10: Weight by Commodity Type (from Other Regions of Florida to Region121)

Commodity Type	**Tonnage (%)**
Basic Chemicals	974 (15.70)
Mixed Freight	758 (12.22)
Wood Products	740 (11.93)
Other Prepared Foodstuffs, Fats and Oils	646 (10.41)
Cereal Grains (includes seed)	541 (8.73)
Gravel and Crushed Stone (excludes Dolomite and Slate)	540 (8.71)
Non-Metallic Mineral Products	392 (6.32)
Miscellaneous Manufactured Products	169 (2.73)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	148 (2.38)
Waste and Scrap (excludes of agriculture or food)	144 (2.33)
Alcoholic Beverages and Denatured Alcohol	142 (2.29)
Other Chemical Products and Preparations	135 (2.18)
Fertilizers	113 (1.82)
Articles of Base Metal	99 (1.60)
Animals and Fish (live)	86 (1.38)

Shipments of gravel and crushed stone represented the highest share in terms of tonnage (38.54%) for freight flows occurring within Miami (see Table 2-11).

Table 2-11: Weight by Commodity Type (Within Region 122)

Commodity Type	Tonnage (%)
Gravel and Crushed Stone (excludes Dolomite and Slate)	46471 (38.54)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	11741 (9.74)
Waste and Scrap (excludes of agriculture or food)	9878 (8.19)
Non-Metallic Mineral Products	8025 (6.65)
Natural Sands	7705 (6.39)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	7025 (5.83)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	6420 (5.32)
Other Prepared Foodstuffs, Fats and Oils	6027 (5.00)
Mixed Freight	2951 (2.45)
Wood Products	1836 (1.52)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	1182 (0.98)
Basic Chemicals	1090 (0.90)
Alcoholic Beverages and Denatured Alcohol	1081 (0.90)
Machinery	1080 (0.90)
Electronic and Other Electrical Equipment and Components, and Office Equipment	783 (0.65)

Agricultural products constituted 23.84 percent of the total tonnage shipped from Miami to other regions of Florida. Second highest was natural sands which accounted for 19.77 percent of total tonnage shipped (see Table 2-12).

Table 2-12: Weight by Commodity Type (from Region 122 to Other Florida Regions)

Commodity Type	Tonnage (%)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	3906 (23.84)
Natural Sands	3239 (19.77)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	1749 (10.67)
Gravel and Crushed Stone (excludes Dolomite and Slate)	1698 (10.36)
Other Prepared Foodstuffs, Fats and Oils	1215 (7.42)
Mixed Freight	1069 (6.53)
Non-Metallic Mineral Products	741 (4.52)
Fertilizers	656 (4.00)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	590 (3.60)
Miscellaneous Manufactured Products	248 (1.52)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	200 (1.22)
Articles of Base Metal	141 (0.86)
Meat, Poultry, Fish, Seafood, and Their Preparations	128 (0.78)
Wood Products	97 (0.59)
Motorized and Other Vehicles (includes parts)	93 (0.57)

From other region of Florida, natural sands bore the highest percentage (34%). Second highest was non-metallic mineral products which accounted 15.74 percent of total weight (see Table 2-13).

Table 2-13: Weight by Commodity Type (from Other Regions of Florida to Region 122)

Commodity Type	Tonnage (%)
Natural Sands	6275 (34.07)
Non-Metallic Mineral Products	2899 (15.74)
Mixed Freight	1647 (8.94)
Other Prepared Foodstuffs, Fats and Oils	1081 (5.87)
Wood Products	1078 (5.86)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	555 (3.02)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	502 (2.72)
Basic Chemicals	441 (2.39)
Gravel and Crushed Stone (excludes Dolomite and Slate)	434 (2.36)
Alcoholic Beverages and Denatured Alcohol	385 (2.09)
Fertilizers	362 (1.97)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	337 (1.83)
Other Chemical Products and Preparations	285 (1.55)
Miscellaneous Manufactured Products	285 (1.55)
Logs and Other Wood in the Rough	197 (1.07)

The top two commodities by tonnage shipped within Orlando are gravel and crushed stone and non-metallic minerals which accounted 26.74 percent and 18.87 percent of total tonnage, respectively (see Table 2-14).

Table 2-14: Weight by Commodity Type (Within Region 123)

Commodity Type	Tonnage (%)
Gravel and Crushed Stone (excludes Dolomite and Slate)	8347 (26.74)
Non-Metallic Mineral Products	5888 (18.87)
Waste and Scrap (excludes of agriculture or food)	4186 (13.41)
Natural Sands	2716 (8.70)
Wood Products	1817 (5.82)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	1624 (5.20)
Other Prepared Foodstuffs, Fats and Oils	981 (3.14)
Mixed Freight	733 (2.35)
Alcoholic Beverages and Denatured Alcohol	721 (2.31)
Logs and Other Wood in the Rough	641 (2.05)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	395 (1.26)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	343 (1.10)
Fertilizers	331 (1.06)
Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	307 (0.98)
Monumental or Building Stone	248 (0.80)

Gravel and crushed stone is the major commodity shipped from Orlando to other regions of FL with more than 30 percent of total tonnage shipped. Second highest is mixed freight which accounted 14.40 percent of total tonnage (see Table 2-15).

Table 2-15: Weight by Commodity Type (from Region 123 to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gravel and Crushed Stone (excludes Dolomite and Slate)	5556 (33.28)
Mixed Freight	2403 (14.40)
Other Prepared Foodstuffs, Fats and Oils	1738 (10.41)
Natural Sands	1087 (6.51)
Non-Metallic Mineral Products	940 (5.63)
Fertilizers	704 (4.22)
Wood Products	623 (3.73)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	551 (3.30)
Miscellaneous Manufactured Products	528 (3.16)
Alcoholic Beverages and Denatured Alcohol	469 (2.81)
Other Chemical Products and Preparations	361 (2.16)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	273 (1.63)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	224 (1.34)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	137 (0.82)
Articles of Base Metal	124 (0.74)

From other regions of Florida, natural sands and agricultural products are the top two commodities shipped into Orlando (see Table 2-16).

Table 2-16: Weight by Commodity Type (from Other Regions of Florida to Region 123)

Commodity Type	Tonnage (%)
Natural Sands	18317 (49.45)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	7257 (19.59)
Mixed Freight	1819 (4.91)
Gravel and Crushed Stone (excludes Dolomite and Slate)	1569 (4.24)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	1297 (3.50)
Non-Metallic Mineral Products	1057 (2.85)
Other Prepared Foodstuffs, Fats and Oils	959 (2.59)
Cereal Grains (includes seed)	674 (1.82)
Wood Products	595 (1.61)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	369 (1.00)
Meat, Poultry, Fish, Seafood, and Their Preparations	318 (0.86)
Alcoholic Beverages and Denatured Alcohol	302 (0.82)
Articles of Base Metal	238 (0.64)
Miscellaneous Manufactured Products	237 (0.64)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	230 (0.62)

Gasoline, aviation turbine fuel and ethanol accounted approximately 33 percent of the total tonnage moved within Tampa (see Table 2-17).

Table 2-17: Weight by Commodity Type (Within Region 124)

Commodity Type	Tonnage (%)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	15058 (32.74)
Gravel and Crushed Stone (excludes Dolomite and Slate)	6816 (14.82)
Non-Metallic Mineral Products	4615 (10.04)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	4518 (9.82)
Waste and Scrap (excludes of agriculture or food)	4079 (8.87)
Cereal Grains (includes seed)	1972 (4.29)
Natural Sands	1434 (3.12)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	749 (1.63)
Mixed Freight	733 (1.59)
Wood Products	691 (1.50)
Alcoholic Beverages and Denatured Alcohol	648 (1.41)
Other Prepared Foodstuffs, Fats and Oils	550 (1.20)
Fertilizers	499 (1.09)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	487 (1.06)
Basic Chemicals	435 (0.94)

From Tampa, gasoline, aviation fuel and ethanol is the highest shipped commodity to other regions in terms of tonnage (23.34%) followed by basic chemicals (see Table 2-18).

Table 2-18: Weight by Commodity Type (from Region 124 to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	4445 (23.34)
Basic Chemicals	2877 (15.11)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	1519 (7.98)
Mixed Freight	1177 (6.18)
Non-Metallic Mineral Products	1171 (6.15)
Other Prepared Foodstuffs, Fats and Oils	1023 (5.37)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	1002 (5.26)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	996 (5.23)
Gravel and Crushed Stone (excludes Dolomite and Slate)	674 (3.54)
Alcoholic Beverages and Denatured Alcohol	573 (3.01)
Logs and Other Wood in the Rough	377 (1.98)
Fertilizers	315 (1.65)
Electronic and Other Electrical Equipment and Components, and Office Equipment	284 (1.49)
Meat, Poultry, Fish, Seafood, and Their Preparations	275 (1.44)
Paper or Paperboard Articles	263 (1.38)

Other non-metallic minerals is the major commodity transported into Tampa from other regions (31.84 %) followed by natural sands (23%) (see Table 2-19).

Table 2-19: Weight by Commodity Type (from Other Regions of Florida to Region 124)

Commodity Type	Tonnage (%)
Other Non-Metallic Minerals (not elsewhere classified)	11612 (31.84)
Natural Sands	8238 (22.59)
Gravel and Crushed Stone (excludes Dolomite and Slate)	4542 (12.45)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	2301 (6.31)
Mixed Freight	1499 (4.11)
Other Prepared Foodstuffs, Fats and Oils	1237 (3.39)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	1046 (2.87)
Wood Products	978 (2.68)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	937 (2.57)
Other Chemical Products and Preparations	651 (1.78)
Non-Metallic Mineral Products	626 (1.72)
Cereal Grains (includes seed)	613 (1.68)
Miscellaneous Manufactured Products	344 (0.94)
Alcoholic Beverages and Denatured Alcohol	331 (0.91)
Fertilizers	266 (0.73)

Top three commodities shipped within rest of Florida are: natural sands (30%), gravel and crushed stone (25%), and non-metallic minerals (10%) (see Table 2-20).

Table 2-20: Weight by Commodity Type (Within Region 129)

Commodity Type	**Tonnage (%)**
Natural Sands	37381 (30.37)
Gravel and Crushed Stone (excludes Dolomite and Slate)	31016 (25.20)
Non-Metallic Mineral Products	13431 (10.91)
Waste and Scrap (excludes of agriculture or food)	8669 (7.04)
Logs and Other Wood in the Rough	5772 (4.69)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	3788 (3.08)
Cereal Grains (includes seed)	3460 (2.81)
Other Prepared Foodstuffs, Fats and Oils	2774 (2.25)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	2578 (2.09)
Wood Products	2523 (2.05)
Mixed Freight	1712 (1.39)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	1397 (1.14)
Alcoholic Beverages and Denatured Alcohol	973 (0.79)
Other Chemical Products and Preparations	790 (0.64)
Fertilizers	772 (0.63)

From remainder of Florida, natural sand is the major commodity shipped to other four regions (Jacksonville, Miami, Orlando and Tampa) of Florida (44.23%) (see Table 2-21).

Table 2-21: Weight by Commodity Type (from Region 129 to Other Regions of Florida)

Commodity Type	Tonnage (%)
Natural Sands	28768 (44.23)
Other Non-Metallic Minerals (not elsewhere classified)	11657 (17.92)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	7282 (11.20)
Non-Metallic Mineral Products	2862 (4.40)
Mixed Freight	2695 (4.14)
Wood Products	2129 (3.27)
Cereal Grains (includes seed)	1784 (2.74)
Other Prepared Foodstuffs, Fats and Oils	1558 (2.40)
Gravel and Crushed Stone (excludes Dolomite and Slate)	1478 (2.27)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	955 (1.47)
Other Chemical Products and Preparations	880 (1.35)
Fertilizers	387 (0.60)
Alcoholic Beverages and Denatured Alcohol	292 (0.45)
Miscellaneous Manufactured Products	269 (0.41)
Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	261 (0.40)

From the other regions of Florida (Jacksonville, Miami, Orlando and Tampa), gasoline, aviation turbine fuel and ethanol is the major commodity shipped to remainder of Florida (18.79%). The next highest commodity shipped by tonnage is agricultural products which accounted almost 16 percent (see Table 2-22).

Table 2-22: Weight by Commodity Type (from Other Regions of Florida to Region 129)

Commodity Type	Tonnage (%)
Gasoline, Aviation Turbine Fuel, and Ethanol (includes Kerosene, and Fuel Alcohols)	5201 (18.79)
Agricultural Products (excludes Animal Feed, Cereal Grains, and Forage Products)	4401 (15.90)
Mixed Freight	2443 (8.83)
Gravel and Crushed Stone (excludes Dolomite and Slate)	2321 (8.39)
Other Prepared Foodstuffs, Fats and Oils	2108 (7.62)
Non-Metallic Mineral Products	1726 (6.23)
Fuel Oils (includes Diesel, Bunker C, and Biodiesel)	1671 (6.04)
Basic Chemicals	1469 (5.31)
Fertilizers	1113 (4.02)
Alcoholic Beverages and Denatured Alcohol	922 (3.33)
Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	718 (2.59)
Wood Products	458 (1.65)
Other Chemical Products and Preparations	356 (1.29)
Animal Feed, Eggs, Honey, and Other Products of Animal Origin	310 (1.12)
Natural Sands	307 (1.11)

2.1.1.8 Ton-miles Analysis

Table 2-23 represents the total ton-miles by each mode. Ton-mile is defined as one ton of freight carried one mile as a unit of traffic. The sum of total ton-miles was highest for truck (106161.70 million) and lowest for air mode (163.82 million) when the shipment was domestic (within Florida, other states to Florida and Florida to other states). When the shipment is imported to Florida, truck had the highest ton-miles (5650.91 million) and pipeline had the lowest ton-miles (29.08 million). For exports from Florida, truck had the highest (3849.99 million) and pipeline had the lowest (0.93 million) ton-miles as well.

Table 2-23: Commodity Ton-miles (Millions) by Mode

Code	Domestic Mode	Domestic Ton-miles	Import to FL Ton-miles	Export from FL Ton-miles
1	Truck	106161.71	5650.91	3849.99
2	Rail	39954.12	3375.09	2092.68
3	Water	12949.62	4362.83	671.35
4	Air (Truck+Air)	163.82	59.37	45.75
5	Multiple Modes & Mail	12658.27	1978.51	350.28
6	Pipeline	9142.00	29.08	0.93
7	Other & Unknown	---	44.41	13.62
Total	**---**	**181029.53**	**15500.21**	**7024.60**

2.1.1.9 Value Analysis

In 2012, Florida domestic commodity flows were valued at $686.45 billion, while export and import commodity flows were valued at $69.56 billion and $71.99 billion, respectively. For shipments within Florida, commodities moved by trucks tend to have higher value per ton as manifested by the higher mode share (93%) in terms of value (see Figure 2-10). Similar trend was observed for flows from other states of the U.S. to Florida (see Figure 2-11) as well as flows from Florida to other states of the U.S. (see Figure 2-12).

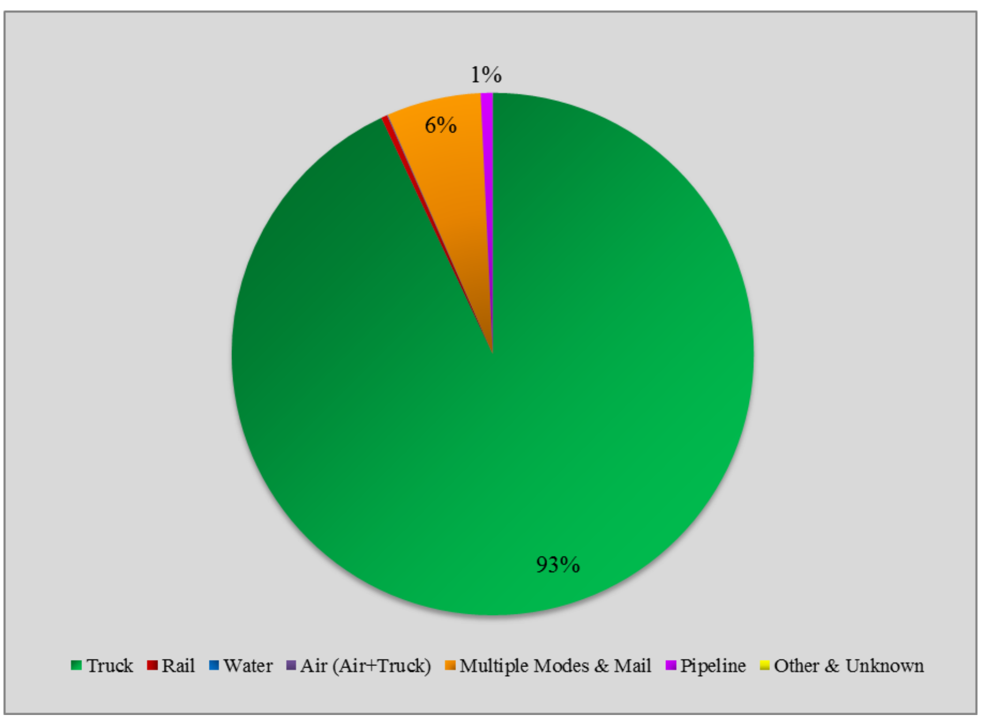


Figure 2-10: Mode Split by Value – Within Florida

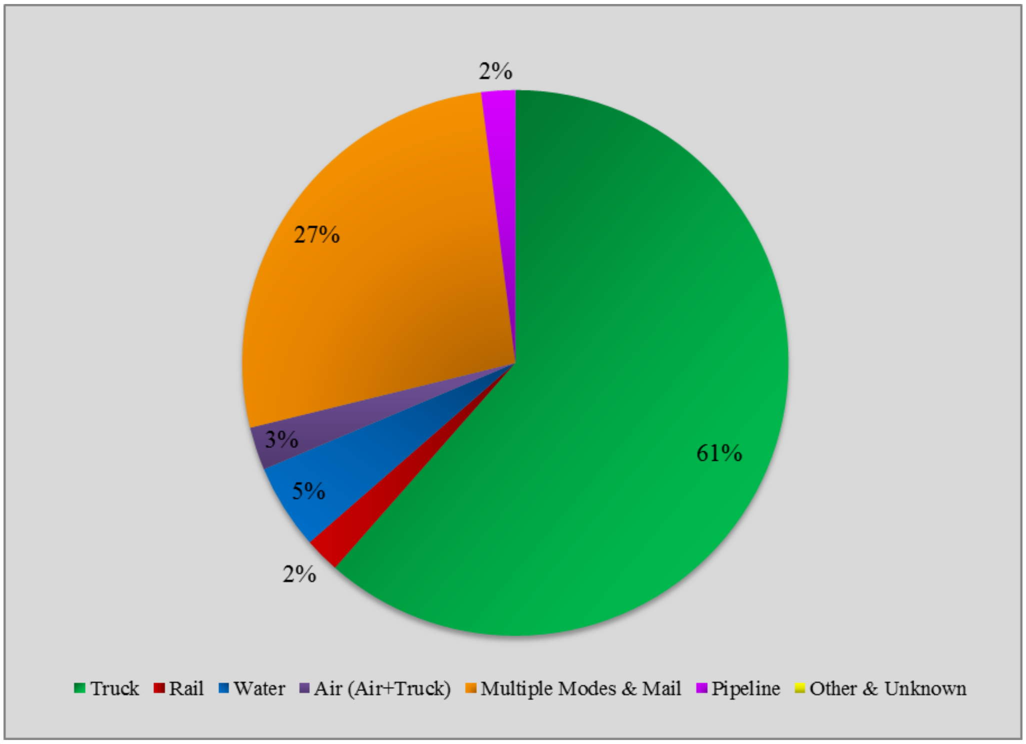


Figure 2-11: Mode Split by Value – Other States of the U.S. to Florida

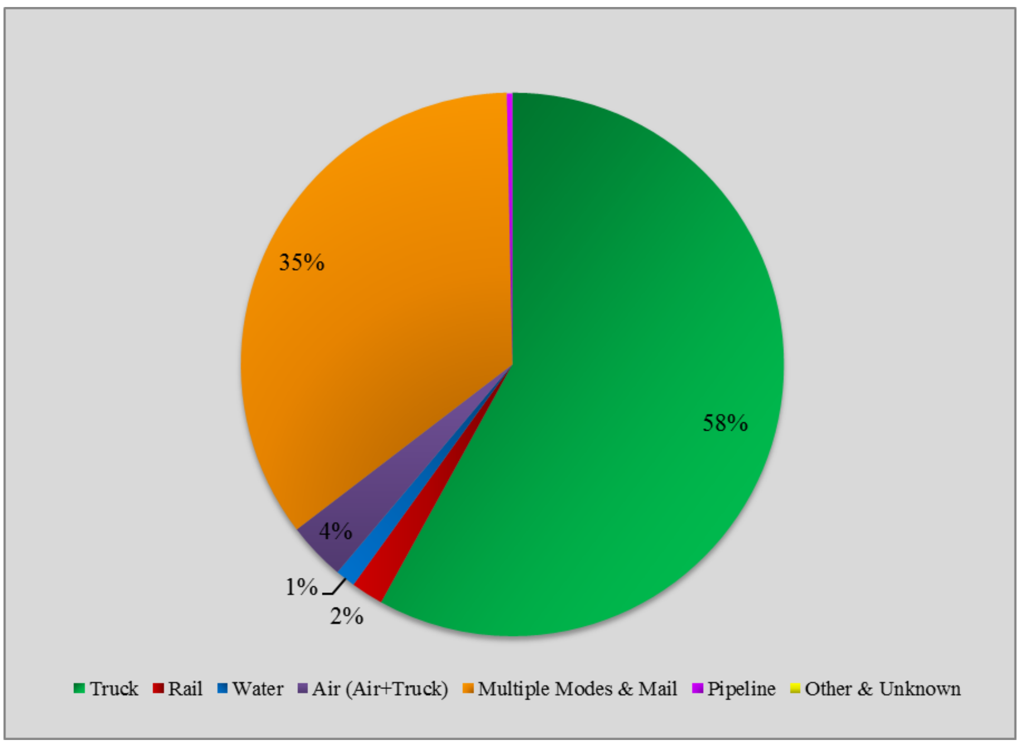


Figure 2-12: Mode Split by Value – Florida to Other States of the U.S.

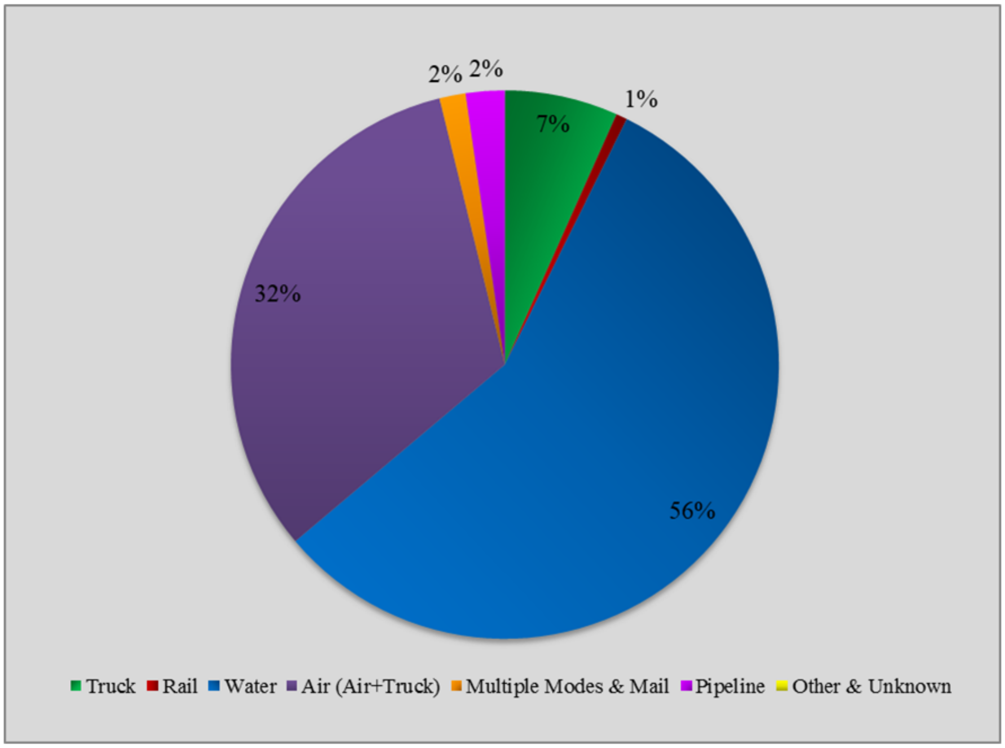


Figure 2-13: Mode Split by Value – Import to Florida

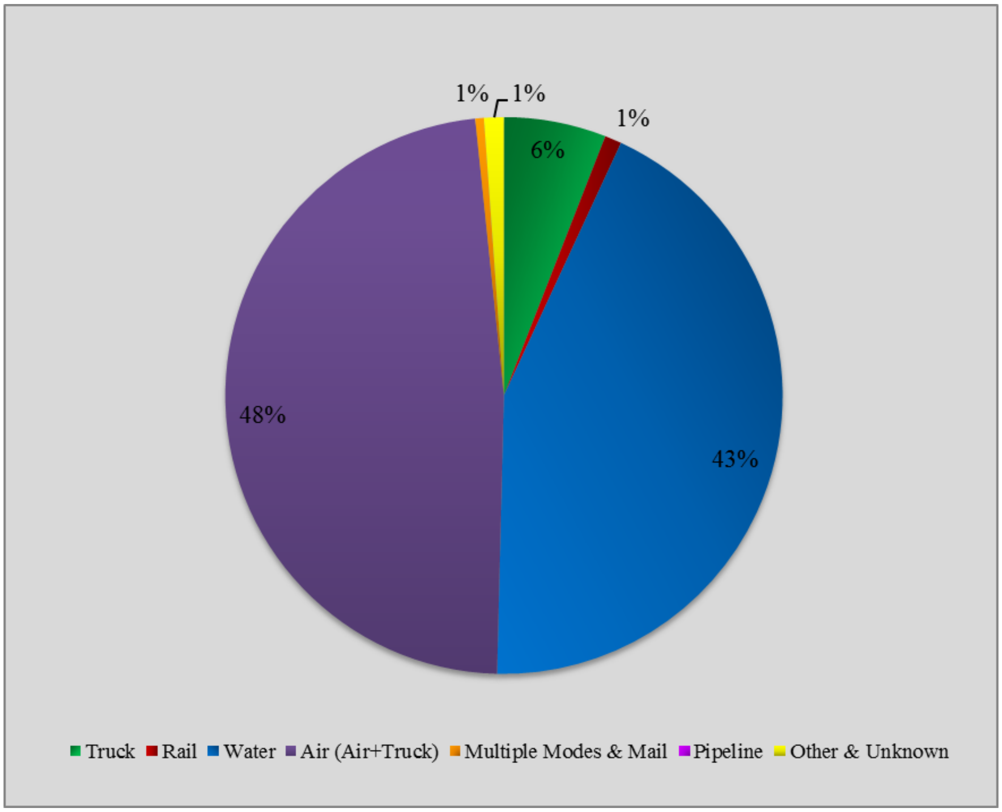


Figure 2-14: Mode Split by Value – Export from Florida

Water mode carries 56% of the total value of import shipments while air mode accounted 32% of total commodity value (see Figure 2-13). On the other hand, the value worth of air mode is higher than water mode (48 % vs 43%) for export shipments (Figure 2-14).

2.1.1.10 Trading Partners

In addition to the analysis by mode and commodity summarized in the previous sections, it is also important to identify the state's key trading partners. By measurement of weight, most of the commodities are imported from Rest of Americas (Puerto Rico) which is greater than the weight exported to that foreign region. Compared to the commodities exported to Canada and Europe, the weight of imported commodities from these two foreign regions are greater. The total tonnage of imported and exported commodity from and to South-West and Central Asia and South-East Asia and Oceania is almost same. The weight of commodity exported to Africa is very low in 2012 (see Figure 2-15).

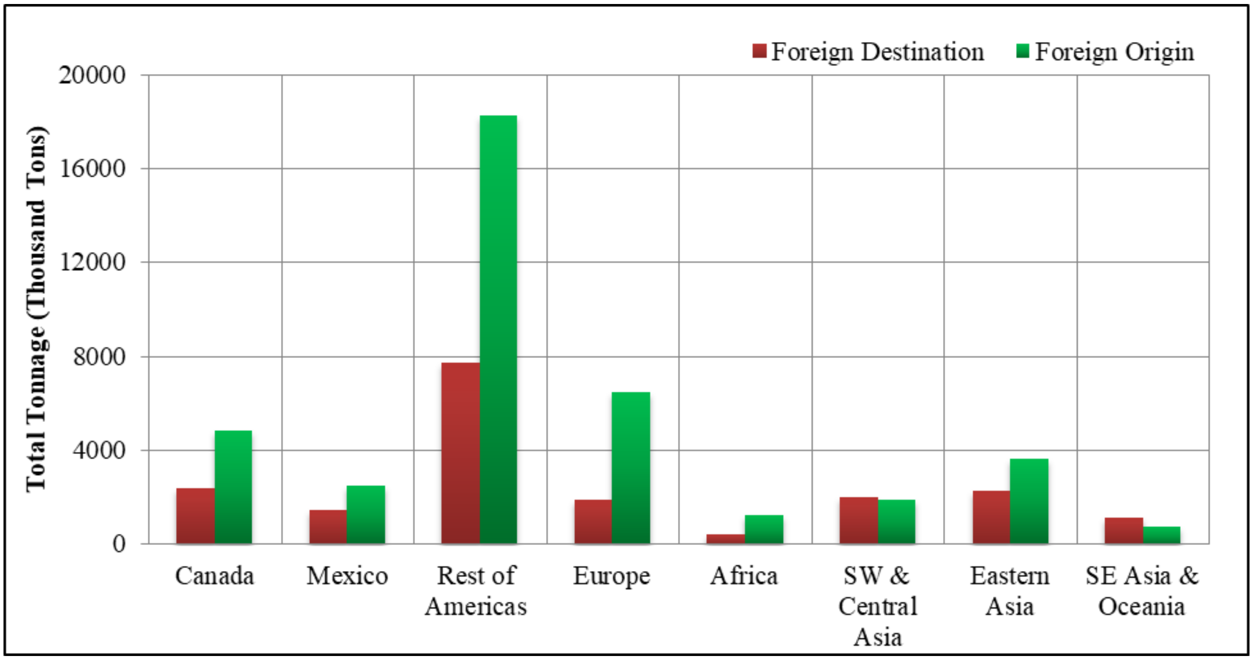


Figure 2-15: Total Tonnage of Commodity by Foreign Origin and Destination

2.1.2 Dataset 2: Transearch

Transearch is a proprietary carrier centric comprehensive freight database owned and maintained by Global Insight Inc. It provides detailed information on commodity type (as per Standard Transportation Commodity Classification (STCC)), tonnage, value, ton-mile, origin-destination and mode used for freight movement. A Transearch domestic commodity flow database for the state of Florida was purchased from IHS/Global Insight by FDOT for the year 2011. In addition to the base year data, the database also provided projection till 2040 at a five-year interval starting from 2015.

2.1.2.1 Tonnage Share Analysis

For analysis purpose, we divided the commodity flows into four categories. These are: domestic, import, export, and through. The domestic flow is further subdivided into three groups: inbound, outbound, and within Florida. The definitions are outlined below:

- Domestic:
    - Inbound: Freight flows that originated in other states of the U.S. except Florida and are destined to Florida.
    - Outbound: Freight flows that originated in Florida and are destined to other states of the U.S. except Florida.
    - Within Florida: Freight flow that originated and terminated in the state of Florida.
- Import: Freight flows that originated in foreign countries outside of the U.S. and are destined to Florida.
- Export: Freight flows that originated in Florida and are destined to foreign countries outside of the U.S.
- Through: All domestic and international freight flows that neither originated nor were destined to Florida, but passed through the state for some leg of the journey.

This flow classification scheme is comparable with that of the FAF dataset. According to Transearch data, in the year 2011, a total of 4.5 billion tons of goods moved from, to, and within the State of Florida. Domestic flows represented 50 percent of the total tonnage, followed by inbound flows (34%) from foreign regions. Total exported tonnage was less in amount than total imported tonnage. Figure 2-16 illustrates the distribution of total domestic tonnage. We can see that 51 percent of the domestic flows occur within Florida, followed by inbound flows (35%). The low share (14%) of commodity tonnage originating in Florida and terminating in the rest of the U.S. signifies the dominance of the service industry in Florida.

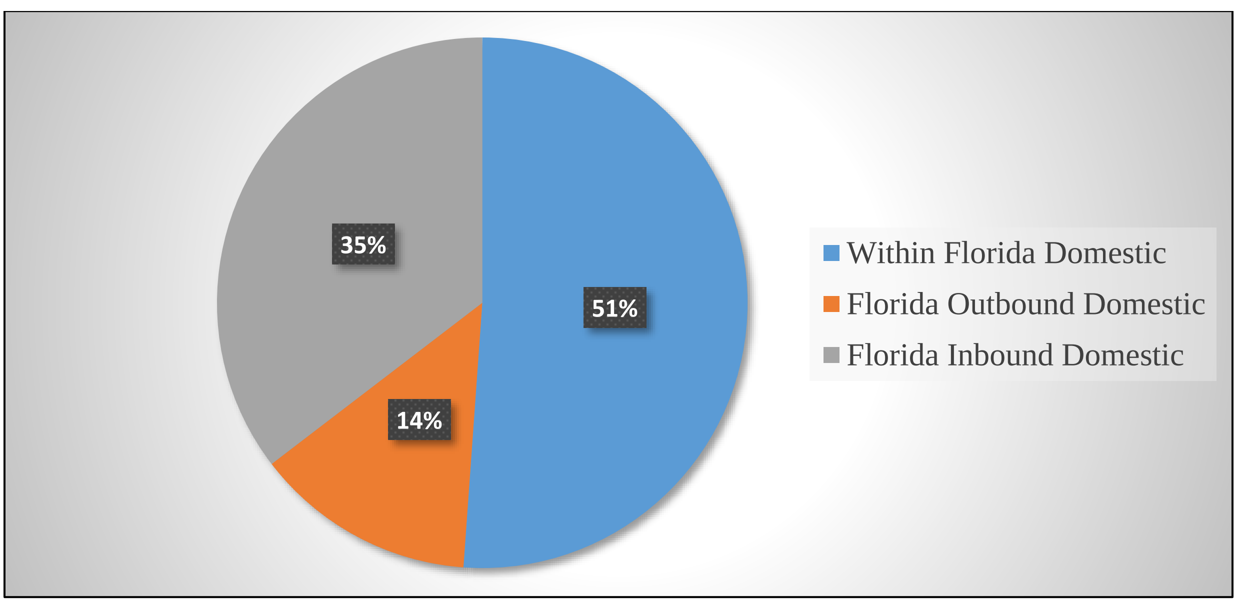


Figure 2-16: Tonnage Distribution of Domestic Flows

2.1.2.2 Comparison of the FAF and Transearch Databases

One of the most important parts of this research project was a thorough comparison of FAF and Transearch databases. The following section presents the results of this comparison exercise.

Comparison of Total Weight and Value of Commodities

In the first step, we conducted the comparison between total tonnage and value of commodities. The results are shown in Table 2-24. Overall, Transearch reports less than half the tonnage (707 million vs. 448 million) and two-thirds of the value ($904 billion vs. $635 billion) captured by FAF. Of the five trade types, the difference (both for tonnage and value) is the highest for export and import freight movements. For domestic trade types, FAF freight values exceed Transearch by a factor ranging from 1 to 2.1.

Table 2-24: Comparison of Tonnage and Value by Trade Type

Trade Type	Weight (Million Tons)			Value (Billion USD)		
	Transearch	FAF	Comparison (FAF/Transearch)	Transearch	FAF	Comparison (FAF/Transearch)
Export	2.39	19.27	8.06	5.54	69.56	12.56
Import	5.95	39.49	6.64	7.62	71.99	9.45
Inbound Domestic	153.99	123.70	0.80	291.45	253.13	0.87
Outbound Domestic	58.61	46.94	0.80	117.93	136.95	1.16
Within Florida	222.46	468.55	2.11	212.18	296.37	1.40
Through	3.88	8.36	2.10	--	8.37	--
Total	**447.27**	706.31	1.58	**634.72**	828.00	1.30

Please note that a major difference between FAF and Transearch arises from how foreign flows into and out of Florida are reported. Transearch reports flows to and from three foreign regions only: Canada, Mexico and Rest of Americas (Virgin Island and Puerto Rico). On the other hand, FAF data reports flows to and from eight international regions including Canada, Mexico, Rest of Americas (Virgin Island and Puerto Rico), Europe, Africa, South West and Central Asia, Eastern Asia, and South East Asia and Oceania. That is, a significant portion of import and export flows is not reported in the Transearch dataset.

Comparison of Total Tonnage and Value by Trade Type and Mode

In addition, we conducted comparison of total tonnage and value by trade type and mode as well (Table 2-25 to Table 2-27). The highest variation in tonnage reporting was observed for other modes. This is expected, since Transearch doesn't cover freight movement using Pipeline mode and Pipeline represents the major share in the other modes category.

Table 2-25: Mode Share by Weight and Value

Mode	Weight (Million Tons)			Value (Billion USD)		
	FAF	Transearch	Comparison (FAF/Transearch)	FAF	Transearch	Comparison (FAF/Transearch)
Truck	580.47	314.77	1.84	642.40	461.80	1.39
Rail	51.57	77.43	0.67	11.29	80.81	0.14
Water	27.85	50.96	0.55	26.05	49.94	0.52
Air	0.69	0.24	2.88	62.88	42.11	1.49
Others	45.74	0.01	4574.00	161.19	0.06	2686.57
Total	**706.31**	**443.40**	**1.59**	**903.81**	**634.72**	**1.42**

Summary

FAF and TS databases contain annualized commodity flow data that can be used in long range freight forecasting. FAF database is prepared based on the Commodity Flow Survey (CFS) conducted periodically. It is freely available to the public and can be downloaded from the Federal Highway Administration (FHWA) website (1). It provides freight flows (by weight, value and mode) for 43 commodity types classified by Standard Classification of Transported Goods (SCTG 2-digit) code. The commodity flow information is available at a very coarse spatial resolution - 132 domestic zones across the United States and 8 foreign zones. The baseline year for current FAF data (FAF^4) is 2012 and includes forecasts on freight flows between 2015 and 2045 at a 5-year interval.

The Transearch database, a proprietary product developed by IHS Global Insight, provides detailed information on freight flows (by weight, value and mode). The database is constructed from various commercial and public sources including: Annual Survey of Manufacturers (ASM), Surface Transportation Board (STB) Rail Waybill Sample, Army Corps of Engineers Waterborne Commerce data, Federal Aviation Administration (FAA), Enplanement Statistics, and Airport-to-airport cargo volumes. However, the algorithm used to generate the final data product is not publicly available. The freight flows in TS are reported by commodity type based on the Standard Transportation Commodity Code (STCC) in more than 500 categories. The data can be purchased at a fine spatial resolution (such as county level). However, the database is expensive to acquire and requires substantial investment from transportation agencies.

Although both FAF and TS provide annual commodity flows in the United States, several differences exist between these sources. The most obvious difference arises from the variability in data collection mechanism employed; FAF relies on processing commodity flow data (such as CFS 2012) while TS employs various sources of data to generate county level flows using a proprietary algorithm. A second difference arises from what the commodity flows in each dataset represent. FAF flows represent actual transportation network flows while TS flows represent production-consumption commodity flow. To illustrate the difference, consider that X units of a commodity is shipped from location A (production zone) to location B (consumption zone) through an intermediate location C. The FAF flows would represent these flows as X units from A to C and X units form C to B. On the other hand, in TS, these flows are only represented as X units from A to B. Thus, FAF would report a total tonnage of 2X units transferred while TS would report only a transfer of X units.

For understanding transportation network usage measured through network flows, FAF is a more appropriate database as the reporting is based on realized network flows. On the other hand, the flows represented in the TS database are annual production-consumption measures from the TS defined regions and do not represent the actual transportation network path flows. To be sure, there is significant value in understanding production and consumption trends to develop a behavioral framework of freight commodity flows in the future. In terms of cost, FAF data is freely available while TS database is an expensive database and the algorithm employed is inaccessible to users. The commodity type definition across the two datasets is also different – 43 commodity types in FAF and over 500 commodity types in TS. Finally, the coarser spatial and commodity type resolution in FAF makes it challenging to generate reliable network flow estimates. While TS provides data at a fine spatial and commodity type resolution, the production consumption behavior of the database requires additional analysis to realize transportation network flows. Overall, the comparison of the databases highlights the inherent strengths and weaknesses of the two databases.

Table 2-26: Mode Share by Weight (Million Tons) and Trade Type (FAF and Transearch)

Mode	Export		Import		Inbound Domestic		Outbound Domestic		Within Florida		Total	
	FAF	TS	FAF	TS	FAF	TS	FAF	TS	FAF	TS	FAF	TS
Truck	18.41	0.97	29.57	0.87	50.56	77.19	33.11	42.48	448.81	193.25	580.47	314.77
Rail	1.5	0.75	2.52	0.69	26.74	36.26	6.00	11.59	14.81	28.13	51.57	77.43
Water	2.03	0.66	8.91	4.37	14.32	40.40	2.44	4.46	0.15	1.07	27.85	50.96
Air	0.33	0.01	0.23	0.01	0.07	0.14	0.06	0.07	0.00	0.00	0.69	0.24
Others	1.14	0.00	2.48	0.00	32.01	0.00	5.31	0.00	4.79	0.00	45.73	0.00
Total	**23.41**	**2.39**	**43.71**	**5.95**	**123.7**	**153.99**	**46.94**	**58.61**	**468.55**	**222.46**	**706.31**	**443.39**

Table 2-27: Mode Share by Value (Billion USD) and Trade Type (FAF and Transearch)

Mode	Export		Import		Inbound Domestic		Outbound Domestic		Within Florida		Total	
	FAF	TS	FAF	TS	FAF	TS	FAF	TS	FAF	TS	FAF	TS
Truck	69.85	3.60	61.88	3.99	155.64	184.30	79.48	75.65	275.55	194.26	642.40	461.80
Rail	1.16	0.46	1.04	0.53	5.311	46.99	2.63	16.48	1.14	16.35	11.29	80.81
Water	5.24	0.77	6.39	1.90	12.77	36.02	1.63	10.06	0.01	1.19	26.05	49.94
Air	34.14	0.68	17.38	1.18	6.45	24.14	4.74	15.73	0.16	0.38	62.88	42.11
Others	7.11	0.04	13.17	0.02	72.95	0.00	48.46	0.00	19.49	0.00	161.19	0.06
Total	**117.50**	**5.54**	**99.87**	**7.62**	**253.13**	**291.45**	**136.95**	**117.93**	**296.37**	**212.18**	**903.81**	**634.72**

2.1.3 Database 3: American Transportation Research Institute (ATRI) Data Products from FDOT Project BDK84-977-20

The ATRI data products to be used in this project are those developed in a previous FDOT research project BDK84-977-20. The overarching goal of this previous project was to investigate the use of ATRI's truck GPS data (of the year 2010) for statewide freight performance measurement, statewide freight truck flow analysis, and other freight planning and modeling applications. Over 145 Million raw GPS data records for four months in 2010 – March, April, May and June – were utilized to develop a variety of different data products. The current project will only utilize the aggregate data products delivered from the project BDK84-977-20, as opposed to the disaggregate truck-GPS data. This section provides a brief description of the aggregate data products developed in the previous project. It is worth noting here that most of the description/material in this section is drawn from the final report of the project BDK84-977-20.

2.1.3.1 Freight Performance Measures on Florida's SIS Highway Network

The project resulted in the development of average truck speed data for each (and every) mile of the Strategic Intermodal System (SIS) highway network for different time periods in the day - AM peak, PM peak, mid-day, and off-peak - using three months of ATRI's truck GPS data in the year 2010. The SIS highway network shape file and the data on average truck speeds by time-of-day were submitted in a GIS shape file that can be used in an ArcGIS environment.

2.1.3.2 A Database of over 2 Million Truck Trips within, into, and out of Florida

Over 145 Million of raw GPS traces were converted into a database of truck trips traveling within, into, and out of the state. The resulting database comprised more than 1.2 million truck trips traveling within, into, and out of the state. The truck trip database developed from four months of ATRI's truck GPS data was used to analyze a variety of truck travel characteristics in the state of Florida. The truck travel characteristics analyzed include trip duration, trip length, trip speed, time-of-day profiles, and OD flows. In addition, the truck trips were used in conjunction with the GPS data to derive distributions of OD travel distances, travel times, and travel speeds between more than 1,200 TAZ-to-TAZ OD pairs in the FLSWM.

2.1.3.3 Assessment of ATRI's Truck GPS Data and Its Coverage of Truck Traffic in Florida

This project resulted in a better understanding of ATRI's truck GPS data in terms of its coverage of truck traffic in the state of Florida. This includes deriving insights on (a) the geographical coverage of the data in Florida, and (b) the proportion of the truck traffic flows in the state covered by the data.

ATRI's truck GPS data represent a sample of truck flows within, coming into, and going out of Florida. This sample is not a census of all trucks traveling in the state. Also, it is unknown what proportion of heavy truck flows in the state is represented by this data sample. To address this question, truck traffic flows implied by one-week of ATRI's truck GPS data were compared with truck counts data from more than 200 Telemetered Traffic Monitoring Sites (TTMS) in the state. The results from this analysis suggest that, at an aggregate level, the ATRI data provide 10.1 percent coverage of heavy truck flows observed in Florida. When the coverage was examined separately for different highway facilities (based on functional classification), the results suggested that the data could provide a representative coverage of truck flows through different types of highway facilities in the state.

2.1.3.4 OD Tables of Statewide Truck Flows
An important outcome of the project was to use ATRI's truck GPS data in combination with other available data to derive OD tables of freight truck flows within, into, and out of the state of Florida. The OD flow tables were derived at the following levels of geographic resolution for the year 2010:

a) TAZs of the FLSWM, where Florida and the rest of the country are divided into about 6,000 TAZs,
b) County-level resolution, where Florida is represented at a county-level resolution and the rest of the country is represented at a state-level resolution, and
c) State-level resolution, where Florida and the rest of the country are represented at a state-level resolution.

As part of this task, first, the truck trip database developed from four months of ATRI's GPS data were converted into OD tables at the TAZ-level spatial resolution used in the FLSWM. Such an OD table derived only from the ATRI data; however, is not necessarily representative of the freight truck flows in the state. This is because the ATRI data does not include the *census* of trucks in the state. Besides, it is not necessarily a random sample and is likely to have spatial biases in its representation of truck flows in the state. To address these issues, the OD tables derived from the ATRI data were combined with observed truck traffic volumes at different locations in the state (and outside the state) to derive a more robust OD table that is representative of the freight truck flows within, into, and out of the state. To achieve this, a mathematical procedure called the Origin-Destination Matrix Estimation (ODME) method was employed to combine the OD flow table generated from the ATRI data with observed truck traffic volume information at different locations within and outside Florida. The OD flow table estimated from the ODME procedure is likely to better represent the heavy truck traffic volumes in the state, as it uses the observed truck traffic volumes to weigh the ATRI data-derived truck OD flow tables.

For the current project on fusing different data sources, the database of truck trips and the OD flow tables derived in the earlier project could be useful. These data products could be of use in determining origin-destination truck flows in the state for different industry sectors.

2.1.4 Database 4: Weigh-in-Motion (WIM)
The weigh-in-motion (WIM) data was collected at some of the Telemetric Traffic Monitoring Sites (TTMS) that have the capability to weigh the vehicle passing through the site. All sites with WIM capability measure the weight and classification (i.e., number of axles etc.) of all the trucks passing through the sites throughout the year (unless the site malfunctions on certain days). Each record in the WIM data is an instance of a truck passing through a WIM site. For each such record, the WIM data provided by FDOT comprises attributes describing the WIM site as well as the truck passing through the site. Four attributes named county code, unit number, direction of the weight, and the number of lanes are specific to the WIM site. The remaining four attributes, namely the date, time interval, vehicle classification, and the gross weight of the truck, are the attributes of the specific truck passing through the WIM site.

This section presents a brief descriptive analysis of the data provided by FDOT. Figure 2-17 illustrates the proportions of four groups of vehicles – passenger cars (class 2), buses (class 4), light trucks (class

5-7), and heavy-duty trucks (class 8-13) in the data. As can be observed, the FDOT provided-WIM data did not include passenger cars (because passenger cars are not of interest to this project). Among other classes of vehicles, we retained only heavy-duty trucks (FHWA class 8 or above) for further analysis.

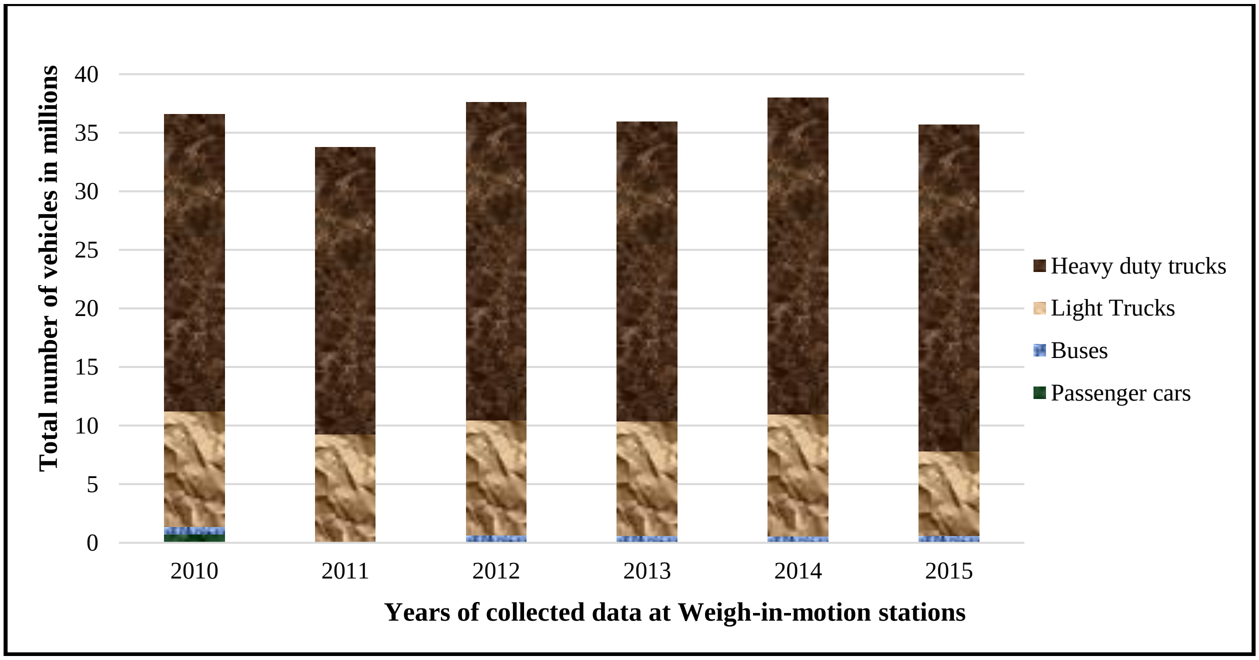


Figure 2-17: Distribution of Number of Vehicles Going through 40 Weigh-In-Motion Stations in Florida from 2010 to 2015

2.1.4.1 Statistical Summaries of the WIM Data for the Year 2010

Table 2-28: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	3,084,819	(12.2%)
Bay	299,622	(1.2%)
Brevard	711,888	(2.8%)
Charlotte	3,132	(0.01%)
Columbia	1,404,975	(5.5%)
Duval	7,476,490	(29.5%)
Escambia	1,117,524	(4.4%)
Fl. Turnpike	3,233,294	(12.8%)
Gadsden	48,614	(0.2%)
Hendry	644,859	(2.5%)
Hillsborough	2,481,978	(9.8%)
Jackson	52,931	(0.2%)
Jefferson	1,285,392	(5.1%)
Levy	110,514	(0.4%)
Miami-dade	558,253	(2.2%)
Okaloosa	30,428	(0.1%)
Polk	953,071	(3.8%)
Santa rosa	147,070	(0.6%)
Suwannee	3,210	(0%)
Volusia	1,672,370	(6.6%)
Walton	36,633	(0.1%)
Total Number of Trucks	**25,357,067**	**(100%)**

Table 2-29: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	25,357,067	(99.9%)
Total Number of Trucks	25,357,067	(100%)

Table 2-30: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	9,814,311	(38.7%)
S	9,840,548	(38.8%)
E	2,865,937	(11.3%)
W	2,836,271	(11.2%)
Total Number of Trucks	**25,357,067**	**(100%)**

Table 2-31: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	9,559,668	(37.7%)
2	3,167,151	(12.5%)
3	168,301	(0.7%)
4	4,435,287	(17.5%)
5	2,959,136	(11.7%)
6	5,067,524	(20%)
Total Number of Trucks	**25,357,067**	**(100%)**

Table 2-32: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	2,691,819	(10.6%)
9	20,358,321	(80.3%)
10	240,641	(0.9%)
11	772,106	(3%)
12	393,502	(1.6%)
13	213,639	(0.8%)
14	31	(0%)
15	687,008	(2.7%)
Total Number of Trucks	**25,357,067**	**(100%)**

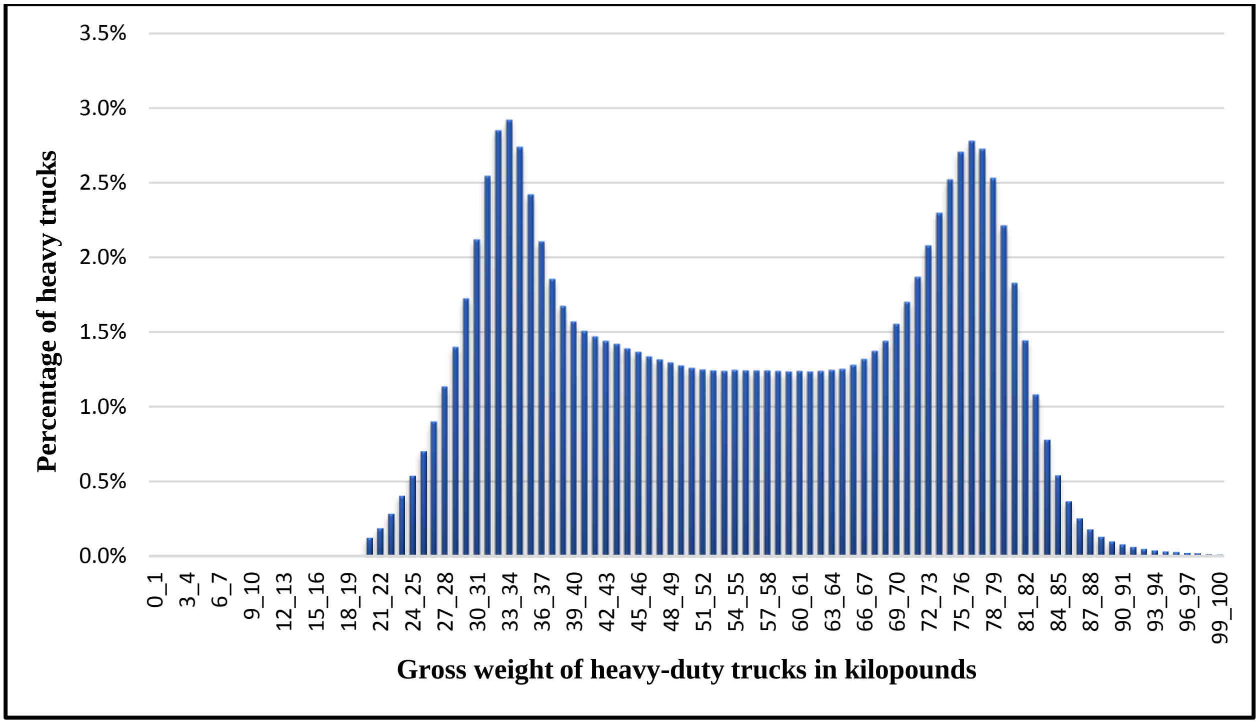


Figure 2-18: Distribution of the Truck Gross Weight in 2010 (Unit: kilo pound)

2.1.4.2 Statistical Summaries of the WIM data for the Year 2011

Table 2-33: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	2,320,609	(9.5%)
Bay	276,164	(1.1%)
Brevard	1,136,202	(4.6%)
Columbia	1,348,839	(5.5%)
Duval	7,102,569	(29.0%)
Escambia	1,337,565	(5.5%)
Fl. Turnpike	3,446,093	(14.1%)
Gadsden	45,597	(0.2%)
Hendry	365,789	(1.5%)
Hillsborough	2,042,972	(8.3%)
Jackson	66,912	(0.3%)
Jefferson	1,379,166	(5.6%)
Levy	106,924	(0.4%)
Miami-Dade	589,887	(2.4%)
Okaloosa	20,075	(0.1%)
Polk	946,100	(3.9%)
Santa Rosa	37,433	(0.2%)
Sumter	325,921	(1.3%)
Volusia	1,609,515	(6.6%))
Total Number of Trucks	**24,504,32**	**(100%)**

Table 2-34: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	24,466,417	(99.8%)
2	37,915	(0.2%)
Total Number of Trucks	**24,504,332**	**(100%)**

Table 2-35: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	2,965,897	(12.1%)
S	9,343,724	(38.1%)
E	9,280,728	(37.9%)
W	2,913,983	(11.9%)
Total Number of Trucks	**24,504,332**	**(100%)**

Table 2-36: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	9,299,968	(37.9%)
2	3,018,242	(12.3%)
3	167,324	(0.7%)
4	4,749,164	(19.4%)
5	2,938,300	(12%)
6	4,331,334	(17.7%)
Total Number of Trucks	**24,504,332**	**(100%)**

Table 2-37: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	2,527,224	(10.3%)
9	19,990,376	(81.6%)
10	213,982	(0.9%)
11	770,633	(3.1%)
12	382,943	(1.6%)
13	106,447	(0.4%)
15	512,727	(2.1%)
Total Number of Trucks	**24,504,332**	**(100%)**

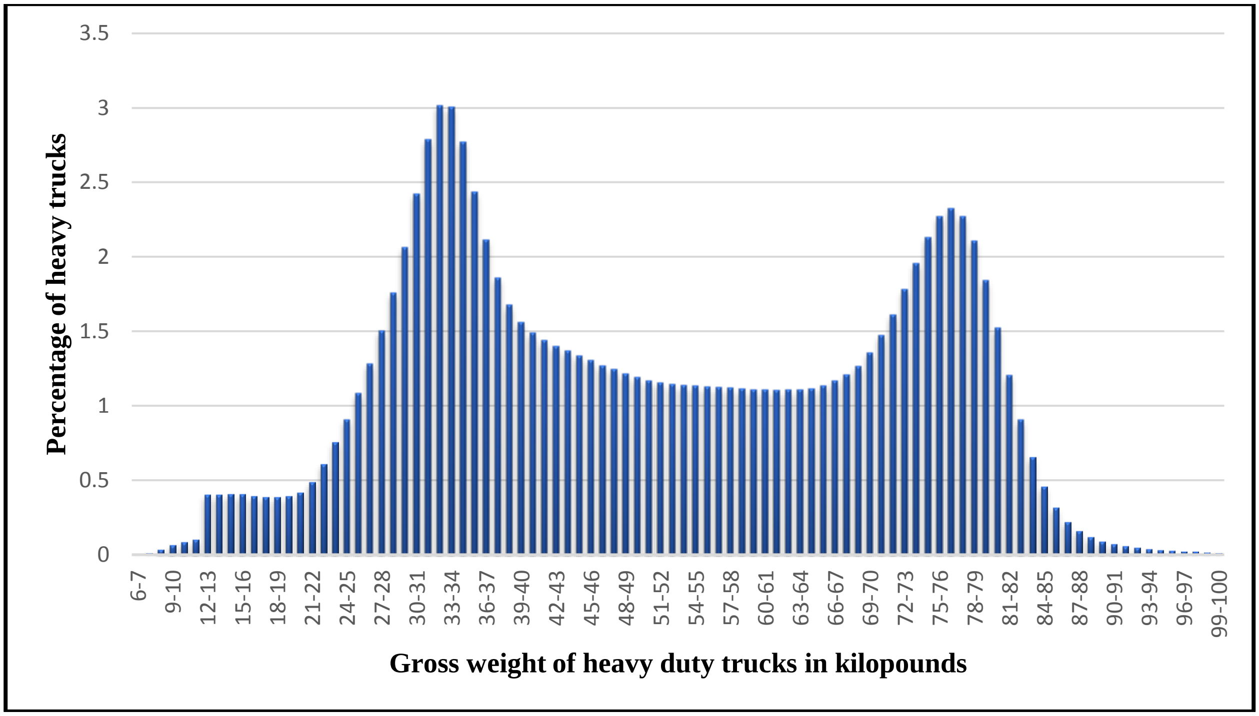


Figure 2-19: Distribution of the Truck Gross Weight in 2011 (Unit: kilo pound)

2.1.4.3 Statistical Summaries of the WIM data for the Year 2012

Table 2-38: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	2,690,906	(9.2%)
Bay	288,771	(1%)
Brevard	1,231,061	(4.2%)
Collier	809,992	(2.8%)
Columbia	1,366,424	(4.7%)
Duval	6,322,646	(21.5%)
Escambia	1,346,623	(4.6%)
Fl. Turnpike	3,189,608	(10.9%)
Gadsden	41,521	(0.1%)
Hendry	615,632	(2.1%)
Hillsborough	2,221,983	(7.6%)
Jackson	64,826	(0.2%)
Jefferson	1,250,780	(4.3%)
Levy	116,025	(0.4%)
Miami-Dade	613,728	(2.1%)
Okaloosa	31,411	(0.1%)
Palm Beach	256,193	(0.9%)
Polk	2,812,742	(9.6%)
Santa Rosa	21,715	(0.1%)
Sumter	2,389,389	(8.1%)
Volusia	1,682,785	(5.7%)
Total Number of Trucks	**29,364,761**	**(100%)**

Table 2-39: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	29,210,184	(99.5%)
2	154,577	(0.5%)
Total Number of Trucks	**29,364,761**	**(100%)**

Table 2-40: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	10,328,292	(35.2%)
S	11,263,122	(38.4%)
E	3,860,403	(13.1%)
W	3,912,944	(13.3%)
Total Number of Trucks	**29,364,761**	**(100%)**

Table 2-41: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	10,470,018	(35.7%)
2	3,808,879	(13%)
3	279,456	(1%)
4	5,349,618	(18.2%)
5	3,548,781	(12.1%)
6	5,908,009	(20.1%)
Total Number of Trucks	**29,364,761**	**(100%)**

Table 2-42: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	3,800,794	(12.9%)
9	23,236,252	(79.1%)
10	271,706	(0.9%)
11	781,140	(2.7%)
12	407,430	(1.4%)
13	138,505	(0.5%)
15	728,933	(2.5%)
19	1	(0%)
Total Number of Trucks	**29,364,761**	**(100%)**

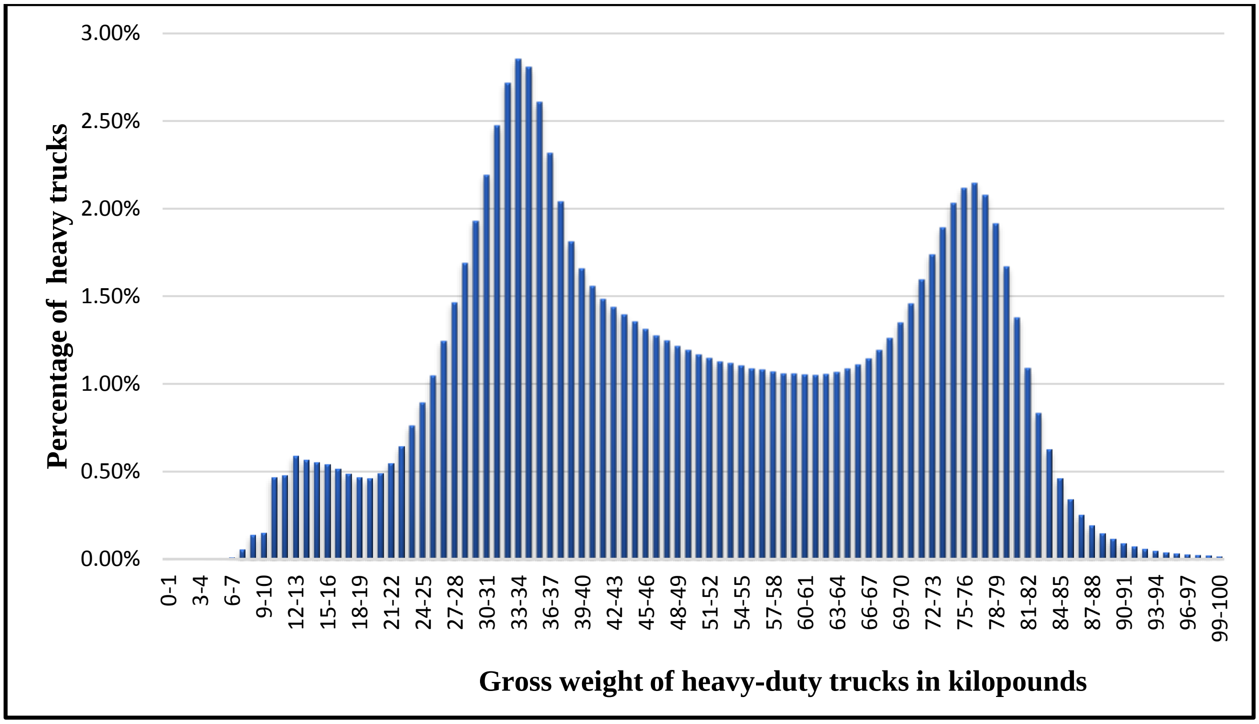


Figure 2-20: Distribution of the Truck Gross Weight in 2012 (Unit: kilo pound)

2.1.4.4 Statistical Summaries of the WIM data for the Year 2013

Table 2-43: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	1,911,191	(7.7%)
Bay	146,460	(0.6%)
Brevard	1,092,636	(4.4%)
Collier	720,889	(2.9%)
Columbia	1,312,403	(5.3%)
Duval	5,222,728	(21.1%)
Escambia	1,133,980	(4.6%)
Fl. Turnpike	3,336,322	(13.5%)
Gadsden	29,893	(0.1%)
Hendry	521,921	(2.1%)
Hillsborough	1,269,741	(5.1%)
Jackson	43,129	(0.2%)
Levy	88,526	(0.4%)
Miami-Dade	265,130	(1.1%)
Okaloosa	7,823	(0%)
Palm Beach	1,329,392	(5.4%)
Polk	2,684,115	(10.8%)
Santa Rosa	17,404	(0.1%)
Sumter	2,106,584	(8.5%)
Volusia	1,563,454	(6.3%)
Total Number of Trucks	**24,803,721**	**(100%)**

Table 2-44: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	24,069,503	(97%)
2	734,218	(3%)
Total Number of Trucks	**24,803,721**	**(100%)**

Table 2-45: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	8,761,741	(35.3%)
S	9,909,205	(40%)
E	3,110,328	(12.5%)
W	3,022,447	(12.2%)
Total Number of Trucks	**24,803,721**	**(100%)**

Table 2-46: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	8,589,098	(34.6%)
2	4,023,917	(16.2%)
3	155,401	(0.6%)
4	4,146,787	(16.7%)
5	2,682,329	(10.8%)
6	5,206,189	(21%)
Total Number of Trucks	**24,803,721**	**(100%)**

Table 2-47: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	2,230,539	(9%)
9	21,283,312	(85.8%)
10	175,988	(0.7%)
11	678,484	(2.7%)
12	390,567	(1.6%)
13	44,831	(0.2%)
Total Number of Trucks	**24,803,721**	**(100%)**

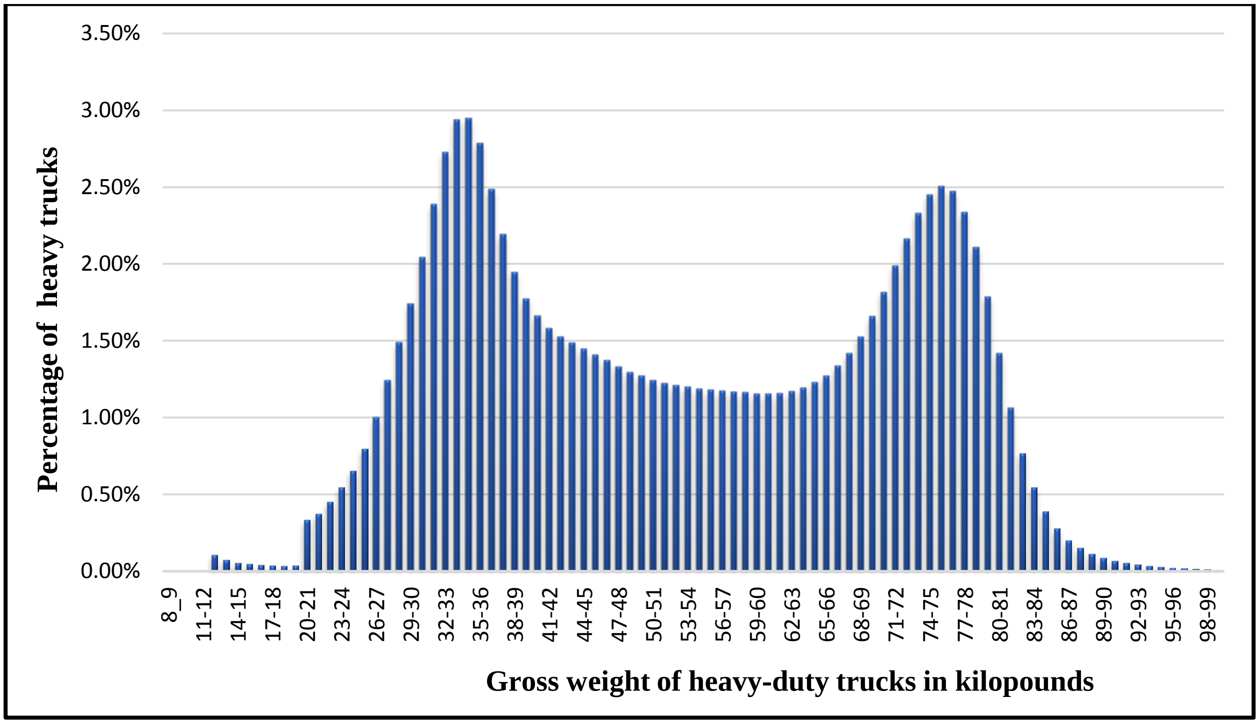


Figure 2-21: Distribution of the Truck Gross Weight in 2013 (Unit: kilo pound)

2.1.4.5 Statistical Summaries of the WIM data for the Year 2014

Table 2-48: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	1,961,788	(7.3%)
Bay	244,109	(0.9%)
Brevard	1,154,761	(4.3%)
Collier	842,244	(3.1%)
Columbia	1,395,268	(5.2%)
Duval	4,473,277	(16.6%)
Escambia	1,242,493	(4.6%)
Fl. Turnpike	3,636,625	(13.5%)
Gadsden	35,526	(0.1%)
Hendry	665,959	(2.5%)
Hillsborough	983,256	(3.6%)
Jackson	56,541	(0.2%)
Jefferson	429,813	(1.6%)
Levy	72,650	(0.3%)
Madison	979,584	(3.6%)
Miami-Dade	486,763	(1.8%)
Palm Beach	1,427,524	(5.3%)
Polk	2,933,563	(10.9%)
Santa Rosa	5,662	(0%)
Sumter	2,310,142	(8.6%)
Volusia	1,666,658	(6.2%)
Total Number of Trucks	**27,004,206**	**(100%)**

Table 2-49: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	26,253,364	(97.2%)
2	750,842	(2.8%)
Total Number of Trucks	**27,004,206**	**(100%)**

Table 2-50: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	9,500,746	(35.2%)
S	9,479,746	(35.1%)
E	4,081,943	(15.1%)
W	3,941,771	(14.6%)
Total Number of Trucks	**27,004,206**	**(100%)**

Table 2-51: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	9,855,556	(36.5%)
2	4,244,408	(15.7%)
3	274,095	(1%)
4	5,898,476	(21.8%)
5	2,515,142	(9.3%)
6	4,216,529	(15.6%)
Total Number of Trucks	**27,004,206**	**(100%)**

Table 2-52: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	2,520,547	(9.3%)
9	23,086,669	(85.5%)
10	199,533	(0.7%)
11	746,629	(2.8%)
12	404,689	(1.5%)
13	46,139	(0.2%)
Total Number of Trucks	**27,004,206**	**(100%)**

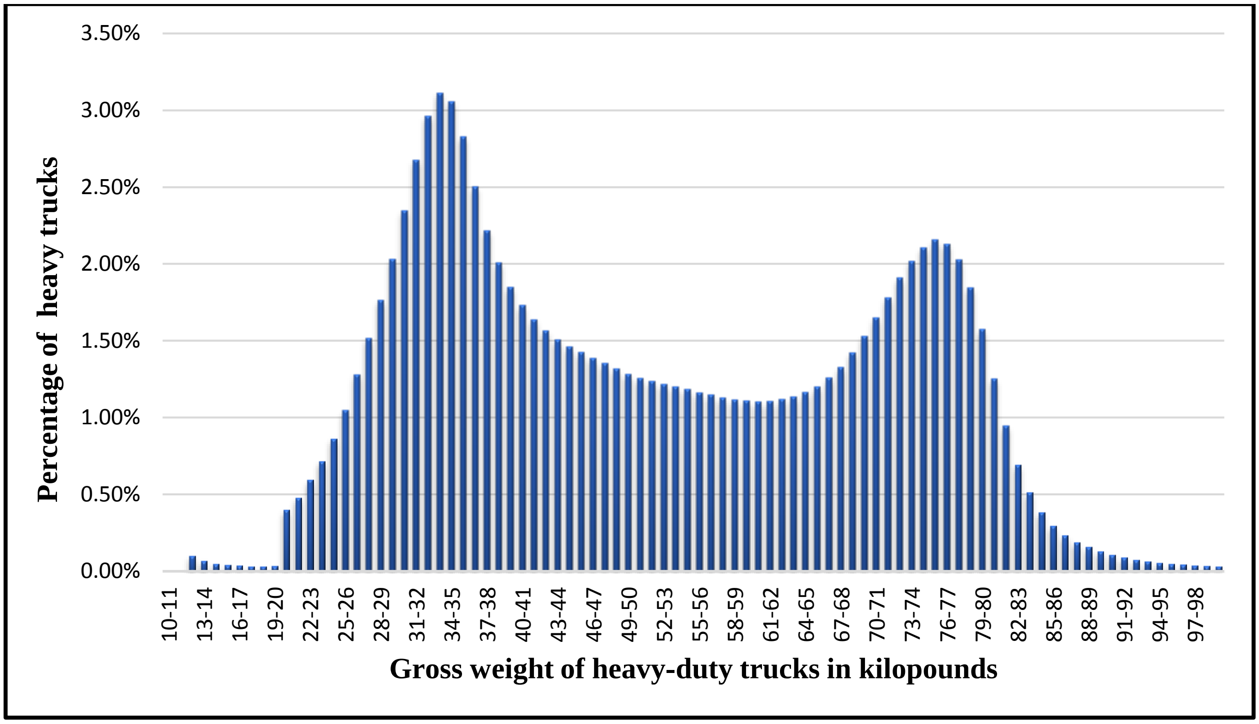


Figure 2-22: Distribution of the Truck Gross Weight in 2014 (Unit: kilo pound)

2.1.4.6 Statistical Summaries of the WIM data for the Year 2015

Table 2-53: Distribution of Trucks in Counties

County	Number of Trucks	Percentage
Alachua	1,287,060	(6.9%)
Bay	168,001	(0.9%)
Brevard	801,092	(4.3%)
Collier	592,539	(3.2%)
Columbia	887,161	(4.8%)
Duval	4,009,101	(21.5%)
Escambia	842,895	(4.5%)
Fl. Turnpike	2,560,672	(13.7%)
Gadsden	22,195	(0.1%)
Hendry	479,523	(2.6%)
Hillsborough	332,543	(1.8%)
Jackson	34,595	(0.2%)
Levy	69,112	(0.4%)
Madison	951,328	(5.1%)
Miami-Dade	422,078	(2.3%)
Palm Beach	923,541	(5%)
Polk	1,878,922	(10.1%)
Sumter	1,464,219	(7.9%)
Volusia	906,094	(4.9%)
Total Number of Trucks	**18,632,671**	**(100%)**

Table 2-54: Counts of Trucks by Units

Unit Number at the Site	Number of Trucks	Percentage
1	18,144,500	(97.4%)
2	488,171	(2.6%)
Total Number of Trucks	**18,632,671**	**(100%)**

Table 2-55: Directional Distribution of Truck Flows

Direction of the Truck	Number of Trucks	Percentage
N	6,380,587	(34.2%)
S	7,205,009	(38.7%)
E	2,652,638	(14.2%)
W	2,394,437	(12.9%)
Total Number of Trucks	**18,632,671**	**(100%)**

Table 2-56: Distribution of Truck Flows by Number of Lanes

Number of Lanes	Number of Trucks	Percentage
1	6,892,169	(37%)
2	2,874,308	(15.4%)
3	180,924	(1%)
4	4,042,334	(21.7%)
5	1,887,277	(10.1%)
6	2,755,659	(14.8%)
Total Number of Trucks	**18,632,671**	**(100%)**

Table 2-57: Distribution of Truck Flows by Truck Classes

Classification of Truck	Number of Trucks	Percentage
8	1,702,853	(9.1%)
9	15,966,743	(85.7%)
10	148,823	(0.8%)
11	516,903	(2.8%)
12	262,813	(1.4%)
13	34,511	(0.2%)
15	25	(0%)
Total Number of Trucks	**18,632,671**	**(100%)**

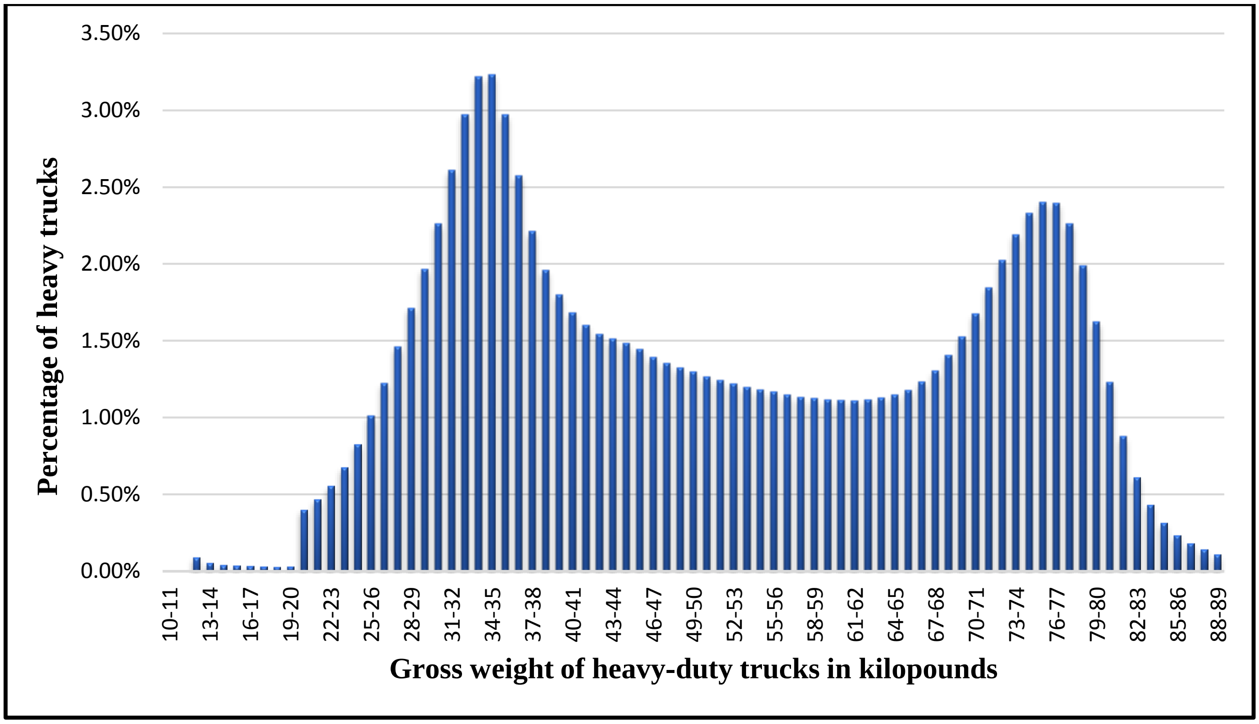


Figure 2-23: Distribution of the Truck Gross Weight in 2015 (Unit: kilo pound)

Figure 2-24 below plots the 40 locations at which heavy trucks (FHWA class 8 or above) were noted in the Florida WIM data. These 40 WIM sites are located in 26 counties of the state (Alachua, Bay, Brevard, Charlotte, Collier, Columbia, Duval, Escambia, Fl. Turnpike, Gadsden, Hendry, Hillsborough, Jackson, Jefferson, Levy, Madison, Miami-Dade, Nassau, Okaloosa, Palm Beach, Polk, Santa Rosa, Sumter, Suwanee, Volusia, Walton).

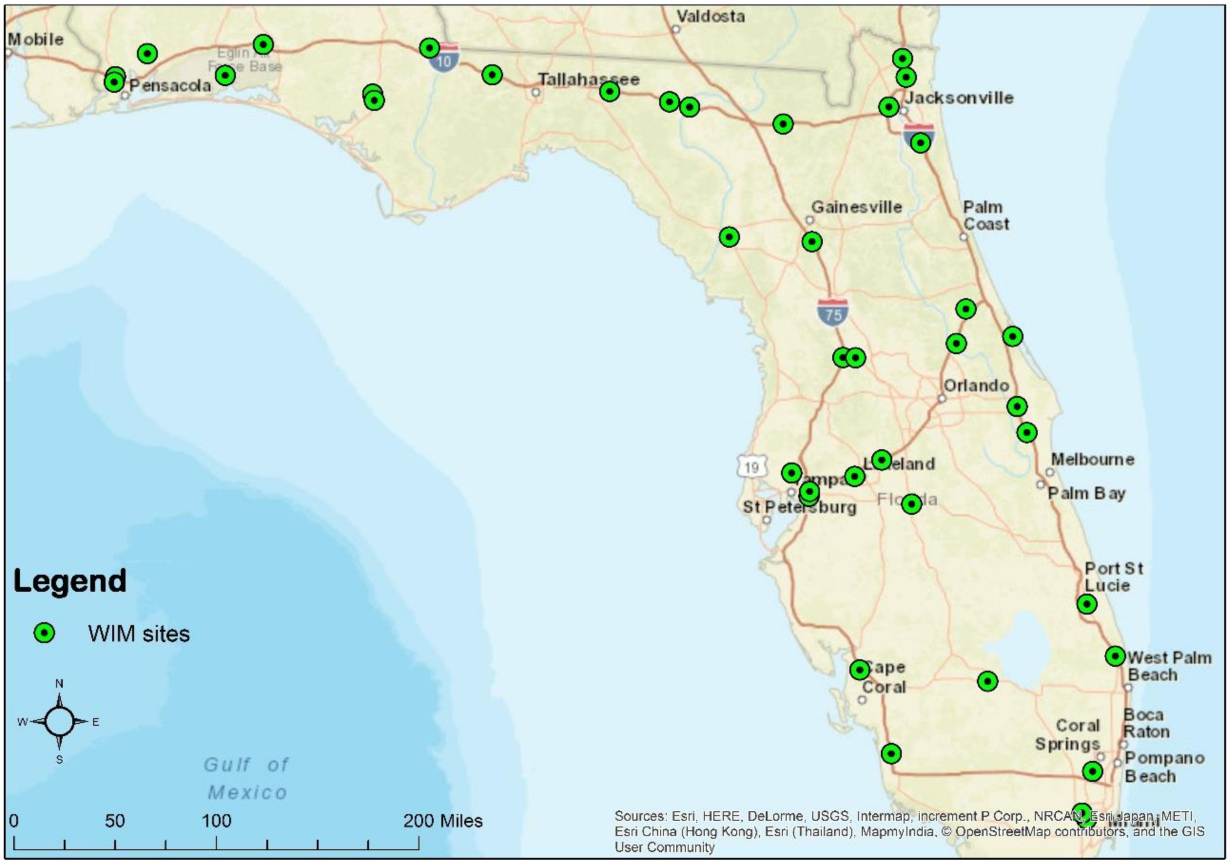


Figure 2-24: Spatial Distribution of 40 WIM Stations Visited by Heavy-duty Trucks (2010-2015)

The above analysis is done for the records of heavy- duty trucks from Weigh-In-Motion stations in Florida for the years 2010, 2011, 2012, 2013, 2014 and 2015. The data from 2012 is used for the following analysis of directional distribution of weight specifically for heavy-duty trucks classified as class 9. The class 9 trucks are selected for analysis since they constitute of around 80% of vehicles analysed for the year 2012. The weight distribution of class 9 vehicles at different Weigh-In-Motion stations located on interstate and non- interstate roads in north, west, south and east directions for the year 2012 are given in following figures. The records from Weigh-In-Motion stations on interstate roads and non-interstate roads in north and west directions are grouped together for the analysis considering them as the outbound trucks from Florida. Likewise, records from Weigh-In-Motion stations on interstate roads and non-interstate roads in south and east directions are grouped together considering them as the inbound trucks to Florida. Figure 2-25 shows the weight distribution of trucks for each direction of flow. Figure 2-26 through Figure 2-29 show the weight distribution for each WIM location. It can be observed from all these figures (Figure 2-26 through Figure 2-29) that the trucks traveling in the north and east direction are skewed toward lower weights compared to trucks traveling in the South and West directions. This demonstrates the imbalance in the weights between the weight of trucks traveling into Florida (some of the South and East bound trucks) and those leaving Florida (some of the North and West bound trucks).

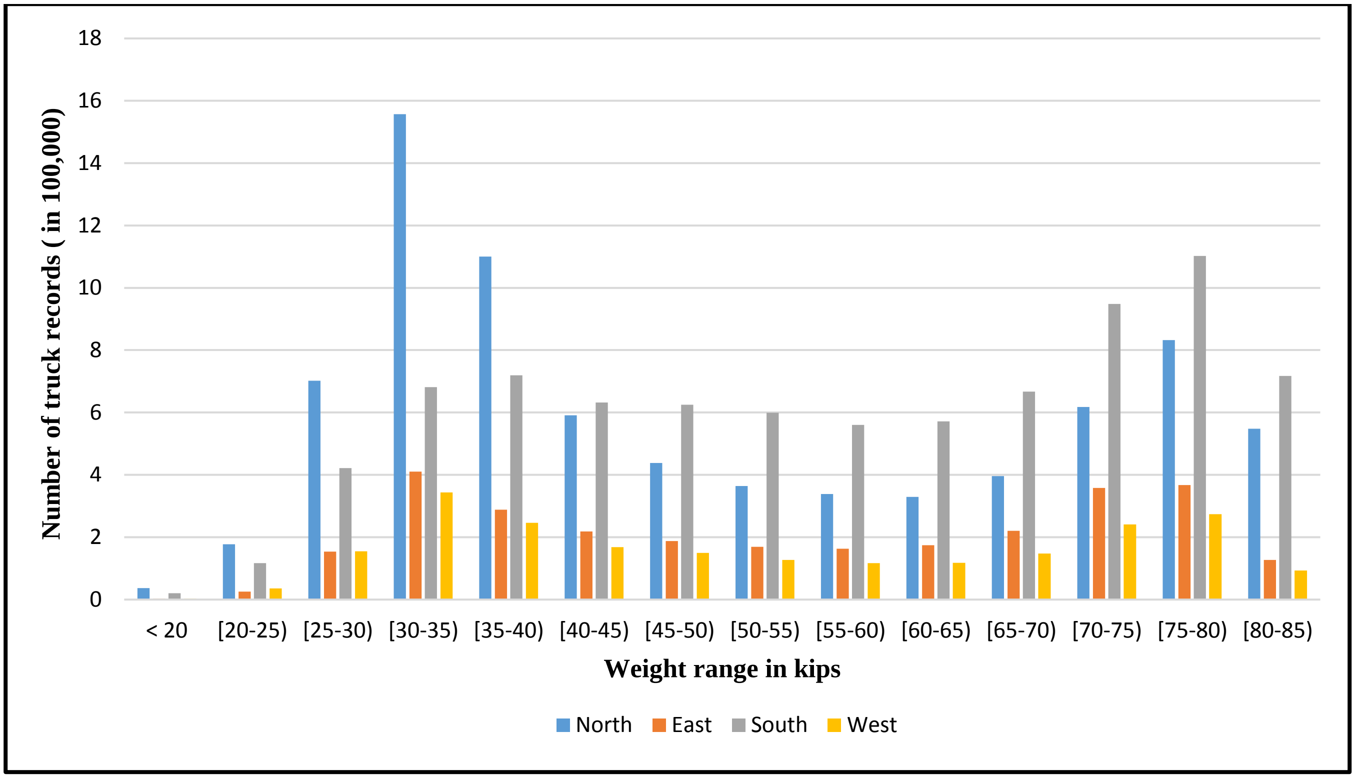
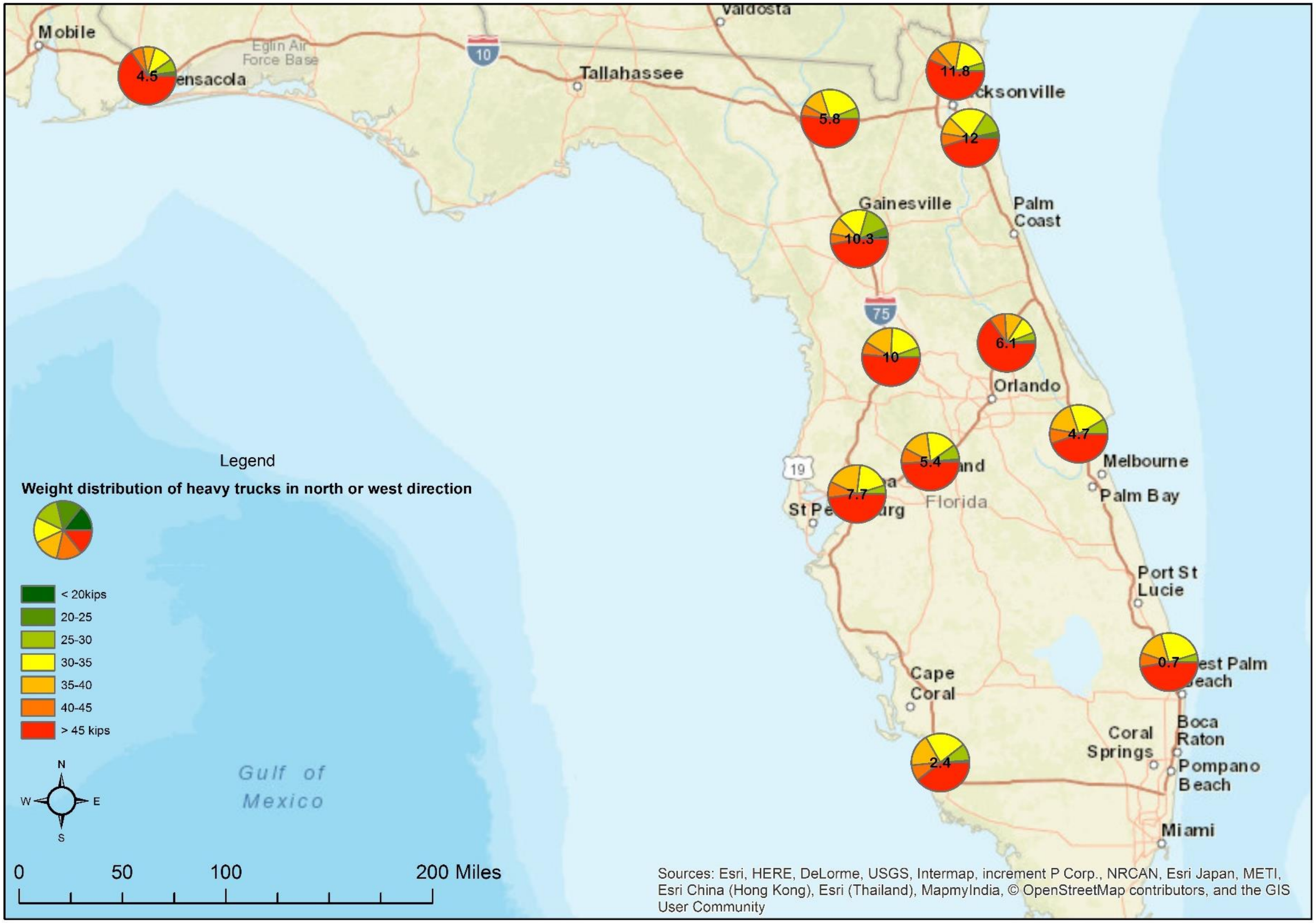
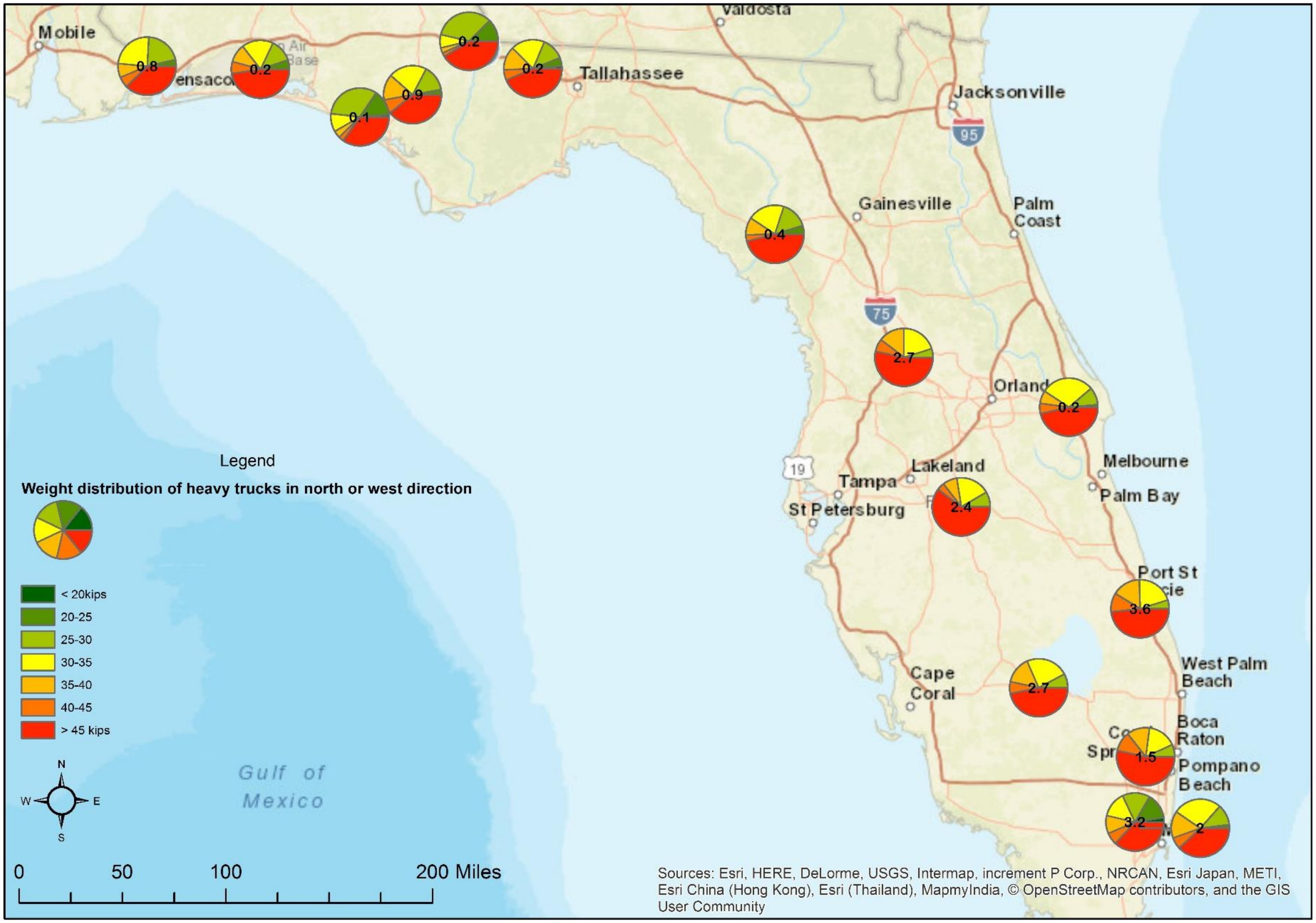


Figure 2-25: Weight Distribution of Class 9 Vehicles in North, East, South and West Directions for the Year 2012



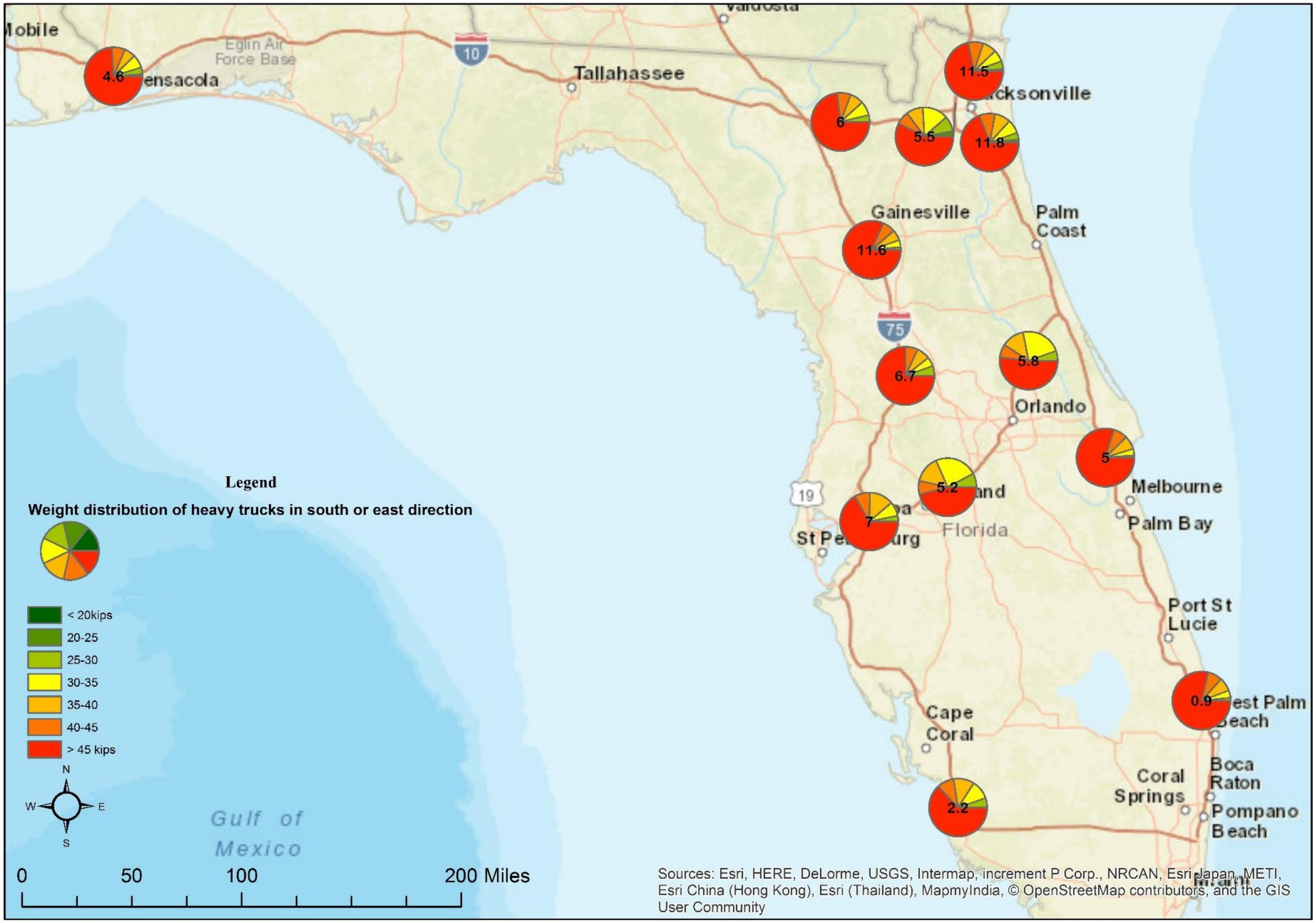
Note: Number in the pie chart represents the number of class 9 truck records observed in the year 2012 (in 100,000)

Figure 2-26: Weight Distribution of Cass 9 Vehicles at Different WIM Sites Located on North or West Directions of Interstate Roads in 2012



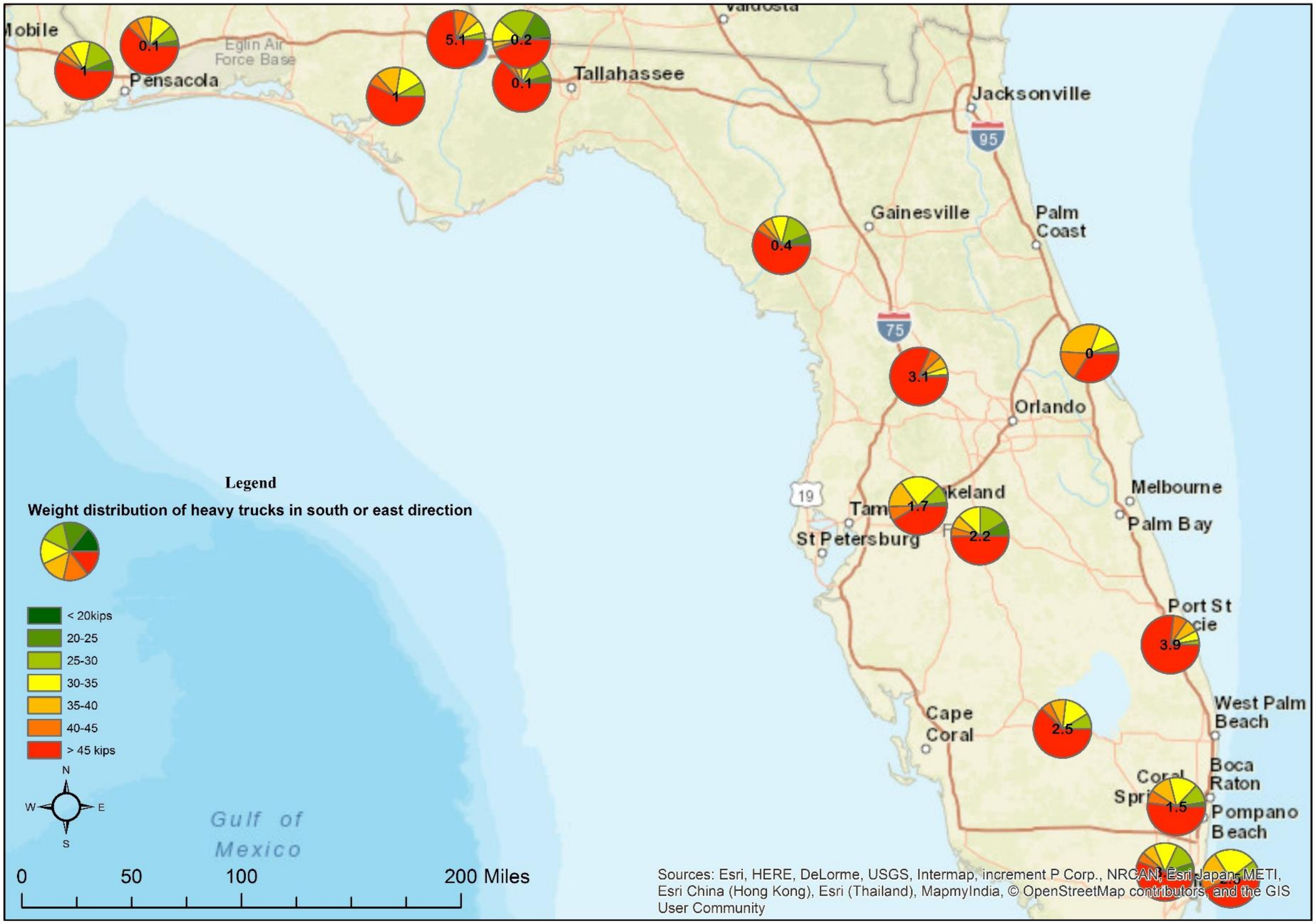
Note: Number in the pie chart represents the number of class 9 truck records observed in the year 2012 (in 100,000)

Figure 2-27: Weight Distribution of Class 9 Vehicles at Different WIM Sites Located on North and West Directions of Non-Interstate Roads in 2012



Note: Number in the pie chart represents the number of class 9 truck records observed in the year 2012 (in 100,000)

Figure 2-28: Weight Distribution of Class 9 Vehicles at Different WIM Locations on South and East Directions on Interstate Roads in 2012



Note: Number in the pie chart represents the number of class 9 truck records observed in the year 2012 (in 100,000)

Figure 2-29: Weight Distribution of Class 9 Vehicles at Different WIM Locations on South and East Directions of Non-Interstate Roads in 2012

2.1.5 Database 5: Vehicle Class Data

The WIM data sites in Florida are part of a larger group of Telemetered Traffic Monitoring Sites (TTMS) in the state. All TTMS locations (which includes the WIM data sites), if functioning, will do vehicle count. Among these, vehicle classification sites are equipped with the ability to classify each vehicle (according to the number of axles) as well as to measure the vehicle speed. The WIM stations, which are a subset of these sites, can measure weight of each vehicle (in addition to the classification and speed).

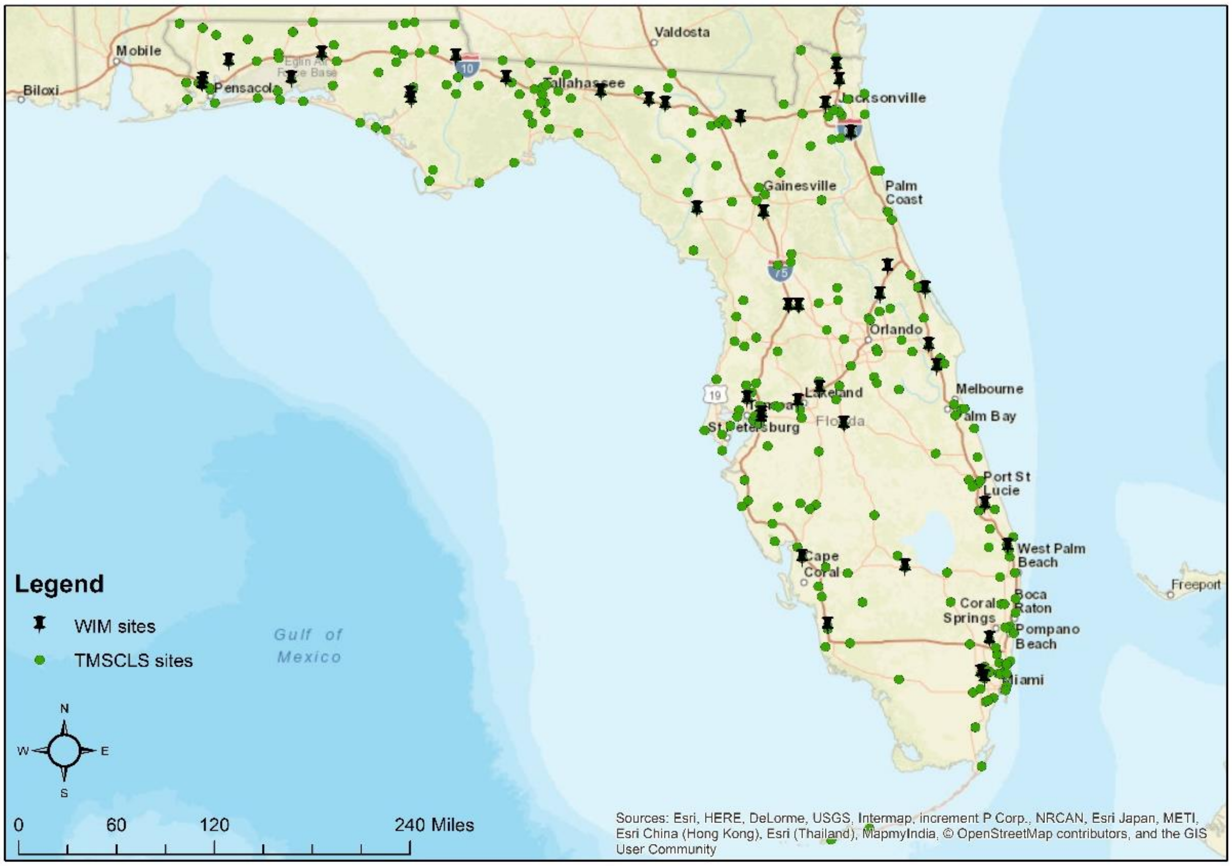


Figure 2-30: Distribution of TMSCLS Sites and WIM Sites in Florida in 2015

For the project, vehicle classification data were obtained from FDOT. In addition to reviewing the WIM data, the research team conducted a preliminary review of the TMSCLS data on vehicle classification counts. Figure 2-30 above presents the spatial distribution of the TMSCLS stations that provided data for the year 2015 (green dots in the figure). These comprise over 260 sites throughout Florida. A subset of these are 40 WIM stations shown in the form of black coloured pins in the figure above (these 40 WIM stations are also shown in Figure 2-24) and at which trucks of class 8 and above were noted.

The data were available for six years, from 2010 to 2015. The exploratory analysis was mainly conducted for 2010 and 2015. However, some descriptive statistics are presented for the other years as well. All the databases are consistent and contain information on 24-hour counts of 15 classes of vehicles defined by the FHWA in addition to the information on county and site location of the counting stations as well as starting date, direction, and type of counting. In the following sections, we document the findings regarding variability in truck traffic volumes by FHWA vehicle classification scheme.

Table 2-31 presents the comparison of records across the six years. Total number of records varied between 140,000 to 160,000. We can see that the highest number of records of vehicle count data was available for 2015 dataset (counts were taken from 265 stations) followed by 2010 dataset (counts were taken from 255 stations).

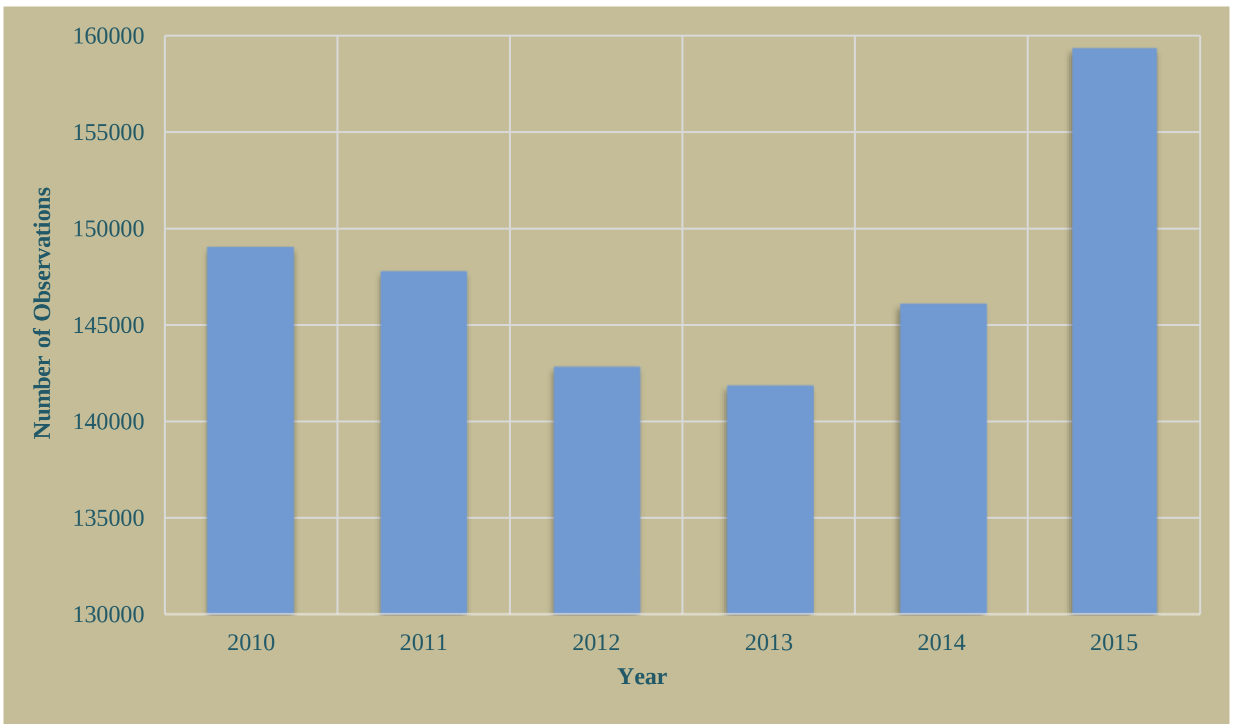


Figure 2-31: Number of Records by Year

The analysis is conducted along three major directions: (1) total volume analysis, (2) weekly directional volume analysis, and (3) monthly directional volume analysis.

2.1.5.1 Total Volume Analysis

We started data exploration with total volume analysis. According to the FHWA classification, Class 5 to Class 13 represented trucks. The definitions of the truck classes are presented in Table 2-58. For our analysis, we segregated the truck classes into two categories. These are: (1) Small trucks (Class 5 – Class 7) and (2) Large trucks (Class 8 – Class 13).

Table 2-58: Definition of Truck Classes

Vehicle Class		Definition
Small Truck	Class 5	Two axle, six tire single unit
	Class 6	Three axle, single unit
	Class 7	Four or more axle, single unit
Large Truck	Class 8	Four or less axle, single trailer
	Class 9	Five axle, single trailer
	Class 10	Six or more axle, single trailer
	Class 11	Five or less axle, multi-trailer
	Class 12	Six axle, multi-trailer
	Class 13	Seven or less axle, multi-trailer

Table 2-59 shows the distribution of large trucks, small trucks, total trucks, and total vehicle volumes by year. The following observations can be made from the Table.

- There is an 11 percent increase in the large truck volumes from 2010 to 2015.
- The increase in small truck volume (18%) is 1.65 times higher than the increase in large truck volume.
- Overall, trucks represent 8 percent of the total traffic volume counts in all years. Interestingly, proportion of large trucks in total traffic declined from 5.27 percent to 5.16 percent whereas proportion of small truck increased from 2.99 percent to 3.15 percent from 2010 to 2015.

In the 2010 database, vehicle counts were collected from a total of 255 locations from 64 counties. In Table 2-32 we show the distribution of large truck (top) and small truck (bottom) volumes by county. The top ten counties in terms of large truck volumes were: Duval, Florida Turnpike, Hillsborough, Columbia, Marion, Palm Beach, Broward, Brevard, Polk, and Alachua and top ten counties in terms of small truck volumes were: Florida Turnpike, Broward, Duval, Hillsborough, Palm Beach, Miami-Dade, Seminole, Polk, Sarasota, and Brevard.

Table 2-59: Distribution of Large and Small Truck Volumes (Million) by Years

Volume	2010	2011	2012	2013	2014	2015
Large Truck	116.67	110.76	106.09	109.40	114.73	129.51
Small Truck	66.92	62.37	61.24	63.09	68.56	78.99
Total Truck	183.59	173.14	167.33	172.48	183.30	208.49
Total Volume	**2235.37**	**2100.34**	**2079.27**	**2102.57**	**2199.76**	**2507.05**

2.1.5.2 Weekly Directional Volume Analysis

In the next step, we conducted weekly directional volume analysis. Figure 2-33 and Figure 2-34 represents the weekly variation by direction for the large truck classes. In general, the following observations can be made from the figures.

- As expected, compared to weekdays, truck traffic is lower during weekends in all direction. Sunday traffic volumes were the lowest of the week for all large truck classes.
- Mondays generally have slightly lower truck volumes than other weekdays.
- Truck flow for all classes increase sharply after Monday and maintain a steady volume Tuesday through Friday.

2.1.5.3 Monthly Directional Volume Analysis

Our final analysis was monthly directional volume analysis. Figure 2-35 and Figure 2-36 represents the monthly variation by direction for the large truck classes. In general, the following observations can be made from the figures.

- Truck flows reduce in the winter and increase in the summer.
- An interesting directional variation in truck flows was observed. During spring, southbound directional flow is higher for Class 9 – Class 12.

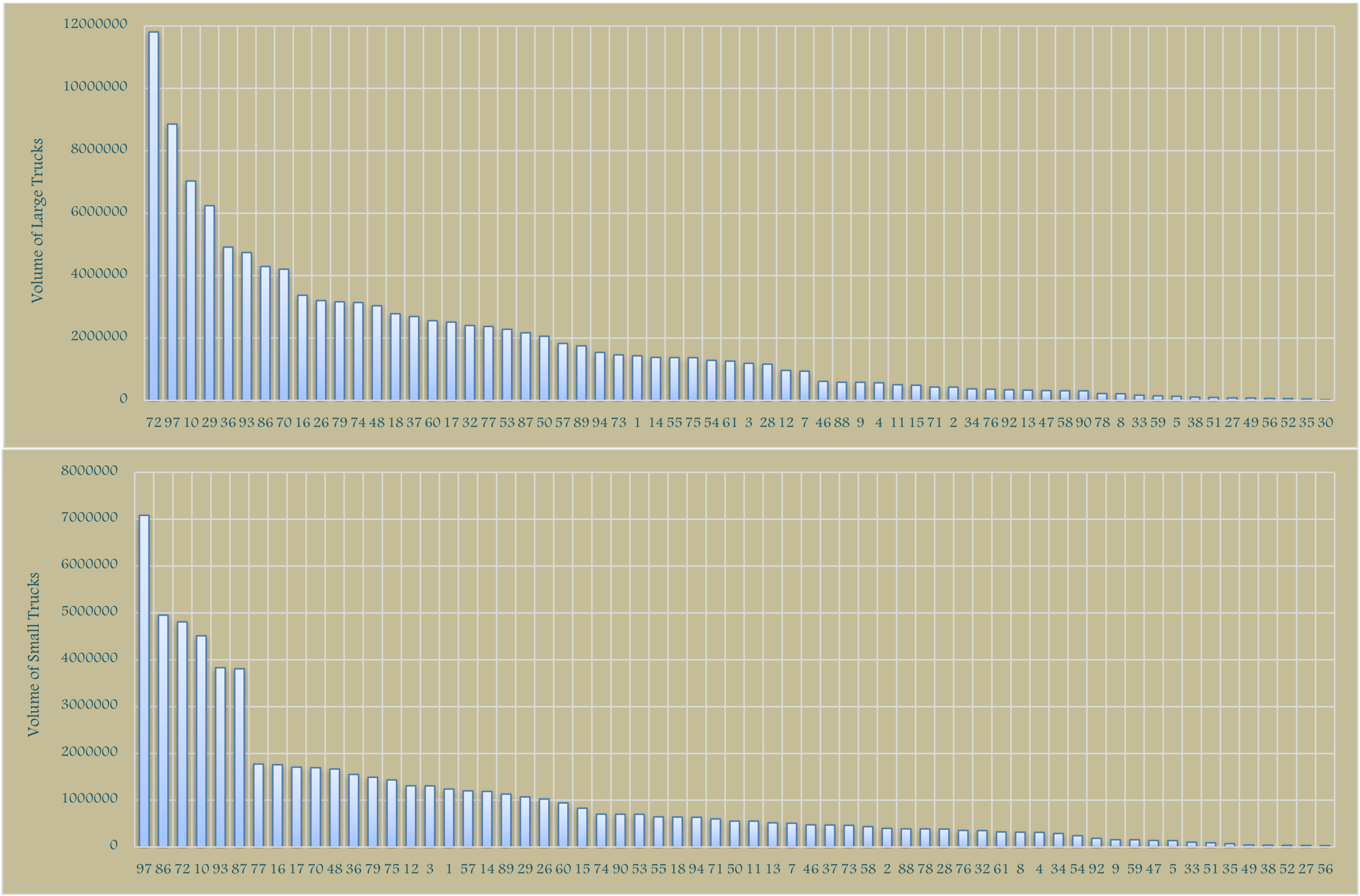


Figure 2-32: Distribution of Large Truck (Top) and Small Truck (Bottom) Volumes by County

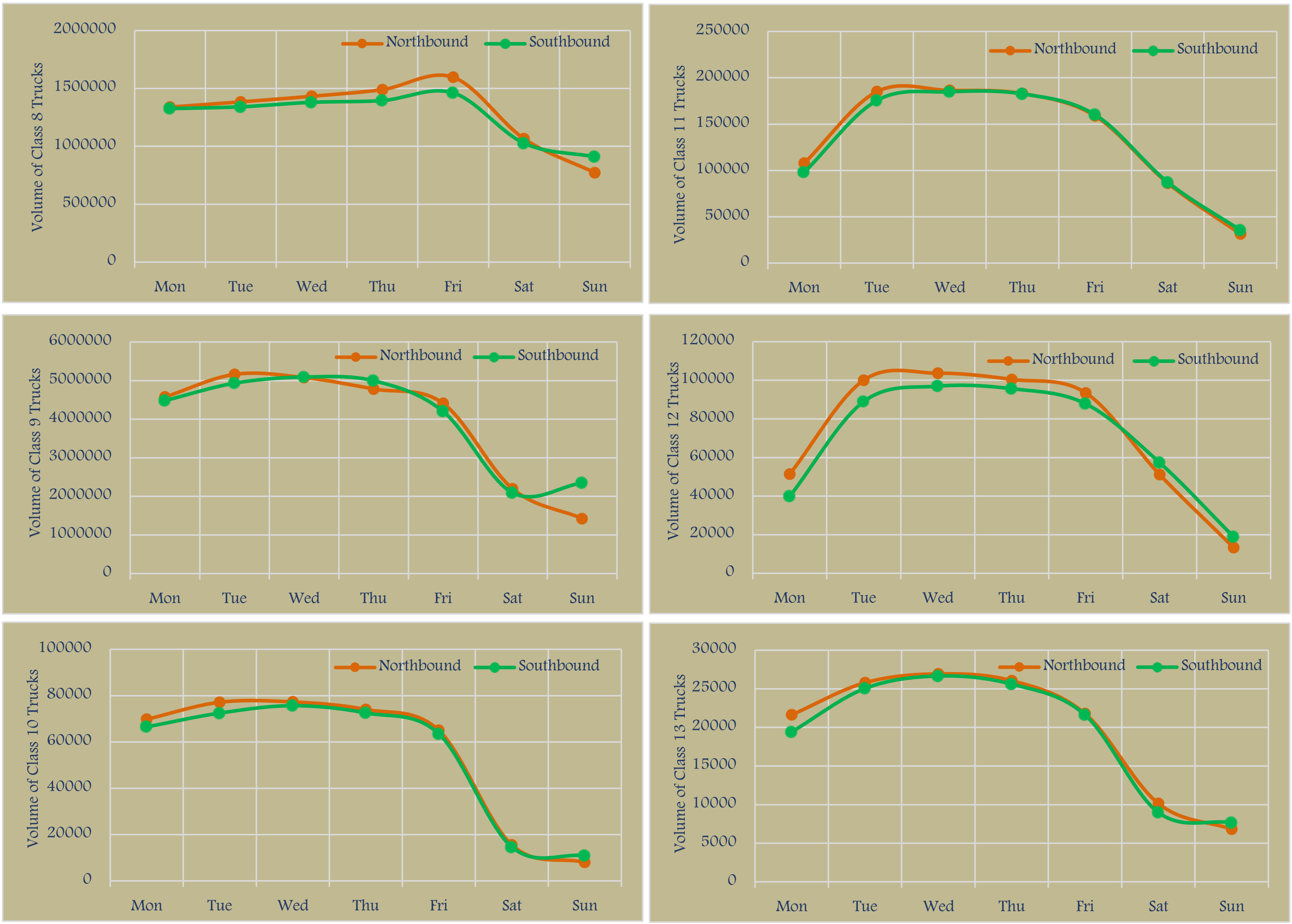


Figure 2-33: Weekly Directional (Northbound and Southbound) Distribution of Large Truck Classes (2010)

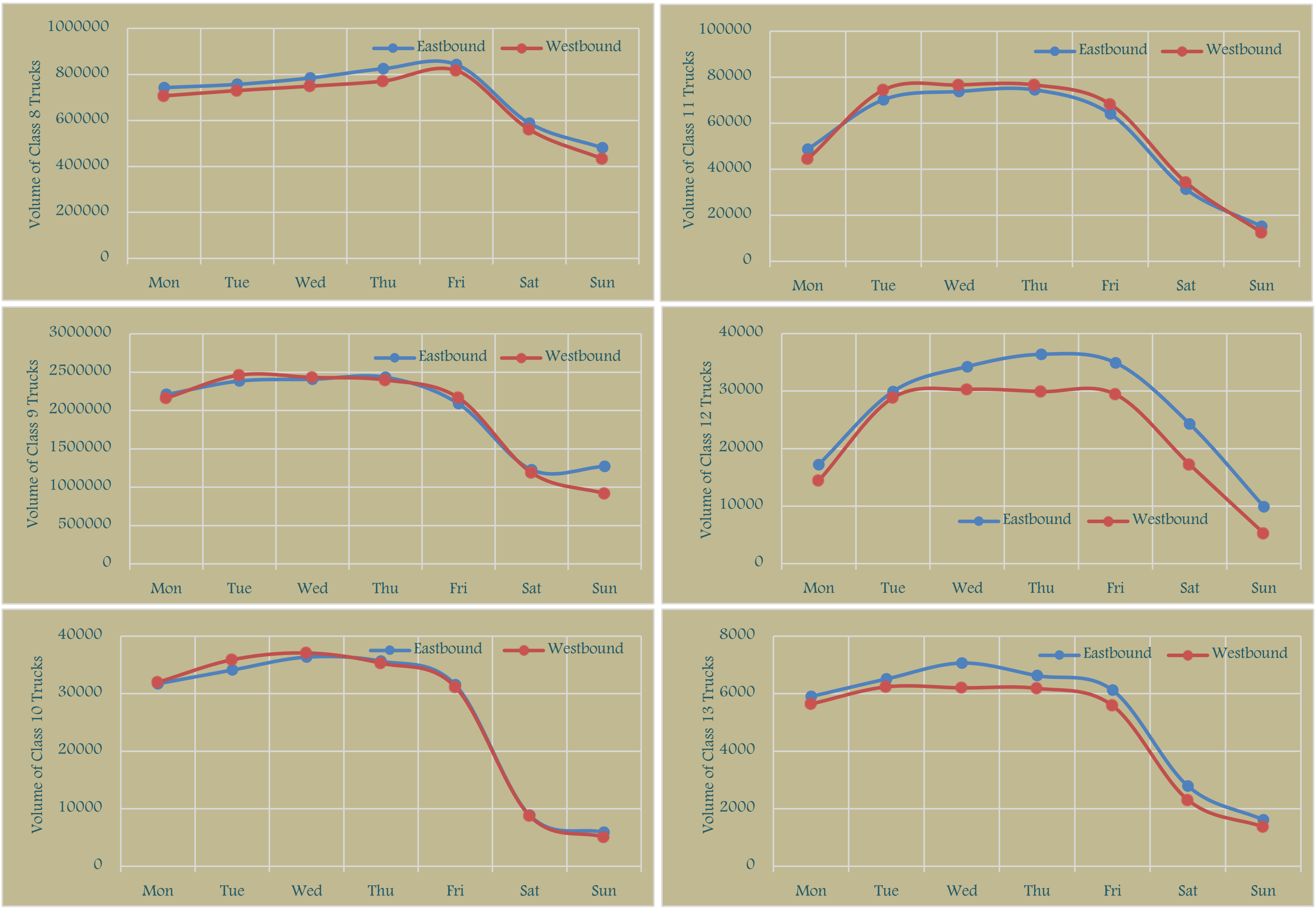


Figure 2-34: Weekly Directional (Eastbound and Westbound) Distribution of Large Truck Classes (2010)

Figure 2-35: Monthly Directional (Northbound and Southbound) Distribution of Large Truck Classes (2010)

Figure 2-36: Monthly Directional (Eastbound and Westbound) Distribution of Large Truck Classes (2010)

2.1.6 Database 6: Parcel Level Land Use Data

Figure 2-37 illustrates graphically the major land use types in the state of Florida. We can observe that majority of the lands are primarily used for agricultural purposes. As expected, residential and retail/office areas are more clustered around the coastal regions.

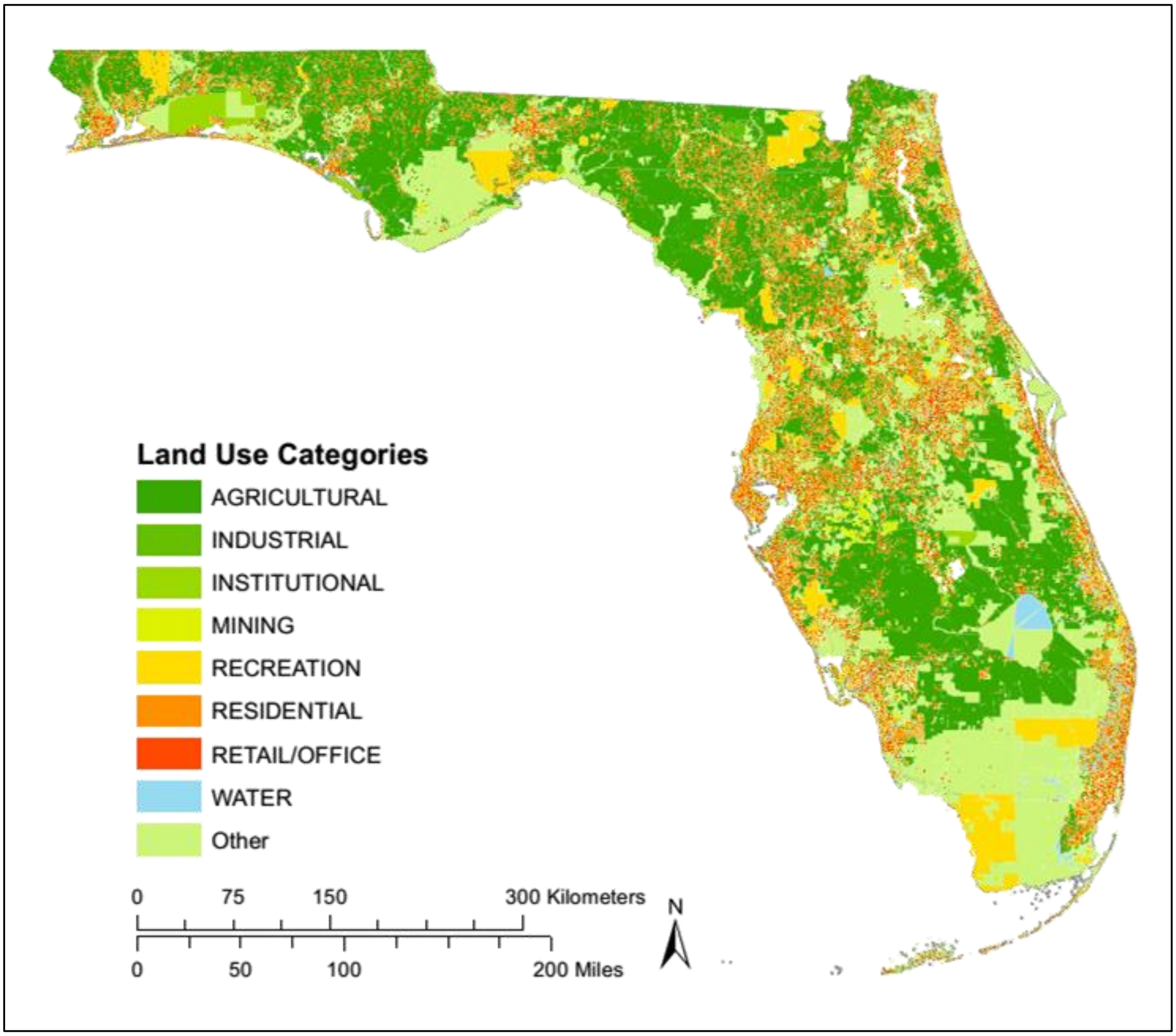


Figure 2-37: Major Land Use Types in Florida

Figure 2-38 shows the population distribution across STAZs in Florida.

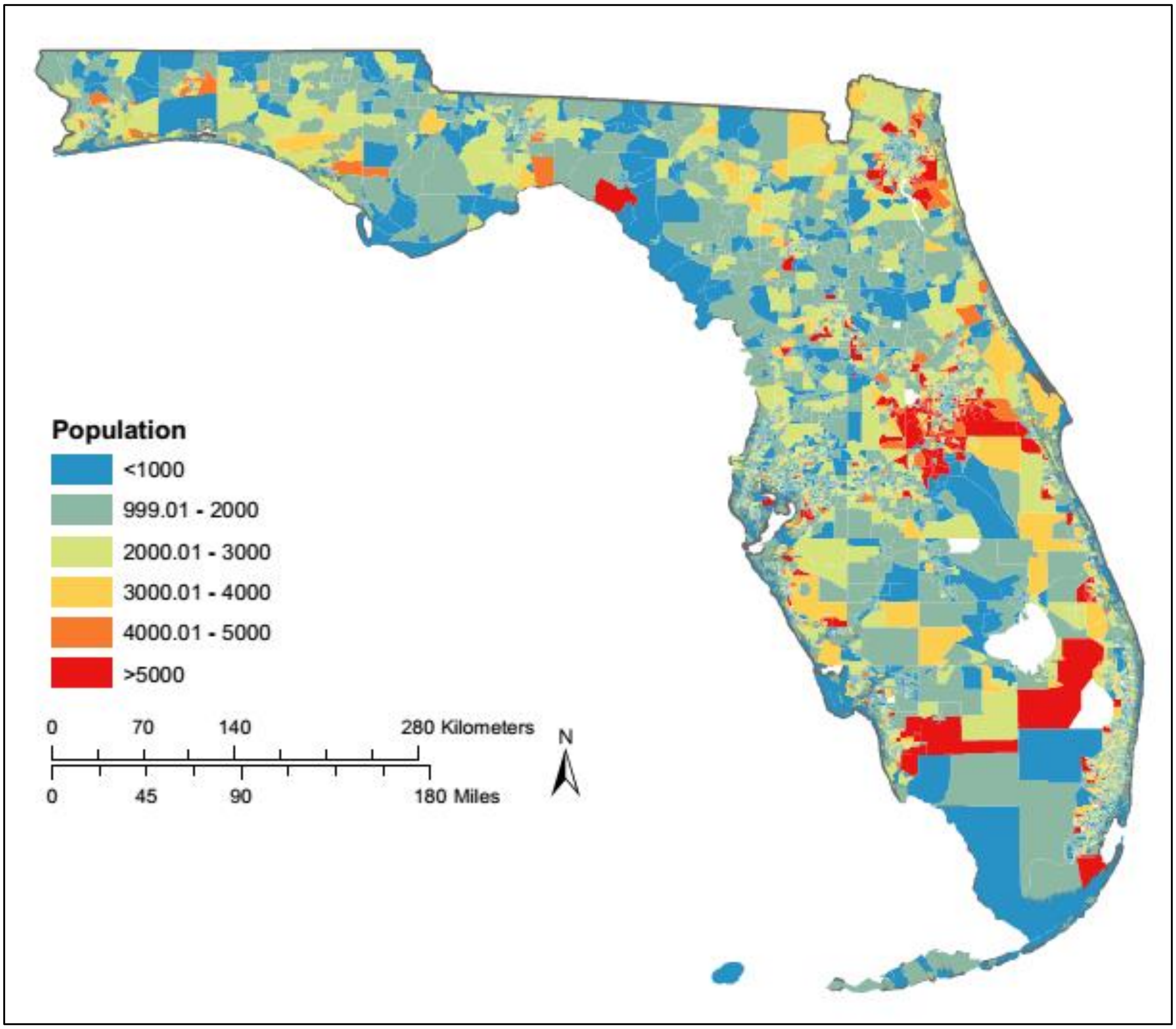


Figure 2-38: Population Distribution across Florida

Figure 2-39 shows the no of jobs distribution across FAF regions. As expected, employment concentration is higher in places where there is higher concentration of population.

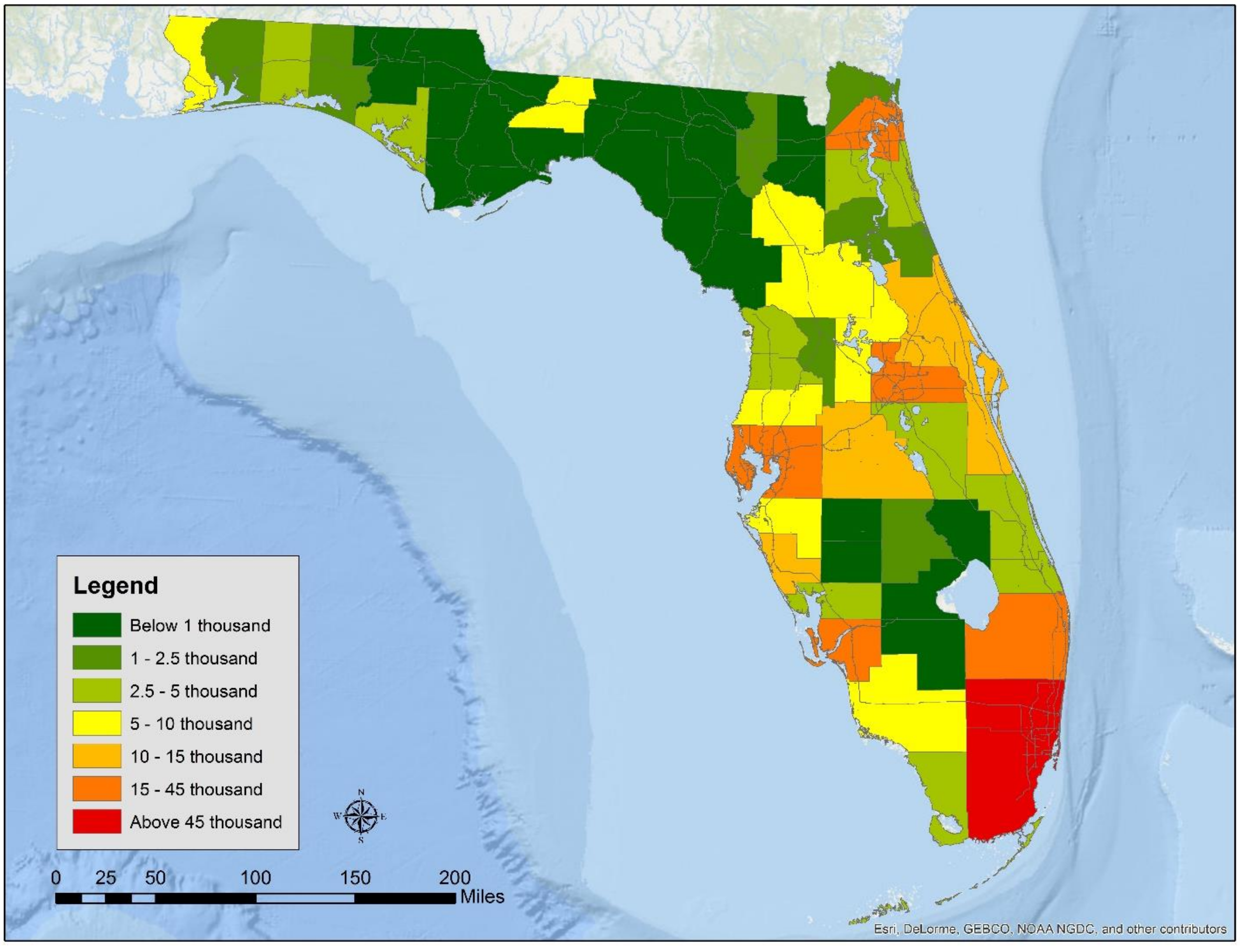


Figure 2-39: Job Distribution across Florida

Figure 2-40 shows the warehouse area distribution across Florida. As expected, we have higher concentration of warehouse areas near the port areas.

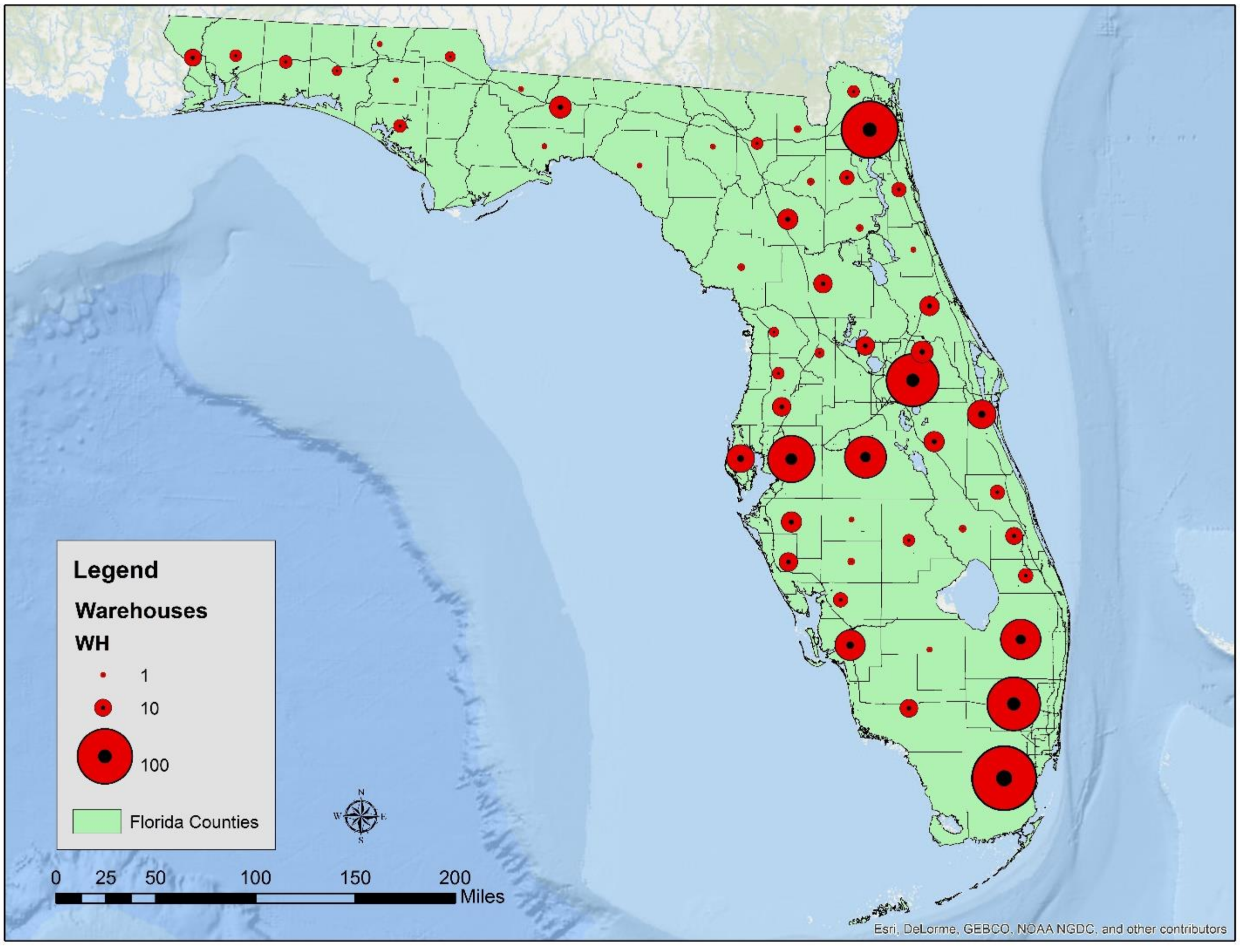


Figure 2-40: Warehouse Area Distribution across Florida

CHAPTER III: LITERATURE REVIEW

3.1 REVIEW OF DATA FUSION METHODOLOGIES

Several research efforts have attempted to address the spatial resolution challenge with FAF data. A summary of earlier literature summarizing freight data merging efforts is provided in Table 3-60. The table provides information on the study, datasets employed, objective of the research effort, modeling methodology, and exogenous variables considered.

Several observations can be made from the table. First, a majority of the studies developed a procedure for disaggregating FAF data from the FAF zone level to a county level or traffic analysis zone (TAZ) level. Second, several states in the U.S. have developed disaggregation procedures including Texas, California, New Jersey, Wisconsin, Georgia, and Florida. Third, the various methods considered to disaggregate FAF flows include (i) proportional weighting method (applied for socio-economic variables or vehicle miles traveled (VMT)) and (ii) statistical methods.

In the proportional weighting method, a "disaggregation factor" is estimated using various socio-economic variables (such as employment and population), land use, and truck VMT variables by computing the ratio of the variables of interest at the disaggregate spatial resolution and aggregate spatial resolution. Using these factors, the freight flow allocation to the disaggregate spatial resolution is made. The disaggregation factors are considered to vary based on the type of origin and destination spatial configuration (such as internal - internal zonal pair or external - internal zonal pair). The statistical methods considered in freight modeling include linear or log-linear regression, structural equation modeling, economic input output models, and fractional split methods that employ socio-economic and demographic variables such as employment and population as exogenous variables. The models developed are employed to generate freight flows at the desired disaggregate spatial resolution. The models are typically validated by aggregating freight flows at the finer resolution and comparing it to the observed flows at the aggregate resolution. Fourth, in disaggregation studies, the variables of interest includes tonnage, value, and/or ton-miles. Finally, the variables considered to be of significance in the data merging process include employment, population, travel time and cost, business establishments, and transportation system characteristics.

Based on the literature review, it is evident that multiple research efforts have considered disaggregation of FAF commodity flow to a lower spatial resolution such as county TAZ. While the disaggregation is of immense value, the approach employed is purely a factoring exercise without any attempt to address production consumption relationships. FAF data inherently does not provide production consumption relationship and hence using FAF alone to arrive at production consumption flows is not possible. To be sure, earlier research employed TS flows for evaluating FAF disaggregation outputs for validation purposes.

Table 3-60: Review of Earlier Studies

Study	State	Dataset Used	Objective	Modeling Methodology	Variables Used
Giuliano et al., 2010	Los Angeles and San Francisco	2010 Census CSA Data	Identify freight activities spatial pattern	Freight landscape: spatial patterns of freight activity	Population and employment density quartiles and transport system supply
Bujanda et al., 2014	Texas	FAF3, and Transborder Freight Flow	Disaggregate regional flows using FAF3	Multilevel query for the ODs and GIS allocation of truck flows	Shortest path routes, origin, destination (input-output) control points
Aly and Regan, 2014	California	FAF2	Disaggregate the FAF flow for both ton and value	Proportional weighting method for both origin and destination	Employment, population, VMT, Truck VMT
Opie et al., 2009 & Rowinski et al., 2008	New Jersey	FAF2, Transearch	Disaggregate the FAF flow at county level for different commodity	Proportional weighting method	Commodity-specific employment, truck VMT, total employment, population
Ranaiefar, et al., 2013, 2014	California	FAF3	Develop SEM to improve individual regression	Structural equation modeling	Employment, Establishments, population, farm acreages, GDP, capacities of refineries, 5 annual consumption and production of power plants, etc.
Roman-Rodriguez et al., 2014	California	FAF mode for analysis, and Transearch for validation	Mode split disaggregation of FAF flow	Mode split fractions	Mode specific variables (i.e., Cost, Time, VMT)
Harris, et al., 2010	Alabama	FAF2	A case study to review the modeling methodology for small urban area	Traditional demand model	International Port
Mitra, and Tolliver, 2009	North Dakota	FAF2, commodity input-output table by BEA industry, the U.S. Army Corps and BTS	Disaggregate freight trips at TAZ levels	Traditional I-O model for trip attraction, and disaggregation by gravity model	Employment, travel impedance such as cost.
Vishwanathan et al., 2008	Florida	FAF2	Disaggregate FAF flows for smaller geographies to generate freight flows at county level	Proportional weighting method and regression model	employment rates, population and total employment within the FAF region

Table 3-61 (Continued): Review of Earlier Studies

Study	State	Dataset Used	Objective	Modeling Methodology	Variables Used
Ruan and Lin, 2010	Wisconsin	CFS, Transearch	Review different data synthesis method to disaggregate FAF flow to a smaller spatial resolution	Proportional weighting method, Direct regression, and Optimal disaggregation model	Commodity specific employment, facility count
Ross et al., 2016	Georgia	FAF3, CBP, Census, NHFN, Tonnage – truck conversion table (SC association of Governments)	Produce county and TAZ level O-D matrix for nationwide and state-wide respectively	Regression for aggregated flow and disaggregated by Proportional weighting for TAZs between the OD	Socioeconomic (i.e., employment, income), and transportation network data (i.e., network length)
Holguin-Veras et al., 2001	New York Metropolitan Region	-	Explain a regional freight model focusing on transportation activity and economy by comparing the method	Compare the Input-Output models, Spatial Interaction models Origin-Destination synthesis formulations	-
Oliveira-Neto et al., 2012	Whole USA	CFS,	Disaggregation of FAF flow (ton-mile) at county level	Aggregated ton-mile modeled using production-attraction of the OD; disaggregation using regression model	Shipment distance, total employment and population

3.2 REVIEW OF TRUCK PAYLOAD FACTOR ALLOCATION

Different commodity based methods followed by researchers to obtain truck flows using truck payload factors

1. "An empirical study of truck payload allocation" by Areekamol et al. (2014)

The focus of this study is on the estimation of the number of trucks by type and the level of service on the Interstate highway 15 (I - 15) located in Utah. The predicted commodity flow data from the Freight Analysis Framework version 3 (FAF) for 2015 data and CFS data are used to obtain the Annual Average Daily Truck Traffic (AADTT) by commodity and percentage share in UTAH. The process of conversion is given below.

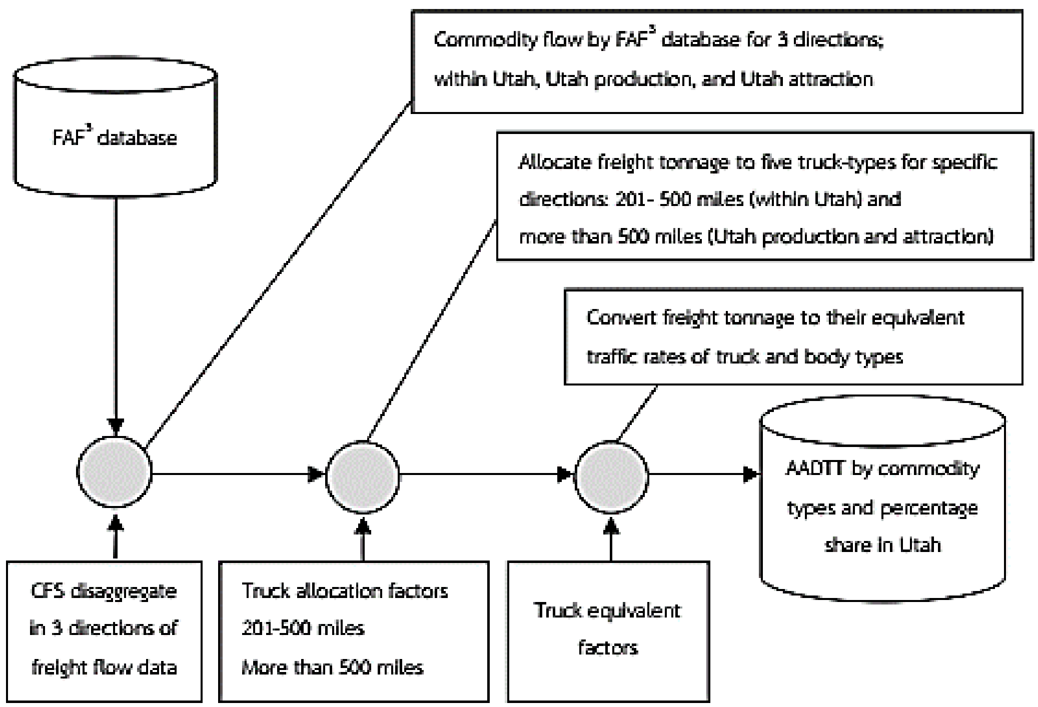


Figure 3-41: The Process to Convert FAF Commodity Flow Data to ADTT

The methodology is as follows:

1. Directions of commodity flow is first determined. They are classified as within Utah, and Utah productions and attraction (from and to Utah).
2. Then the driving distance of trucks is determined. Truck movement within UTAH is limited to 201-500 miles and from – to UTAH commodity flow is greater than 500 miles.
3. Then FAF truck configuration (Truck types) and truck body types are considered. In this study, 5 FAF truck configurations and 9 FAF body types are considered.
4. Percentage of truck shares (allocation factor- fraction of truck type with body type) are obtained from VIUS 2002 depending on the distances.
5. Then the truck equivalent factors (mean payload of moving commodity by truck type with body type) from VIUS 2002 will be used to allocate the commodity weight to the number of trucks by specific body type.

Methodology that was adopted in obtaining the Annual Average Daily Truck Traffic is shown below. Notations:

Y_j: the number of trucks in type j, where j = 1,2,..,5

X_i: tonnage of commodity i, where i = 1,2,.....,43

β_{ijk}: fraction of commodity i moved by truck type j with body type k, where k = 1,2,...,9

ω_{ijk}: mean payload of moving commodity i by truck type j with body type k

$X_i\beta_{ijk}$: tonnage of commodity X_i carried by truck type j and body type k

$X_i\beta_{ijk}/\omega_{ijk}$: the number of trucks j with body type k required to move $X_i\beta_{ijk}$ tons

The number of trucks of type1 required to carry commodity i is equal to $Y_{j=1}$, where

$$Y_{j=1} = \frac{X_i\beta_{i11}}{\omega_{i11}} + \frac{X_i\beta_{i12}}{\omega_{i12}} + ... + \frac{X_i\beta_{i19}}{\omega_{i19}} = \sum_{k=1}^{k=9} \frac{X_i\beta_{i1k}}{\omega_{i1k}} \tag{3.1}$$

The total number of trucks require to move all commodities is given by

$$\text{Total\_Trucks} = \sum_{i=1}^{i=43} X_i \sum_{j=1}^{j=5} \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3.2}$$

AADTT by commodity types and percentage share in UTAH are obtained multiplying the truck payload factors with commodity flows.

Finally, the truck equivalent factor is equal to TEF_{ijk} where i, j , k represents commodity type, truck type, body type respectively. Truck equivalent factors and also payload factors (ωijk) for each commodity is given by:

$$TEF_{ijk} = \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3.3}$$

2. "Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems" by Krishnan and Hancock (1998).

The primary objective for this research was to develop a GIS-based approach for distributing and assigning freight flows in Massachusetts. An intermediate goal was to develop a quantitative methodology for estimating freight traffic on major roads in Massachusetts from newly released interstate commodity flow data. The statewide freight flow data was extracted from the CFS for 1993 and corresponds to tons, in thousands, of commodity shipped by truck. Trucks were classified based on FHWA classification. According to this study, the O-D matrices for each Standard Industrial Classification (SIC) commodity category was not completely extractable from the CFS for 1993. A majority of commodity flow data for the farming, fisheries and forestry, and mining categories either were not disclosed or were unavailable because they did not meet publication standards. The other sectors category consisted of up to 95 percent of all the commodities data and the individual analyses conducted showed that they dominated the results. Hence, all commodity categories were combined and a single analysis procedure was adopted.

$$N=\frac{W}{\rho_{avg}\sum_{i=3,i\neq 4}^{i=13} p_i v_i}$$

$$N=\frac{1.3W}{\sum_{i=3,i\neq 4}^{i=13} p_i w_i (1-p_{ei})} \qquad (3.4)$$

N = total number of all types of trucks for a given commodity weight W;

W = weight of commodity shipped annually between any two O-D pairs, in kilograms;

ρ_{avg} = average density of freight shipped = 202.68 kg/m^3;

p_i = average percentage of truck type i;

v_i = average volume of truck type i in m^3;

w_i = average weight of nonempty trucks of type i,in kilograms;

p_{ei} = average percentage of empty vehicles of type i.

Theoretical basis for the equation for calculating total number of trucks are as follows,

a. Empty trucks will bring down average density of goods shipped (ρ_{avg} = 202.68 kg/m^3 or 12.5 lb/ft^3).
b. Average weight of trucks ranges from 25 percent to 35 percent of the commodity weight they carry (hence total weight of truck in the equation is 1.3 times commodity weight).
c. Trucks of Type 4 (i = 4) are buses and are not considered.

This conversion incorporates the effects of various truck sizes and dead haul (trucks returning empty after delivery). By using a low-density value in Equation 3, a deadhead (dead haul) component gets automatically added to each direction of movement into and from the state.

3. "Intermodal Freight Transportation Planning using Commodity Flow Data" by Zhang et al. (2003)

This study presents a methodology to conduct statewide freight transportation planning by utilizing public domain data, primarily the Commodity Flow Survey database in the State of

Mississippi. In this study, the composition of vehicle types used to transport different commodities are determined based on the VIUS database. The CFS database, together with other related databases such as VIUS and Cargo Density Database (CDD), was used in the study to describe freight flows coming into, going out, within and through the state of Mississippi.

In the Mississippi study, VIUS data was used to determine the vehicle capacity by truck type as well as vehicle distribution by commodity group. This information is helpful when converting commodity flow to truck trips. The 1997 VIUS data was also used to estimate yearly truck usage, which was used to convert the annual truck trips to Average Daily Truck Traffic (ADTT) used in the study. Cargo densities were obtained from a book distributed by the U.S. Department of Transportation titled “A Shipper’s Guide to Stowage of Cargo in Marine Containers”. Density and average load of different commodity groups was estimated and annual truck trips were obtained using average loads. Expansion factors were computed using empty and unloaded vehicles from the VIUS database and the annual trips were adjusted to take into account the presence of empty vehicles.

The procedures of the conversions are:
1. The number of trucks for transporting a specific commodity is determined by dividing assigned commodity tonnage by average load for the specific commodity.
2. Based on the truck distribution, the number of trucks by truck type is determined for each commodity group.
3. Total number of truck flows is determined by expanding the commodities to accommodate the excluded commodities during the analysis.

The formulas used for the conversion are:

$$N_j = \frac{W_j}{(\sum_i^n w_{ij})/n} \quad (3.5)$$

where,
Nj = annual total number of all vehicles transporting commodity j
Wj = annual weight of commodity j in tons
Wij = average weight of truck type i for transporting commodity j
n = number of truck types studied

$$N_{ij} = N_j P_{ij} X_i \quad (3.6)$$

where,
N_{ij} = annual total number of all vehicles transporting commodity j using truck type i
N_j = annual total number of all vehicles transporting commodity j
P_{ij} = percentage of truck type i for transporting commodity type j
X_i = vehicle expansion factor for empty truck type i

and these factors were obtained using commodity characteristics. The vehicle expansion factor captures the likelihood that a particular commodity is backhauled. These values range from 1 to 2, where, 1 represents that the truck is carry some commodity while returning and 2 represents that the truck is returning empty from the delivery station (such as chemical tankers).

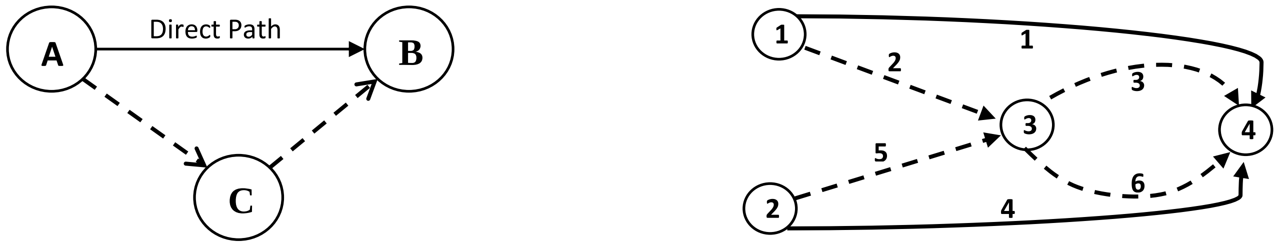
CHAPTER IV: FUSING FAF AND TRANSEARCH

4.1 ECONOMETRIC FRAMEWORK

This section describes the procedure developed for disaggregating FAF data and fusing with Transearch data. More specifically, we undertake disaggregation of FAF flows while augmenting with production consumption-based TS flows. To this end, we formulate and estimate a joint econometric model framework grounded in the maximum likelihood approach to estimate county level commodity flows. The framework has two separate modules to ensure matching estimated county level flows with commodity flows in FAF and TS at the appropriate spatial resolution. A third module generates a behavioral connection between FAF and TS. In our algorithm, we connect the flows between TS and FAF by generating potential paths between the origin and destination of interest for TS flows. Note that the inherent differences in the data cannot be completely reconciled. Hence, the framework focuses on building a fused database that maximizes the match with the commodity flows in the two databases. The consideration of behavioral trends in the model framework can assist us in parameterizing TS flow relationships thus allowing us to circumvent TS for the future (if needed). The proposed algorithm is implemented for the commodity flow information from 2012 FAF data for five FAF zones and 2011 TS databases. Prior to discussing the algorithm details, the notations and terminology used in the algorithm are presented.

4.1.1 Network Representation

The study defines nodes, paths, and links in the usual network theoretic approach. Nodes represent county centroids. These represent either origin, destination, or intermediate points. A direct connection between any two nodes is defined as a link. Paths represent a series of links that connect an origin and destination. To elaborate on the terminology, a simple representation is provided in the Figure 4-42. In the Figure 4-42(a), from origin county ‘A’, freight flow can be transferred to destination county ‘B’ in a direct path (i.e., no intermediate nodes) indicated by a solid line. The flow could also move along an indirect path. In our study, given that the model is a statewide model, we assume that one intermediate node is adequate for considering all possible paths between OD pairs to ensure computational tractability of the algorithm. The path with one intermediate node is referred to as a one-hop path. In the Figure 4-42(a), a one-hop path from county ‘A’ to county ‘B’ with an intermediate stop at county ‘C’ is shown with the dashed line. In the Figure 4-42(b), origin node ‘1’ and destination node ‘4’ have the following possible paths on the network. (i) ‘1’ - ‘4’ direct (link ‘1’ – say, path 1), (ii) ‘1’ - ‘3’ - ‘4’ in a one-hop path (link ‘2’ – link ‘3’ – say path 2, or link ‘2’ – link ‘6’ – say path 3). Therefore, three different paths are considered here from origin ‘1’ to destination ‘4’ that uses four different links (i.e., links ‘1’, ‘2’, ‘3’, and ‘6’).



(a) Paths between OD pairs, A, and B

(b) Links and nodes on a network

$A =$

	O – D 1 – 4			O – D 2 – 4		
Link\Path	1	2	3	1	2	3
1	1	0	0	0	0	0
2	0	1	1	0	0	0
3	0	1	0	0	1	0
4	0	0	0	1	0	0
5	0	0	0	0	1	1
6	0	0	1	0	0	1

(c) Links- path matrix for the simple network shown on (b)

Figure 4-42: Paths, Links, and Nodes of a Simple Transportation Network

To represent the relationship between paths and links in our system, a link path matrix is generated. For the network in Figure 4-42(a) and Figure 4-42(b), the link-path matrix (A) is shown in Figure 4-42(c). The rows represent the links and the columns represent the paths between the given OD pairs (see Figure 4-42 for details). Each element of the matrix is a binary indicator that represents if the link 'i' is included in the corresponding path. The variable of interest in the algorithm is the transportation network county to county flows generated by fusing TS data at the county level and FAF data at the FAF region level. Let V_{ij} represent the link flows between county pair i and j. The entire set of link flows are considered in a matrix form as V. Given the link-path matrix A, and path flow vector 'h', the link flow matrix, 'V' is given by the following equation (4.7).

$$V = A * h \tag{4.7}$$

4.1.2 Joint Model System

Let, y_{ij} represent the natural logarithm of the actual TS flow, and $\hat{y}_{ij}$ the estimated transearch flow. With these notations, the log-linear model takes the following form:

$$y_{ij} = \beta X_{ij} + \varepsilon_{ij} \tag{4.8}$$

where, X_{ij} are the independent variables for the specific OD pair $i - j$ and β represents the corresponding vector of parameters. Assuming the usual linear regression formulation, the likelihood for the estimation takes the following form:

$$LL_{TS} = \frac{\emptyset(\frac{\hat{y}_{ij} - y_{ij}}{\sigma_{TS}})}{\sigma_{TS}} \quad (4.9)$$

where, $\emptyset$ represent the probability density function of the standard normal distribution, and σ_{TS} is the standard deviation of ε_{ij}.

Given that TS flow is an input-output flow, the objective is to decompose these flows into actual network level link flows by considering the various paths between each OD pair. The path flows will allow us to determine the link flows. These flows are generated employing a fractional split approach. The actual path flow is unobserved; hence, a latent variable is considered, and the resulting link flows are matched with observed flows. The probability for each path is determined in a random utility approach as follows:

$$\cup_{ij}^{k} = \sum_{i,j \in O,D;\ k=1}^{K} \alpha_{ij}\, X_{ij}^{k} \quad (4.10)$$

$$P\left(X \middle| x_{ij}^{k}\right) = \frac{\exp(\cup_{ij}^{k})}{\sum_{l=1}^{K} \exp(\cup_{ij}^{l})} \quad (4.11)$$

Based on the path flow probability the actual flow assigned to each path is determined as follows:

$$h_{ij}^{k} = \hat{y}_{ij} * P(X|x_{ij}^{k}) \quad (4.12)$$

The path flow estimation leads to the estimation of the link flows V, using Equation (4.7). Given that these flows are available at the county level, we need to aggregate them to a coarser level to compare the flows to observed FAF flows. The aggregation is achieved as:

$$\hat{F}_{OD} = \sum\nolimits_{l \in O, q \in D} V_{lq} \quad (4.13)$$

Let F_{OD} be the observed FAF flows. The log-likelihood for comparing the predicted FAF flows with observed FAF flows in the linear regression form is given by the following mathematical expression, where, σ_{FAF} is the standard deviation of the estimate of FAF flows.

$$LL_{FAF} = \frac{\emptyset(\frac{\hat{F}_{OD} - F_{OD}}{\sigma_{FAF}})}{\sigma_{FAF}} \quad (4.14)$$

Given the aggregation proposed, the contribution of the FAF log-likelihood needs to be carefully computed. While origin and destination counties have their corresponding FAF zones, the intermediate zones also have a FAF zone. Therefore, the allocation is obtained for an OD pair by apportioning the error to all FAF zones involved over the entire path set for that OD pair. For this purpose:

$$LL_{FAF}{}^{k} = \frac{\sum_{r=1}^{n} LL_{FAF}{}^{n}}{n} \quad (4.15)$$

where, n is the number of link in the path k = $\begin{cases} 1, & for\ direct\ path \\ 2, & for\ one - hop\ paths \end{cases}$

Further, FAF zones can represent a large number of counties. To normalize for the number of counties, we employ the following equation:

$$LL_{FAF}{}^{OD,Norm} = \frac{\sum_{s=1}^{N} LL_{FAF}{}^{k}}{N_C} \quad (4.16)$$

where, N_c is the number of county pairs in the OD FAF region pairs. Finally, the joint log-likelihood is provided by the sum of log-likelihood for FAF and TS flow.

$$LL_{total\ i,j} = \sum_{i,\ j \in TAZ} (LL_{TS_{i,j}} + LL_{FAF}{}^{OD,Norm}{}_{i,j}) \quad (4.17)$$

The proposed algorithm is programmed in Gauss matrix programming language. The steps are shown in the flow chart (Figure 4-43).

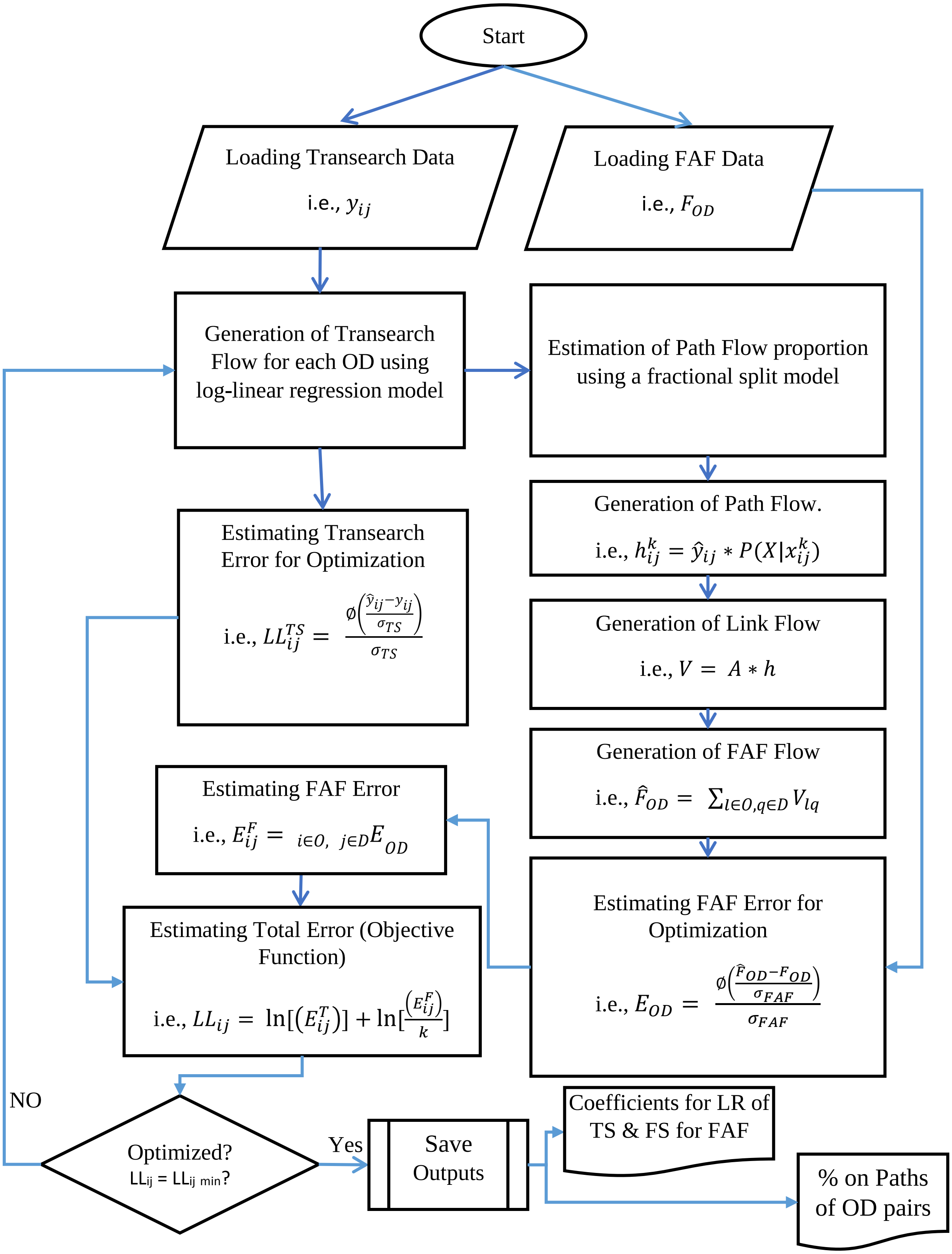


Figure 4-43: Flow Chart of Algorithm

4.2 MODEL APPLICATION

In this section, we briefly discuss the data preparation procedure and the results of the joint model.

4.2.1 Commodity Type Conversion

There were 43 commodity types in FAF while Transearch commodities were classified in to 562 commodity types. To generate a comparable commodity type classification, we consolidated the different commodity types into 13 comparable commodity types in both datasets following the classification scheme in the Florida Freight Demand Model. The commodity types are: agricultural products, minerals, coal, food, nondurable manufacturing, lumber, chemicals, paper, petroleum, other durable manufacturing, clay and stone, waste, miscellaneous freight (including warehousing). We show the conversion in the tables below (Table 4-62 to Table 4-64). Please note that miscellaneous freight and warehousing were grouped together since FAF does not contain any information on warehousing.

Table 4-62: FCC Commodity Types

FCC Code	FCC Name
1	Agricultural products
2	Minerals
3	Coal
4	Food
5	Nondurable manufacturing
6	Lumber
7	Chemicals
8	Paper
9	Petroleum products
10	Other durable manufacturing
11	Clay and stone
12	Waste
13	Miscellaneous freight and Warehousing
14	Unknown

Table 4-63: Conversion of SCTG Commodities to FCC Commodity Types

FCC Code	FCC name	SCTG Code	SCTG name
1	Agricultural products	1	Live animals and live fish
		2	Cereal grains
		3	Other agricultural products
2	Minerals	10	Monumental or building stone
		11	Natural sands
		12	Gravel and crushed stone
		13	Nonmetallic minerals n.e.c.*
		14	Metallic ores and concentrates
3	Coal	15	Coal
4	Food	4	Animal feed and products of animal origin, n.e.c.*
		5	Meat, fish, seafood, and their preparations
		6	Milled grain products and preparations, bakery products
		7	Other prepared foodstuffs and fats and oils
		8	Alcoholic beverages
5	Nondurable manufacturing	9	Tobacco products
		30	Textiles, leather, and articles of textiles or leather
		35	Electronic and other electrical equipment and components and office equipment
		39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs
6	Lumber	25	Logs and other wood in the rough
		26	Wood products
7	Chemicals	20	Basic chemicals
		21	Pharmaceutical products
		22	Fertilizers
		23	Chemical products and preparations, n.e.c.*
8	Paper	27	Pulp, newsprint, paper, and paperboard
		28	Paper or paperboard articles
		29	Printed products
9	Petroleum products	16	Crude petroleum
		17	Gasoline and aviation turbine fuel
		18	Fuel oils
		19	Coal and petroleum products, n.e.c.* (includes natural gas)
10	Other durable manufacturing	24	Plastics and rubber
		32	Base metal in primary or semi-finished form and in finished basic shapes
		33	Articles of base metal
		34	Machinery
		36	Motorized and other vehicles (including parts)
		37	Transportation equipment, n.e.c.*
		38	Precision instruments and apparatus
		40	Miscellaneous manufactured products
11	Clay and stone	31	Nonmetallic mineral products
12	Waste	41	Waste and scrap
13	Miscellaneous freight	43	Mixed freight
14	Unknown	99	Commodity unknown

Table 4-64: Conversion of STCC Commodities to FCC Commodity Types (without Subclasses)

FCC Code	FCC name	STCC Code	STCC name
1	Agricultural products	1	Farm products
		8	Forest products
		9	Fresh fish or marine products
2	Minerals	10	Metallic Ores
		14	Nonmetallic Minerals
3	Coal	11	Coal
4	Food	20	Food Or Kindred Products
5	Nondurable manufacturing	21	Tobacco Products
		22	Textile Mill Products
		23	Apparel Or Related Products
		25	Furniture Or Fixtures
		31	Leather Or Leather Products
		36	Electrical Equipment
6	Lumber	24	Lumber Or Wood Products
7	Chemicals	28	Chemicals Or Allied Products
		4812	Flammable liquids
		4814	Combustible Liquids
		4906-4966	Different types of chemicals
8	Paper	26	Pulp, paper Or Allied Products
		27	Printed Matter
9	Petroleum products	13	Crude Petrol. Or Natural Gas
		29	Petroleum Or Coal Products
		4904-4905	Flammable/non-flammable compressed gases
10	Other durable manufacturing	19	Ordnance Or Accessories
		30	Rubber Or Misc. Plastics
		33	Primary Metal Products
		34	Fabricated Metal Products
		35	Machinery
		37	Transportation Equipment
		38	Instruments, Photo Equipment, Optical Equip
		39	Misc. Manufacturing Products
		4901-4903	Ammunition & Class A/B/C Explosives
11	Clay and stone	32	Clay, concrete, glass Or Stone
12	Waste	40	Waste Or Scrap Materials
		4804-4809	Waste Nonflammable Compressed Gases and liquids
		4815-4875	Waste materials
		4813	Waste combustible liquid
13	Miscellaneous freight	41	Misc. Freight Shipments
		42	Shipping Containers
		43	Mail Or Contract Traffic
		44	Freight Forwarder Traffic
		45	Shipper Association Traffic
		46	Misc. Mixed Shipments
		47	Small Packaged Freight Shipments
14	Warehousing	50	Secondary Traffic
15	Unknown	60	Unclassified

4.2.2 Identifying the Origin and Destination Regions

In our first step of data preparation, we removed the FAF flows for regions not reported in TS. In the next step, we identified the origin-destination regions for the flows. We refer to the regions within Florida as domestic/internal regions and the regions outside of Florida as foreign/external regions. We maintained the spatial configuration of FAF to the reported FAF regions but reconfigured the reported TS regions to Florida counties. This provided us 5 internal regions (5 FAF regions) in the FAF data and 67 internal regions (67 counties) in the TS data (see Figure 4-44).

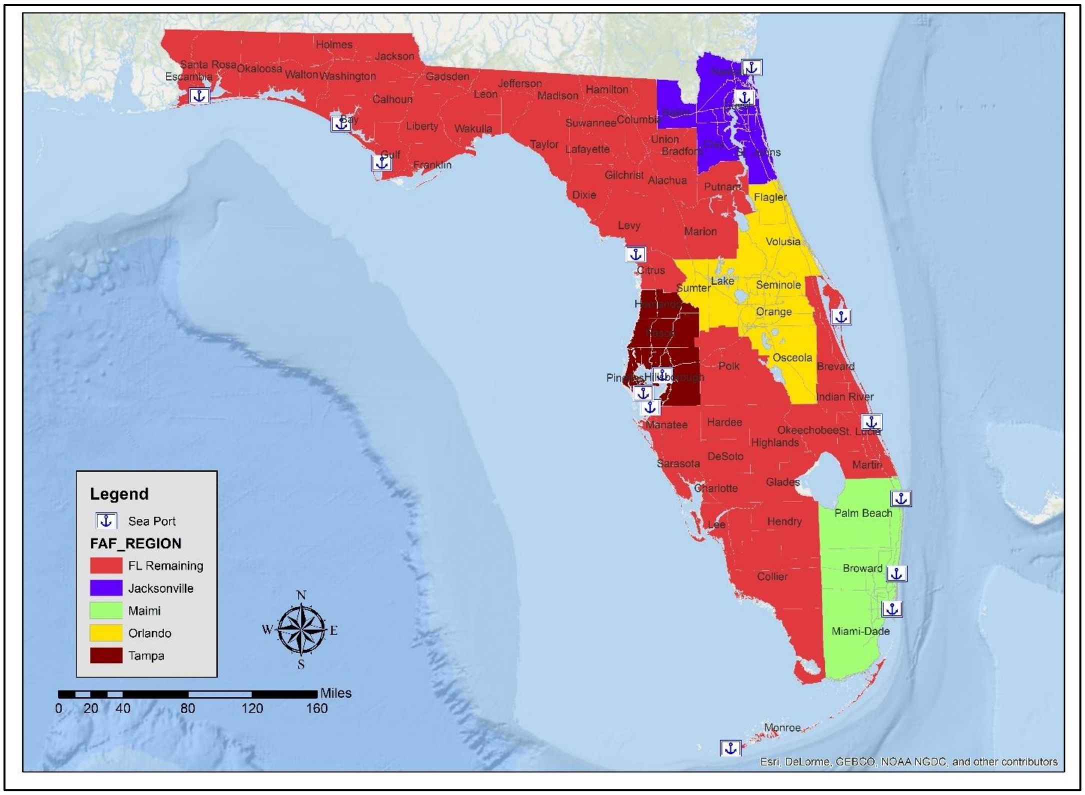


Figure 4-44: Relationship between FAF Regions and Florida Counties

For external flows, we created 12 external zones based on interstates and national highways entering Florida (we assumed that commodities entered/exited Florida from/to the outside regions through these major corridors). States were allocated to the zones based on their interstate/highway coverage. This was implemented using the ArcGIS platform. Most of the states on the east coast and southwest region are connected to Florida by a single major interstate/highway. However, no direct interstate/highway connection was found between Florida and the states in west coast and mid-west regions. In such cases, routes were identified that were connected to the interstates/highways entering Florida. For instance, Louisiana, Texas, Part of Mississippi are connected to Florida via US 90 and US 98. Table 4-65 represents the grouping of states into external zones and the main highways for entering/exiting Florida from/to these external zones while Figure 4-45 presents the spatial representation of the external zones. Please note that Alabama and Georgia surround Florida and hence, all major highways which enter

Florida must have to go through these two states. Therefore, we considered three highways from each of these two states as the connecting highways. In the end, we have 145 (5*5+5*12*2) potential origin-destination pairs for FAF flows while 6097 (67*67+67*12*2) potential O-D pairs for TS flows.

Table 4-65: External Zones and Major Highways

Zone	States Included	Main Highways for Entering/Exiting Florida
1	South Carolina, North Carolina, District of Columbia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, Maine, Virginia, Part of Georgia	I-95
2	Indiana, Wisconsin, Illinois, Part of Georgia, Part of Kentucky	US 41
3	Tennessee, Ohio, Michigan, Part of Alabama	I-75, US 231
4	West Virginia, Part of Georgia	US 19, US 319
5	Louisiana, Texas, Part of Mississippi	US 90, US 98
6	California, New Mexico, Arizona, Part of Alabama, Part of Mississippi	I-10, US 331
7	Kansas, Colorado, Utah, Missouri, Part of Kentucky	I-75 N > I-24 W > I-57 N > I-64 W> I-70 W, US 27
8	Arkansas, Oklahoma, Nevada	I-75 N > I-20 W > 1-22 > 1-40 W > US 93
9	Nebraska, Wyoming, Oregon, Idaho	I-75 N > I-24 W > I-57 N > I-64 W > I-84
10	South Dakota, Montana, Washington	I-75 N > I-24 W > I-57 N > I-64 W > I-90 W
11	Iowa, Minnesota, North Dakota	I-75 N > I-24 W > I-57 N > I-64 W > I-70 W
12	Foreign External Regions	Foreign (US, Canada, and Rest of Americas)

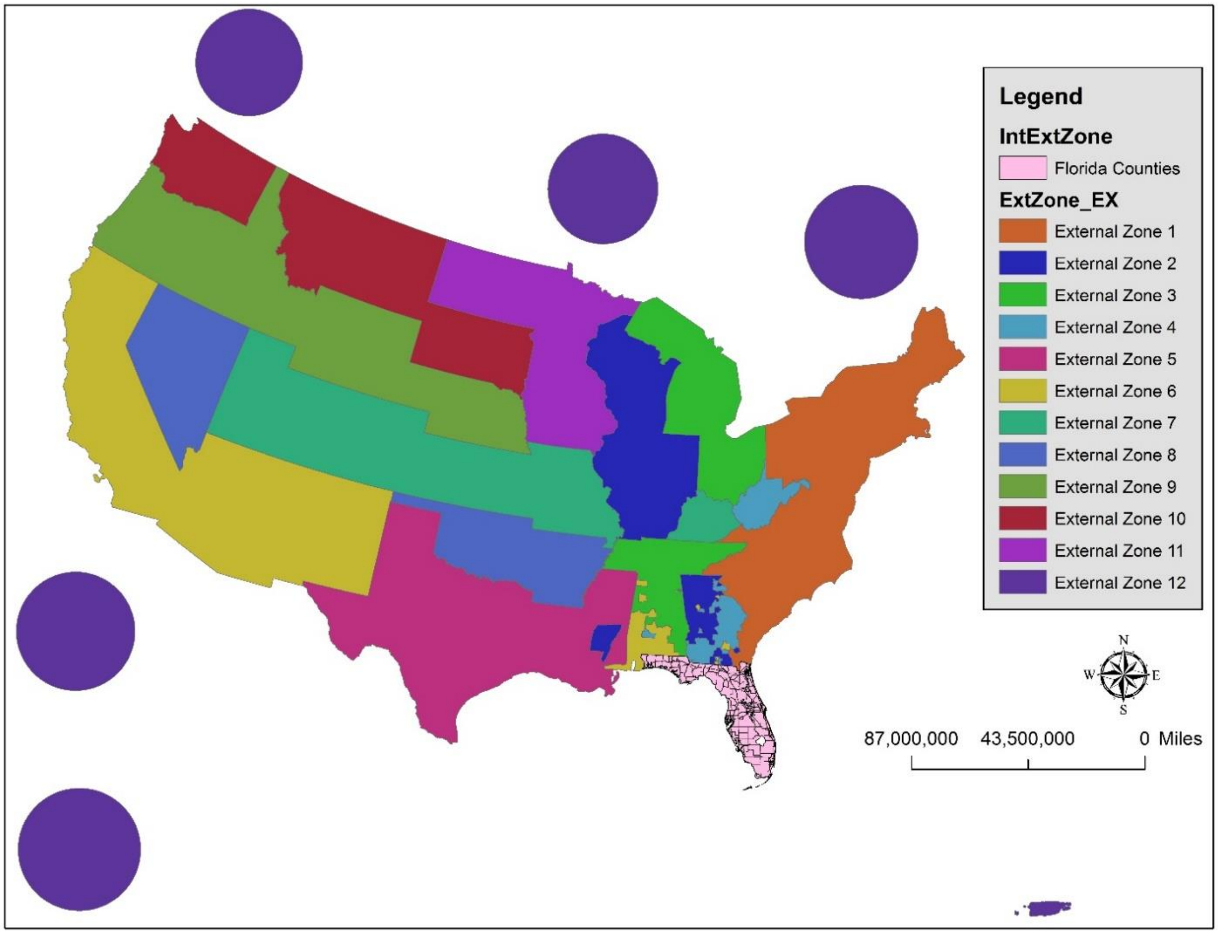


Figure 4-45: External (12) and Internal (67) Zones

4.2.3 Aggregation of Flows per Commodity

Using the ArcGIS platform, the external zone file was intersected with the FAF region shape file to obtain the one-to-one relationship between the FAF regions outside of Florida and the defined external zones. Using the relationship, for each FCC commodity type, the flows (tonnages) occurring between the potential O-D pairs are aggregated. In similar fashion, TS regions shapefile was intersected with the external zone shapefile and flows between the potential O-D pairs were aggregated, per FCC commodity type.

4.2.4 Generation of Independent Variables

We compiled several exogenous variables for the fusion model. These are: (1) origin-destination indicator variables including Origin (or destination) is in Orlando, Tampa, Jacksonville, Miami, Remainder of Florida region, (2) socio-demographic and socio-economic indicators including population and employment, (3) transportation infrastructure indicators including road and railway line length, number of ports, airports, and intermodal facilities, and (4) several interactions of these variables. Of these variables, population data was collected from the U.S. Census Bureau (https://www.census.gov/popclock/) while employment counts were compiled from https://factfinder.census.gov/, both at the county level. Transportation related variables were generated using the ArcGIS platform from intersecting the facility shapefiles collected from Florida Geographic Data Library (FGDL) with that of the county shapefile. Post-processing of the intersected files gave us the length of roadways and railways as well as counts of seaports, airports, and intermodal facilities at the county level. Please note that all of these variables were compiled for the years 2010-2015 and 2011 data was used for base year estimation. Finally, for the fractional split model, we needed to generate all path choice set for every OD pair. For this purpose, we considered 1 direct path and 66 one-hop paths (that pass through another county). The paths were generated for all OD pairs with non-zero flow. The overall path matrix was quite large with number of elements ranging from 6700 to 270000 across various commodities. For the paths created, path distances between origin and destination counties were generated as a sum of the link distances. A link distance for county pairs was determined using the shortest path procedure of ArcGIS's network OD cost tool. The highway route for the local and highways provided by the Florida Department of Transportation (FDOT) was used for this purpose.

Afterwards, projection factors for each of these variables were computed based on the 6-year trend. In order to extrapolate the population for 2020-2040 per county, total population data for 2010-2015 we collected from the U.S. Census Bureau (see Table 4-65). Then a factor was obtained by dividing total population of each year from 2011-2015 by the total population of 2010. We can see a 4% increase in population from 2010 to 2015. Therefore, a growth factor of 1.04 was multiplied with the population of each county to project for future (we made a simplistic assumption that a growth rate of 4% is followed at every 5-year interval). We assumed a growth rate of 6.9% for employment and 2.7% increase in roadway coverage. For fixed facilities such as seaports, airports, and intermodal facilities, we assumed that no change in their counts occurred for the future years. Table 4-66 shows the factors used to get the future year population.

Table 4-66: Total Population and Factor for Years 2010 to 2015

Year	Total Population on April 1st	Factor
2010	308,745,538	1.00
2011	311,095,656	1.01
2012	313,435,513	1.01
2013	315,664,417	1.02
2014	317,980,060	1.03
2015	320,335,611	1.04

For the external zones, we only considered population count and roadway length. We limited ourselves to these two variables only to reduce the data compilation burden. For external zones within the U.S. a growth factor of 1.04 was used. The population data for Canada was obtained from http://www5.statcan.gc.ca/cansim/a47 and for Mexico the data was obtained from http://countrymeters.info/en/Mexico. For these two regions, a similar growth factor of 1.04 was assumed. The National Highway Planning Network shape file was intersected with the external zone to get the total roadway length for 2010 for the external zones within Florida. Assuming that the total roadway length increased by 1.5% each year, the total roadway length was projected for each year from 2020-2040.

4.2.5 Results from the Algorithm

The proposed algorithm is implemented separately for each commodity type. We discuss the results for each commodity separately. The estimated coefficients of the models are presented in the Table 4-67. The TS module corresponds to the overall county to county tonnage flow while the FAF module provides the fractional model estimates.

4.2.5.1 Commodity Type: Agricultural Products

TS Module

The number of intermodal facilities in the origin and destination county are negatively associated with flows. On the other hand, the number of warehouses in the origin and destination counties, population at origin and destination county, and number of ports at destination county are associated positively with flows. In terms of origin and destination indicator variables, external zone as origin and external zone as destination are likely to have higher flow of agricultural products relative to other locations.

FAF Module

The path distances for both internal and external zones were negative as expected; indicating that paths with longer distances are less likely to be chosen for shipping freight. The result clearly indicates a larger flow allocation to direct paths while one-hop paths with very large excess distance receiving smaller share of flows.

4.2.5.2 Commodity Type: Minerals

TS Module

For Minerals, we found that the population at origin and destination county, number of ports in origin county have a positive effect on mineral freight flows. No origin or destination indicator variables were found significant for mineral.

FAF Module

Similar to the model for agricultural products, we found negative relationship between the path distances and the path flow proportions in the model for minerals as well.

4.2.5.3 Commodity Type: Coal

TS Module

For Coal, the number of warehouse at destination county and Tampa origin indicator has positive influence on county level flows.

FAF Module

Similar to the other models, the relationship between the path distances and the path flow proportions are found negative.

4.2.5.4 Commodity Type: Food

TS Module

For Food commodity, employment and road length at origin is negatively associated with freight flows. Population at origin, number of warehouses at origin, employment at destination, population at destination have positive effect on flow movement.

FAF Module

The coefficient for path distances are found negative that indicate direct path has higher proportion of the flow.

4.2.5.5 Commodity Type: Nondurable Manufacturing

TS Module

For Nondurable Manufacturing, number of warehouses at origin and destination, a population of origin at external zone, are likely to increase the flows. As indicator, external origin has positive effect on the flows.

FAF Module

Similar to the coefficient in other model, path distances coefficients are negative. Hence, the one-hop paths are less likely to carry the flows compared to the direct paths.

4.2.5.6 Commodity Type: Lumber

TS Module

Destination employment, Origin and destination population for external zone, interaction between employments at origin and destination, all these factors influenced the flow in positive way. However, interaction variable between origin port and destination employment has a negative influence on the flows.

FAF Module

Path distances and flow proportion on the paths are found to have a negative relationship.

4.2.5.7 Commodity Type: Chemicals

TS Module

For chemicals, the number of intermodal facilities, population at origin and destination for Florida counties and population at destination zone outside of Florida, has a positive impact on the flows. On the other hand, number of ports at origin, and interaction between number of warehouse and employment at destination are associated with the lesser flows. Both origin and destination at external zones are more likely to have more flows.

FAF Module

Like all other commodities, coefficient for path distances are found to have a negative for model for chemicals.

4.2.5.8 Commodity Type: Paper

TS Module

Model for Paper indicates the higher flows are associated with the higher destination population, number of intermodal facilities at origin or destination, ports at destination, and origin ports interaction with destination employment. However, length of roadway network at destination, interaction with destination employment and destination warehouse are likely to be associated with the lesser flows. For paper, it is found that association with external zones as an origin or destination are likely to have more flows.

FAF Module

For paper, the coefficient for path distances are found to have a negative.

4.2.5.9 Commodity Type: Petroleum

TS Module

Petroleum commodity flows are increased with higher warehouse at origin, square of destination population. Besides, the roadway length at origin, destination employment is negatively influencing the flows for this commodity.

FAF Module

Higher path distance paths are less likely to carry higher proportion of the flows between the OD pairs for the commodity. This is consistent with the other models.

4.2.5.10 Commodity Type: Other Durable Manufacturing

TS Module

Number of intermodal facilities at origin and number of warehouses at destination are negatively associated with the flows, for other durable manufacturing. Road network length at origin and interaction of employment at destination zone outside of Florida with number of warehouse at origin county have positive impact on other durable manufacturing flows.

FAF Module

The other durable manufacturing has a consistent outcome of the FAF module part of the model with all other commodity. The coefficient for path distance are also negative for this commodity.

4.2.5.11 Commodity Type: Clay and Stone

TS Module

Model for clay and stone, shows that, origin population and destination employment have a negative direct effect. On the other hand, the interaction variables between employment and destination warehouse, employment interaction between origin and destination and direct effect of origin employment are found positive. Overall, the net effect of employment or population was assessed as positively effecting the flows for this commodity.

FAF Module

For clay and stone, the path distance coefficient is negative. This shows the attraction of direct paths more than that of one hop paths.

4.2.5.12 Commodity Type: Waste

TS Module

For waste, the model indicates that road length at origin, number of intermodal facilities at origin, and population count at destination have positive influence on flows. However, origin or destination in the external zones are negatively associated with the flows between the OD pairs.

FAF Module

Like all other commodities, this also estimates the path distance coefficient as negative.

4.2.5.13 Commodity Type: Miscellaneous Freight & Warehousing

TS Module

This commodity flow increases with higher population at origin, and interaction of origin employment with destination warehouse. Employment square at origin, and interaction between destination employment and origin warehouse, origin employment and destination ports have a negative effect on the flows. Model also indicates that Tampa as origin and Jacksonville as destination are less likely to carry higher flows.

FAF Module

Miscellaneous freight and ware house commodity model also shows negative effect of path distance on the flows between the OD pairs.

Table 4-67: Joint Model Estimates

Variable	FCC1	FCC2	FCC3	FCC4	FCC5	FCC6	FCC7	FCC8	FCC9	FCC10	FCC11	FCC12	FCC15
	Agricultural Products	**Minerals**	**Coal**	**Food**	**Nondurable Manufacturing**	**Lumber**	**Chemicals**	**Paper**	**Petroleum**	**Other Durable Manufacturing**	**Clay and Stone**	**Waste**	**Miscellaneous Freight & Ware House**
Constant	3.043	-0.179	0.206	0.045	3.066	0.015	2.538	2.392	-0.056	0.027	0.047	0.019	0.044
Employment at Origin County	-	-	-	-0.056	-	-	-6.984	-	-	-	-	-	-
Road and Rail network length at Origin County	-	-	-	-0.130	-	-	-	-	-0.246	-	-	0.0035	-
Number of Intermodal Facilities at Origin County	-0.300	-0.318	-	-	-	-	0.298	0.410	-	-0.033	-	0.0250	-
Road network length at Origin Zone outside of Florida	-	-	-	-	-	-	-	0.803	-	0.035	-	-	-
Population at Origin Zone outside of Florida	-	-	-	-	1.414	0.058	-	-	-	-	-	-	0.228
Population at Origin County	1.732	1.024	-	0.210	-	-	15.403	-	-	-	-	-	-
Number of Ports at Origin County	-	0.583	-	-	-	-	-0.543	-	-	-	-	-	-
Number of Warehouse at Origin County	0.780	-	-	0.294	2.637	-	-	-	1.091	-	-	-	-
Employment at Origin County Square	-	-	-	-	-	-	-	-	-	-	0.377	-	-0.401
Population at Origin County square	-	-	-	-	-	-	-	-	-	-	-0.484	-	0.328
Employment at Origin County * Employment at Destination County	-	-	-	-	-	0.037	-	-	-	-	2.922	-	0.601
Employment at Origin County * Number of Warehouse at Destination County	-	-	-	-	-	-	-	-	-	-	-4.879	-	0.340
Population at Origin Zone outside of Florida * Number of Ports at Destination County	-	-	-	-	-	-	-	-	-	-	-	-	-2.875

Table 4-68 (Continued): Joint Model Estimates

Variable	FCC1 Agricultural Products	FCC2 Minerals	FCC3 Coal	FCC4 Food	FCC5 Nondurable Manufacturing	FCC6 Lumber	FCC7 Chemicals	FCC8 Paper	FCC9 Petroleum	FCC10 Other Durable Manufacturing	FCC11 Clay and Stone	FCC12 Waste	FCC15 Miscellaneous Freight & Ware House
Employment at Destination County	-	-	-	0.383	-	0.100	-	-	-	-	-	-	-
Employment at Destination County Square	-	-	-	-	-	-	-	-	-34.062	-	-2.462	-	-
Population at Destination Zone outside of Florida	-	-	-	0.128	-	0.041	1.545	-	-	-	-	-	-
Number of Intermodal Facilities at Destination County	-0.158	-	-	-	-	-	0.262	0.204	-	-	-	-	-
Population at Destination County square	-	-	-	-	-	-	-	-	3.466	-	-	-	-
Number of Ports at Destination County	0.294	-	-	-	-	-	-	0.103	-	-	-	-	-
Road and Rail network length at Destination County	-	-	-	-	-	-	-	-0.422	-	-	-	-	-
Employment at Destination County * Number of Warehouse at Destination County	-	-	-	-	-	-	-6.066	-4.039	-	-	0.549	-	-
Employment at Destination County * Number of Ports at Origin County	-	-	-	-	-	-0.050	-	-	-	-	-	-	-
Employment at Destination Zone outside of Florida * Number of Warehouse at Origin County	-	-	-	-	-	-	-	-	-	3.716	-	-	-0.656
Population at Destination Zone outside of Florida * Number of Ports at Origin County	-	-	-	-	-	-	-	0.329	-	-	-	-	0.352

Table 4-69 (Continued): Joint Model Estimates

Variable	FCC1	FCC2	FCC3	FCC4	FCC5	FCC6	FCC7	FCC8	FCC9	FCC10	FCC11	FCC12	FCC15
	Agricultural Products	Minerals	Coal	Food	Nondurable Manufacturing	Lumber	Chemicals	Paper	Petroleum	Other Durable Manufacturing	Clay and Stone	Waste	Miscellaneous Freight & Ware House
Population at Destination County	0.962	1.880	-	-	-	-	3.231	2.797	-	-	-	0.136	-
Number of Warehouse at Destination County	0.899	-	1.348	-	1.849	-	-	-	-	-0.164	-	-	-
Destination External Zone	3.074	-	-	-	-	-	-	-	-	-	-	-0.017	-
Origin External Zone	1.973	-	-	-	1.290	-	-	-	-	-	-	-0.028	-
Destination Tampa	-	-	4.615	-	-	-	-	-	-	-	-	-	-
Std. Err. (TS)	1.761	4.217	10.479	0.483	2.416	0.129	2.165	2.090	3.069	0.334	0.404	0.271	0.751
Path Distance (External Zones, KM)	-0.287	-0.291	-0.099	-0.291	-0.048	-0.004	-0.220	-0.048	-0.052	-0.364	-0.087	-0.290	-0.183
Path Distance (Internal Zones, KM)	-0.031	-0.058	-0.350	-0.047	-0.292	-0.040	-0.293	-0.291	-0.286	-0.110	-0.014	-0.049	-0.003
Std. Err. (FAF)	3.652	38.751	12.407	9.419	1.739	4.356	1.708	1.801	27.616	2.988	7.180	13.169	5.080

4.2.6 Prediction for Future Years (2015-2040)

This section describes, in detail, the procedure for generating outputs for future years (2015, 2020, 2025, 2030, 2035 and 2040) using the fusion algorithm developed. In addition to the base year data for 2011, TS database also provided projection till 2040 at a five-year interval starting from 2015. Based on the non-zero future tonnages, we identified the OD pairs for each of the projection years as before. Next, we appended the projected explanatory variables to this dataset. In total, we had six waves of TS data for each commodity for prediction. We used the coefficient values of the converged model for base year to do the predictions for the future years. Please see Table 4-67 for the final model estimates. Next, the algorithm was run using the future year data and the outputs for both TS and FAF were obtained. We used the following equation to get the TS outputs: $exp^{\left(\beta x+\sigma^2/_2\right)} - 1$. In the second stage, we obtained the path probabilities from the fractional split part of the joint model system and multiplied it with the predicted TS flows to get the path flows. A customized link-path matrix (A) was extracted as per the OD pairs. Finally, the link flows were obtained from multiplying the path flows with the customized link-path matrix. The procedure was repeated across all commodity types.

4.2.7 Truck Mode Share

The mode share of tonnages was calculated for each of the origin-destination county pairs based on observed mode share values from FAF regional data. After obtaining the flows from the joint model, we multiplied the mode shares with the flows to obtain the truck tonnages. Specifically, the FAF mode shares (%) at a region level were used to expand the mode share to the entire county-to-county pair following the criterion below:

- If origin county and destination county are in same FAF region – the FAF region % was used
- If origin county and destination county are from different FAF regions – average of the two FAF regions as the mode share % was used

Afterwards, based on the payload factors we obtained the truck flows (number of trucks) for each commodity. We would like to note that for calculating the truck flow, we have used the average payload factors (see Table 4-67).

Table 4-70 : Summary of Truck Flows per Commodity Type

FCC Code	Commodity Type	Total No. of Trucks (millions)					
		2015	2020	2025	2030	2035	2040
1	Agricultural Product	1.53	1.60	1.71	1.85	2.05	2.31
2	Minerals	9.98	10.25	10.54	10.34	10.63	10.94
3	Coal	0.02	0.02	0.02	0.04	0.04	0.05
4	Food	2.15	2.24	2.33	2.44	2.55	2.68
5	Nondurable Manufacturing	0.32	0.33	0.34	0.35	0.37	0.39
6	Lumber	9.41	9.71	10.04	10.44	10.85	11.30
7	Chemicals	0.19	0.19	0.19	0.19	0.19	0.20
8	Paper	0.17	0.17	0.17	0.17	0.17	0.17
9	Petroleum Products	1.11	1.15	1.21	1.27	1.36	1.42
10	Other Durable Manufacturing	0.01	0.01	0.01	0.01	0.01	0.01
11	Clay and Stone	2.92	3.09	3.26	3.42	3.57	3.72
12	Waste	1.25	1.28	1.31	1.33	1.36	1.40
13	Miscellaneous Freight	28.72	29.29	30.12	24.70	25.92	27.32

4.3 SCENARIO ANALYSIS USING DISAGGREGATED FLOWS AT COUNTY LEVEL

According to the U.S. Census Bureau, with a population growth rate of 1000 person per day and above the national average employment growth rate, Florida is undoubtedly one of the fastest growing states of the country. Freight industry is one of the industries that are most likely to be impacted by this huge population increase. As the demand for different commodities and services will grow, it will result in increased freight movements within the state. Recognizing that, our scenario analysis was directed towards understanding the change in county-to-county freight flows in the presence of increased population and employment.

For the scenario analysis, the change in population and employment are considered as follows:

- 15% increase in population
- 10% increase in employment

The datasets were created for the scenario for each of the thirteen commodities. However, we present the results only for FCC 1 (Agricultural Products) and FCC 8 (paper). Model specifications obtained from base case analysis are used for prediction of flows with the changed population and employment condition.

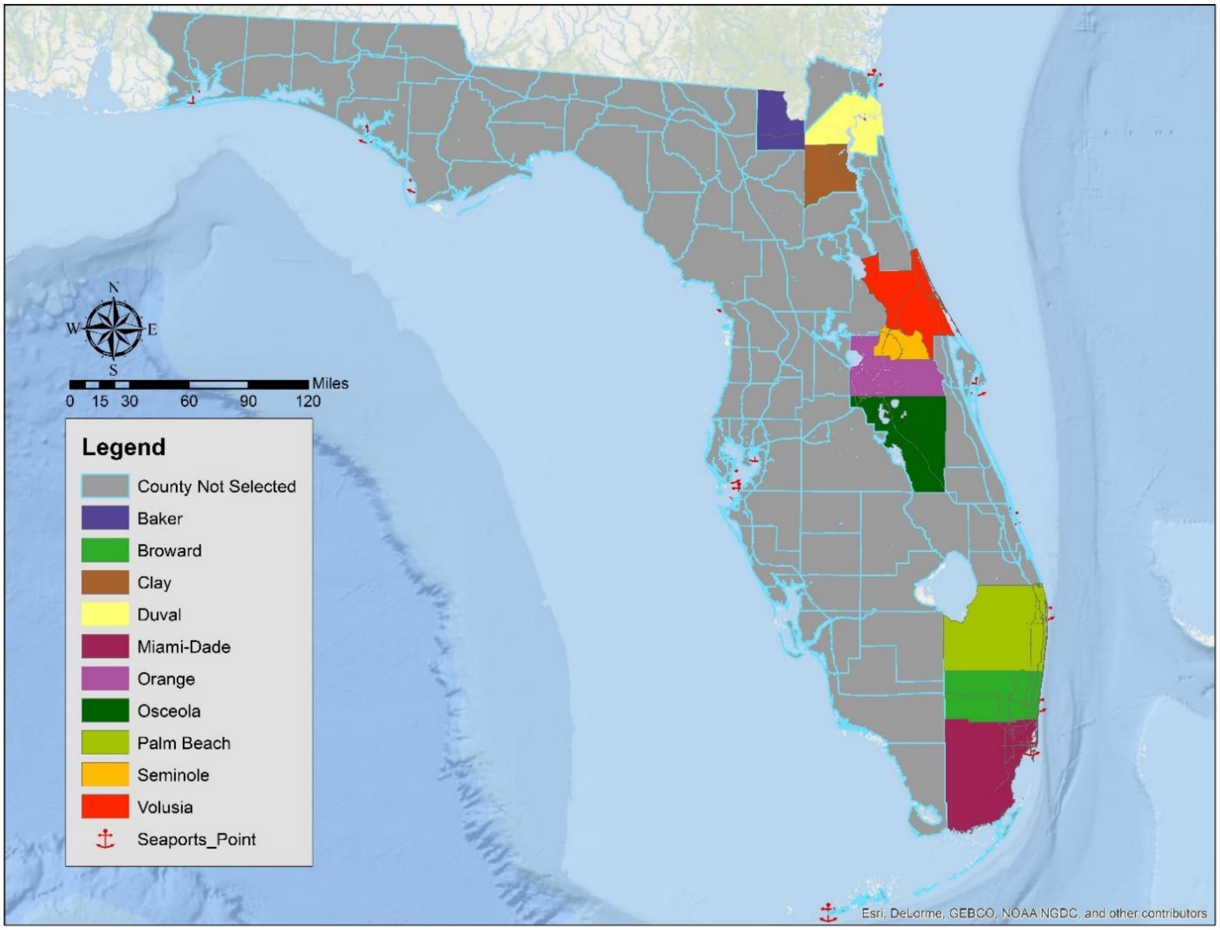


Figure 4-46: Counties Selected for Scenario Analysis

For conducting the scenario analysis, we selected ten counties in Miami (Miami-Dade, Broward, Palm Beach), Orlando (Orange, Osceola, Seminole, and Volusia), and Jacksonville (Duval, Baker, and Clay) regions. The selected counties are shown in the Figure 4-46. The counties are selected based on their location in expanding urban regions. Moreover, these counties generate or receive high share of freight flows compared to the other counties in the state.

4.3.1 Scenario Analysis Results

The results of the scenario analysis are presented in the following tables. Table 4-71 shows the results for FCC 1 while presents the results for FCC 8. In each cell of the tables, the values in the parenthesis are the predicted values.

In Table 4-71 Palm Beach, and Volusia are the two counties for which the incoming flows of agricultural products are found to be increasing by a significant amount due to increased population and employment. For other selected counties, the increase is in the range up to 30% percent. From

Table ***4-72***, it is found that, flows of paper products are increasing at a large rate for all counties selected.

For a further analysis, originating and destined link flows were investigated for the selected counties as shown in Table 4-73 and Table 4- 74 for FCC 1 and FCC 8, respectively. The tables show the change in link flows originating from the selected counties and as well as the flows destined to the counties. For FCC 1, with increase of population and employment, Orlando region has the highest rate of flow increase. In fact, based on our model results we observe that freight flows for FCC 1 increase by about 1765%. We also observe significant increases for Seminole county and Broward county. For FCC 8, for originating flows, the increase across the various counties is of similar order (~20%) with Osceola county as an exception (48%).

In terms of destined flows, Miami region is likely to receive a larger percentage of flows relative to other regions considered. To elaborate, the counties in Miami region experience a growth of the order of up to 5400% while other regions (Orlando and Jacksonville) experience an increase up to 1800%.

Finally, GIS maps of the link flows (base and predicted) for the selected ten counties are generated for further visualization of the changes in flows. Figure 4-47 and Figure 4-48 show the link flows originating from Miami-Dade County for FCC 1 and FCC 8, respectively. Please note that in the figures, only counties selected are shown as the destination. Other flows to other counties are shown with a thin and light-colored line. In Figure 4-47, the largest increase in incoming flows (from Miami-Dade) for agricultural products is observed for Palm Beach and Seminole counties. The largest increase in paper product flows is observed for Palm Beach and Osceola counties (see Figure 4-48).

Table 4-71: Scenario Analysis Results for the Selected Counties for FCC1

Org\Dest	Volusia	Orange	Broward	Palm Beach	Miami-Dade	Seminole	Duval	Baker	Clay	Osceola	Others
Volusia	0.15 (0.15)	0.66 (0.73)	0.01 (0.01)	0.02 (0.02)	0.01 (0.01)	2.04 (2.09)	3.02 (3.23)	0.45 (0.45)	0.90 (0.91)	0.76 (0.77)	60.60 (60.63)
Orange	5.32 (5.38)	0.12 (0.17)	0.06 (0.06)	0.08 (0.08)	0.06 (0.06)	9.92 (10.04)	4.80 (5.00)	0.58 (0.59)	1.13 (1.14)	2.86 (2.88)	181.48 (181.57)
Broward	8.40 (8.47)	19.65 (19.82)	0.01 (0.01)	8.56 (8.67)	3.44 (3.45)	19.85 (19.96)	11.25 (11.35)	0.67 (0.67)	1.60 (1.62)	108.87 (109.01)	747.36 (748.27)
Palm Beach	3.83 (3.87)	9.55 (9.66)	0.98 (0.98)	0.05 (0.06)	0.46 (0.46)	8.82 (8.88)	4.77 (4.84)	0.36 (0.36)	0.84 (0.85)	64.82 (64.89)	275.82 (276.17)
Miami-Dade	8.08 (8.15)	21.18 (21.33)	46.89 (47.05)	9.40 (9.49)	0.00 (0.00)	18.81 (18.92)	17.64 (17.71)	0.65 (0.66)	1.74 (1.77)	132.89 (133.04)	940.84 (942.02)
Seminole	3.55 (3.60)	1.20 (1.39)	0.01 (0.01)	0.03 (0.03)	0.01 (0.01)	0.14 (0.14)	2.32 (2.53)	0.48 (0.48)	0.86 (0.86)	0.95 (0.95)	84.95 (84.97)
Duval	1.47 (1.50)	0.24 (0.29)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	1.21 (1.24)	0.07 (0.09)	1.27 (1.27)	1.60 (1.60)	0.54 (0.55)	115.66 (115.67)
Baker	0.10 (0.10)	0.03 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.07 (0.08)	0.51 (0.68)	0.03 (0.03)	0.86 (0.86)	0.05 (0.05)	14.10 (14.11)
Clay	0.33 (0.34)	0.06 (0.07)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.21 (0.22)	1.10 (1.36)	1.16 (1.16)	0.04 (0.04)	0.14 (0.14)	24.86 (24.87)
Osceola	2.17 (2.21)	1.51 (1.69)	0.03 (0.04)	0.14 (0.18)	0.03 (0.03)	1.99 (2.04)	1.46 (1.63)	0.51 (0.51)	0.82 (0.82)	0.22 (0.23)	375.75 (375.78)
Others	38.54 (39.25)	24.12 (26.80)	1.63 (1.66)	1.86 (2.10)	2.91 (2.91)	40.45 (41.44)	68.88 (75.61)	31.48 (31.63)	44.68 (44.98)	70.08 (70.48)	6948.87 (6954.89)

Table 4-72: Scenario Analysis Results for the Selected Counties for FCC 8

Org\Dest	Volusia	Orange	Broward	Palm Beach	Miami-Dade	Seminole	Duval	Baker	Clay	Osceola	Others
Volusia	0.73 (0.89)	8.95 (12.52)	5.96 (10.06)	5.99 (9.50)	5.54 (10.37)	8.08 (10.09)	12.85 (14.02)	0.19 (0.20)	0.57 (0.63)	2.36 (3.37)	82.42 (86.44)
Orange	6.49 (7.53)	3.24 (4.64)	15.09 (25.54)	16.76 (26.60)	14.35 (26.81)	12.63 (14.59)	5.78 (6.69)	0.21 (0.22)	0.72 (0.80)	6.32 (9.07)	135.60 (145.31)
Broward	1.83 (2.06)	5.09 (6.19)	7.59 (12.75)	19.85 (30.52)	44.38 (82.62)	3.55 (3.87)	2.08 (2.33)	0.09 (0.09)	0.29 (0.33)	14.94 (15.36)	123.47 (125.79)
Palm Beach	1.88 (2.07)	5.73 (6.59)	17.01 (29.01)	7.01 (11.06)	11.59 (21.47)	4.07 (4.38)	2.26 (2.43)	0.07 (0.08)	0.26 (0.30)	29.20 (29.68)	116.35 (118.83)
Miami-Dade	3.24 (3.61)	9.16 (10.50)	59.20 (85.24)	19.33 (28.25)	32.40 (60.75)	6.94 (7.62)	4.93 (5.18)	0.16 (0.17)	0.67 (0.76)	35.53 (36.64)	299.22 (306.35)
Seminole	7.32 (8.67)	20.23 (27.74)	12.96 (21.88)	13.10 (20.76)	11.61 (21.72)	0.86 (1.02)	5.44 (6.51)	0.20 (0.21)	0.68 (0.75)	3.08 (4.42)	76.64 (82.86)
Duval	21.04 (27.49)	16.24 (23.43)	8.72 (14.88)	8.21 (13.15)	10.15 (18.89)	16.95 (22.84)	11.93 (15.48)	5.39 (5.64)	11.76 (13.67)	7.70 (11.92)	446.48 (486.79)
Baker	0.62 (0.84)	0.66 (0.98)	0.42 (0.72)	0.41 (0.65)	0.36 (0.68)	0.58 (0.82)	4.20 (5.47)	0.00 (0.00)	2.10 (2.44)	0.45 (0.71)	23.72 (27.67)
Clay	1.63 (2.11)	1.68 (2.44)	1.35 (2.30)	1.41 (2.25)	1.38 (2.59)	1.24 (1.66)	4.55 (5.73)	0.66 (0.68)	0.00 (0.00)	0.72 (1.08)	37.01 (40.78)
Osceola	1.97 (2.37)	4.30 (6.08)	65.20 (109.68)	89.82 (141.81)	73.65 (138.06)	1.42 (1.67)	2.24 (2.82)	0.13 (0.13)	0.35 (0.38)	0.00 (0.00)	110.78 (113.61)
Others	126.05 (158.17)	252.93 (362.12)	456.24 (769.31)	373.67 (590.64)	530.59 (986.05)	123.55 (159.73)	330.47 (416.36)	23.24 (24.90)	47.51 (51.98)	274.59 (428.41)	6743.31 (7554.87)

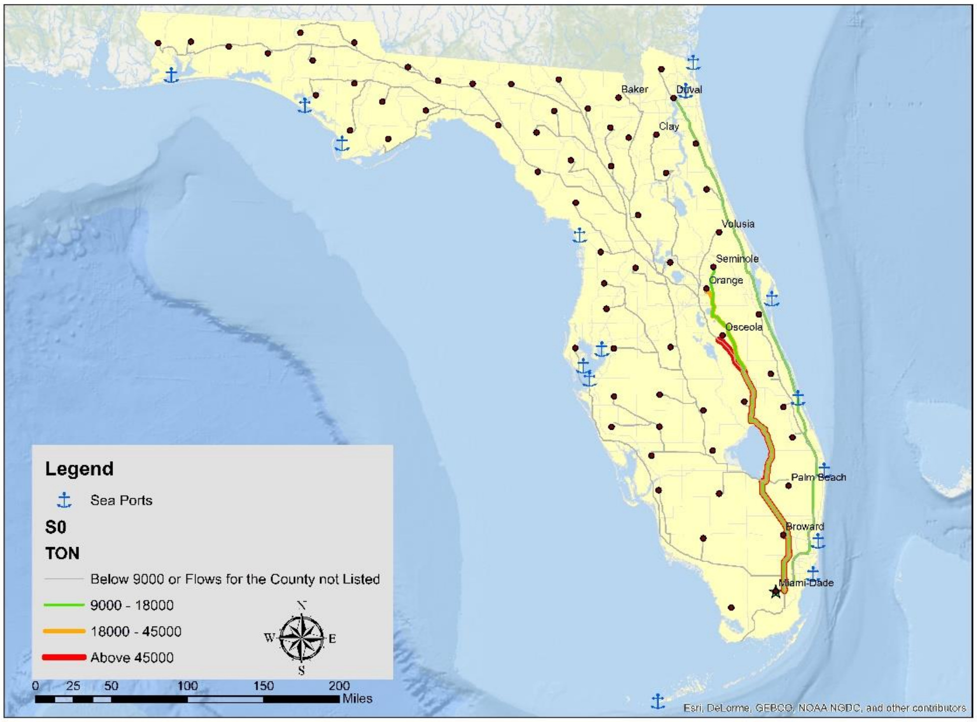
Table 4-73: Predictions of Originating and Destined Link Flows for the Scenarios for FCC 1

Region	County	Link Flow (in 100 Thousand)			
		Originating		Destined	
		Base Case	Scenario I (Change in %)	Base Case	Scenario I (Change in %)
Orlando	Volusia	0.69	0.69 (0.55%)	0.72	0.73 (1.53%)
	Orange	2.06	2.07 (0.27%)	0.78	0.82 (4.73%)
	Seminole	0.95	0.95 (0.54%)	0.50	1.05 (111.69%)
	Osceola	3.85	3.85 (0.13%)	0.20	3.83 (1805.47%)
Jacksonville	Duval	1.22	1.22 (0.13%)	0.07	1.24 (1697.10%)
	Baker	0.16	0.16 (1.16%)	0.38	1.04 (173.81%)
	Clay	0.28	0.28 (1.04%)	0.56	1.16 (108.65%)
Miami	Broward	9.30	9.31 (0.18%)	0.38	0.50 (32.45%)
	Palm Beach	3.70	3.71 (0.19%)	0.21	0.55 (167.48%)
	Miami-Dade	11.98	12.00 (0.17%)	0.07	3.82 (5439.13%)
Others		72.74	72.92 (0.25%)	97.70	97.79 (0.09%)
Total		**106.91**	**107.17 (0.24%)**	**101.56**	**112.52 (10.80%)**

Table 4- 74: Predictions of Originating and Destined Link Flows for the Scenarios for FCC 8

Region	County	Link Flow (in 100 Thousand)			
		Originating		Destined	
		Base Case	Scenario I (Change in %)	Base Case	Scenario I (Change in %)
Orlando	Volusia	1.34	1.58 (18.28%)	1.73	2.16 (24.88%)
	Orange	2.17	2.68 (23.3%)	3.28	4.63 (41.13%)
	Seminole	1.52	1.97 (29.2%)	1.80	10.81 (501.11%)
	Osceola	3.50	5.17 (47.67%)	3.75	8.75 (133.45%)
Jacksonville	Duval	5.65	6.54 (15.87%)	3.87	13.70 (254.28%)
	Baker	0.34	0.41 (22.3%)	0.30	2.28 (650.99%)
	Clay	0.52	0.62 (19.3%)	0.65	4.83 (644.22%)
Miami	Broward	2.23	2.82 (26.33%)	0.32	6.50 (1911.46%)
	Palm Beach	1.95	2.26 (15.59%)	4.83	5.56 (15.03%)
	Miami-Dade	4.71	5.45 (15.78%)	5.41	7.36 (36.12%)
Others		92.82	115.03 (23.92%)	81.95	90.89 (10.91%)
Total		**116.74**	**144.51 (23.79%)**	**107.89**	**157.48 (45.96%)**

(a) Link Flows for Selected Counties in Base Case Scenario for FCC 1



(b) Link Flows for Selected Counties in Scenario I for FCC 1

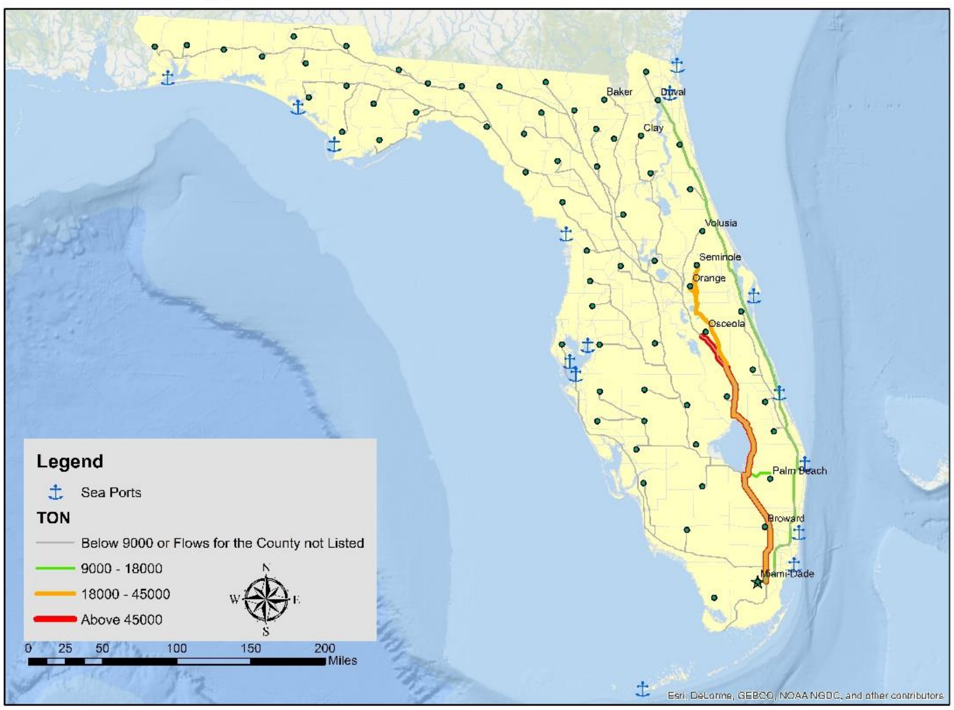


Figure 4-47: Link Flows Originating from Miami-Dade County for Base Case and for Scenario I for FCC 1

(a) Link Flows for Selected Counties in Base Case Scenario for FCC 8

(b) Link Flows for Selected Counties in Scenario I for FCC 8

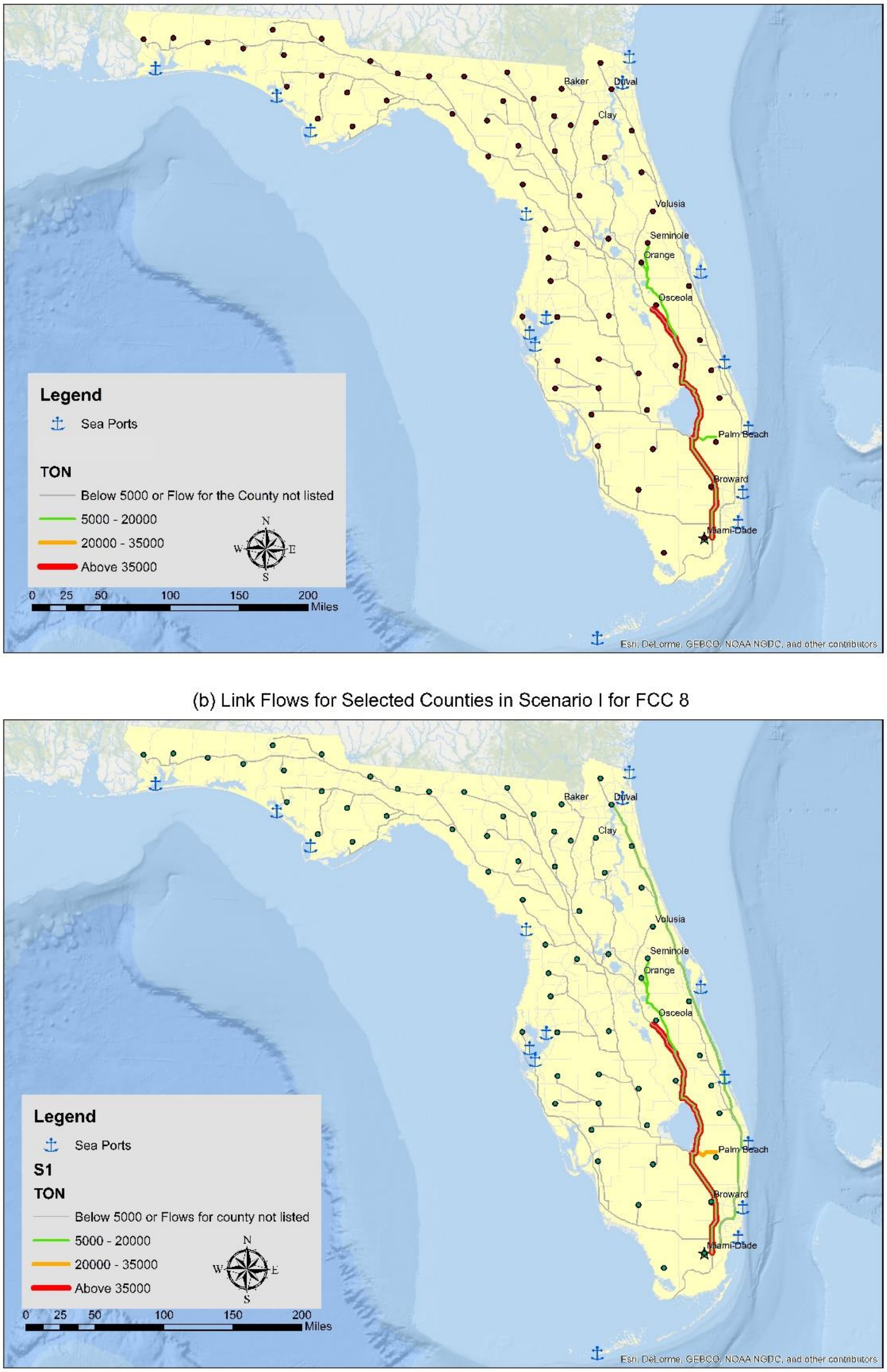


Figure 4-48: Link Flows Originating from Miami-Dade County for Base Case and for Scenario I for FCC 8

4.4 DISAGGREGATION AT STATEWIDE TRAFFIC ANALYSIS ZONE (SWTAZ) LEVEL

The estimated link flows are further disaggregated at a finer spatial resolution (SWTAZ level). This section describes the methodology and outcome of the disaggregation exercise.

At first, we obtained the spatial relationship between Floridian counties and the corresponding SWTAZs as well as the external zones and the corresponding Business Economic Areas (BEA). To carry out the disaggregation, first we generated the observed fractions for both incoming and outgoing flows from the Florida Transearch TAZ scenario file. For example, if a county is comprised of 3 SWTAZs with inbound flows of 30,40, and 30 tons (a total of 100 tons incoming) and outbound flows of 50, 20, 30 tons (a total of 100 tons outgoing), then the observed incoming fractions would be 0.3 (30/100), 0.4 (40/100), and 0.3 (30/100), respectively while the observed outgoing fractions would be 0.5 (50/100), 0.2 (20/100), and 0.3 (30/100). In other words, production end proportions split the flow originated from a certain county and allocate the flows to TAZs within the county whereas consumption end proportions split the incoming flow to the county to the TAZs within the county.

Using these observed fractions, we run two fractional split models – one for origin and one for destination for each commodity. Mathematically, let, $\boldsymbol{y_{qi}}$ be the proportion of originated/destined flow from a TAZ within a county; Where, q is the county of origin/destination, i is the TAZ within the county. Hence, mathematically, $\boldsymbol{0 \leq y_{qi} \leq 1}$, and $\boldsymbol{\sum_i y_{qi} = 1}$. If $\boldsymbol{X_{qi}}$ be the vector for the independent variables, the mathematical structure of the model would be as follows:

$$E(y_{qi}|X_{qi}) = \frac{e^{\beta X_{qi}}}{\sum_j e^{\beta X_{qj}}} \tag{4.18}$$

The probabilities obtained from these models help us disaggregate the fused county to county flows to finer spatial resolution. We considered two variables in the fractional split model specification. These are: population and employment counts (the data sources are mentioned before). All the variables are collected for the year of 2011. For future year we used a simple factor multiplication approach as described in the section 4.2.4.

Using future year population and employment we predicted the proportions for the year of 2015, 2020, 2025, 2030, 2035, and 2040.

Table 4-75: Fractional Split Model Estimates (for Origin Link Flows)

FCC	Population (in millions)		Employment for Florida County (in thousands)
	For Florida Counties	For External Zones	
Agricultural products	1029.23	1.90	0.94
Minerals	1013.54	0.71	1.10
Coal*	-	-	-
Food	901.41	2.42	1.55
Nondurable manufacturing	1339.44	2.31	1.98
Lumber	876.33	1.58	1.29
Chemicals	600.25	2.13	1.49
Paper	885.23	1.99	1.80
Petroleum products	521.29	2.49	2.26
Other durable manufacturing	853.99	2.77	1.55
Clay and stone	922.02	2.00	1.21
Waste	1029.23	1.90	0.94
Miscellaneous freight & warehousing	1029.23	1.90	0.94

** Flows for Coal are very limited, which does not allow model estimation with such a small data record.*

Table 4-76: Fractional Split Model Estimates (for Destination Link Flows)

FCC	Population (in millions)		Employment for Florida County (in thousands)
	For Florida Counties	For External Zones	
Agricultural products	985.77	2.72	1.69
Minerals	948.77	1.85	1.44
Coal*	-	-	-
Food	822.01	2.22	1.90
Nondurable manufacturing	809.45	-	-
Lumber	1021.77	1.59	1.56
Chemicals	802.83	2.68	1.94
Paper	871.80	1.58	2.01
Petroleum products	884.51	1.57	1.61
Other durable manufacturing	936.15	2.38	1.81
Clay and stone	972.09	1.94	1.59
Waste	985.77	2.72	1.69
Miscellaneous freight & warehousing	985.77	2.72	1.69

** Flows for Coal are very limited which does not allow model estimation with such a small data record.*

4.4.1 Consistency Check

After disaggregating the flows at the SWTAZ level, we did a consistency check using the observed Transearch data for 2011 (see Table 4-77).

Table 4-77: Comparison of Observed and Predicted Tonnage by FCC

Year	Observed/Predicted Flow	Tonnage (million tons)												
		FCC 1	FCC 2	FCC 3	FCC 4	FCC 5	FCC 6	FCC 7	FCC 8	FCC 9	FCC 10	FCC 11	FCC 12	FCC 13
2011	Observed TranSearch Flow for Model	33.30	90.73	19.52	39.31	7.02	15.55	25.90	11.24	51.66	23.31	35.30	11.88	78.67
	Observed TranSearch Flow by Truck Mode only	31.76	55.57	0.08	33.90	6.31	13.97	10.57	7.79	21.08	19.58	33.32	10.40	70.46
	Predicted Flow After Truck Flow Conversion	30.23	233.53	0.33	50.01	16.12	22.30	24.89	10.40	61.57	23.55	50.00	26.18	47.00
2015	Predicted Flow After Truck Flow Conversion	30.63	243.42	0.47	49.85	17.86	23.52	25.35	10.76	64.87	25.27	53.29	27.63	50.69
2020	Predicted Flow After Truck Flow Conversion	31.96	250.03	0.48	51.93	18.58	24.27	25.49	10.75	65.69	27.12	54.81	28.37	51.69
2025	Predicted Flow After Truck Flow Conversion	34.18	257.08	0.48	54.19	19.38	25.09	25.75	10.76	66.47	29.06	57.45	29.13	53.16
2030	Predicted Flow After Truck Flow Conversion	36.85	252.02	1.08	56.62	19.90	26.10	26.04	10.65	67.20	31.09	62.44	29.39	55.70
2035	Predicted Flow After Truck Flow Conversion	40.86	259.21	1.10	59.28	20.88	27.12	26.48	10.66	67.79	33.25	74.04	30.19	58.44
2040	Predicted Flow After Truck Flow Conversion	46.18	266.76	1.11	62.17	21.99	28.26	27.00	10.69	68.13	35.57	112.36	31.00	61.61

4.4.2 Disaggregation of FAF Export and Import Flow Other Than Canada and Mexico

Transearch reports flows to and from three foreign regions only: Canada, Mexico, and Rest of Americas (including Virgin Island and Puerto Rico). On the other hand, FAF reports flows to and from eight international regions including Canada, Mexico, Rest of Americas (including Virgin Island and Puerto Rico), Europe, Africa, South West and Central Asia, Eastern Asia, and South East Asia and Oceania. Thus, fusing these two datasets for foreign flows will provide incompatible results. Hence, we resorted to a separate disaggregation procedure similar to Viswanathan et al. (2008).

A log-linear regression model is developed for the imports and exports using FAF dataset. The compiled data has an origin or destination zone in the U.S., an intermediate zone (which is the port of entry or exit) and the external zone outside the U.S. Zonal attributes, namely population, employment and number of establishments are obtained from various data sources. Population and employment are pooled from the 2012 census data, whereas number of establishments in each zone is available for the year 2011 from county business patterns dataset provided by United States Census Bureau. Origin and destination level population, employment and number of establishments were mapped to the FAF origin destination pairs. For the imports and exports, one of the trip ends is an external zone, the attributes of the intermediate zone are used instead of the external zones. The log-linear regression model developed based on the FAF flows and their zonal attributes is presented in the Table 4-78.

Table 4-78: Log-linear Model for Disaggregation of Imports and Exports

Explanatory Variable	Estimates	
	Beta	t-stat
Constant	0.155	3.38
Total Employment at origin (*10^{-4})	0.001	5.37
Total Employment at destination (*10^{-4})	0.001	3.78
Number of establishments at origin interacting with FCC4 (*10^{-2})	0.003	6.16
Population of origin interacting with FCC4 (*10^{-5})	0.001	4.67
Population of origin interacting with FCC5 (*10^{-5})	0.001	4.85
Population of origin interacting with FCC7 (*10^{-5})	0.002	8.97
Population of destination interacting with FCC8 (*10^{-5})	0.001	5.79
Total Employment at origin interacting with FCC9 (*10^{-4})	0.002	1.52
Number of establishments at destination interacting with FCC9 (*10^{-2})	0.004	2.93
Population of origin interacting with FCC10 (*10^{-5})	0.002	7.50
Population of destination interacting with FCC10 (*10^{-5})	0.001	3.90
Employment at origin interacting with FCC12 (*10^{-4})	0.001	2.49
Number of establishments at destination interacting with FCC11 (*10^{-2})	0.001	2.71

In the log-linear regression, all the variables are entered as interaction variables with FCC along with the base variables. The explanatory variables with a *t*-stat greater than 1.0 are retained and all the others were dropped.

4.4.2.1 Prediction

The model presented above is used to predict the disaggregated flows between SWTAZ zones carrying import and export goods. All the SWTAZ zones in the FAF zones with import and export interaction are considered as the trip ends in disaggregation. The predictions from the model are estimated using the expression

$$Predicted\ flow = exp(\beta X + \frac{\sigma^2}{2}) \qquad (4.19)$$

Where β are the estimated coefficients for the explanatory variables X. σ is the standard error of the regression model. The predicted flow may not match with the aggregated FAF flow. So, the SWTAZ flows are normalized to match with FAF flow at FAF zonal level. Factors for each of the FAF origin destination pair are estimated by using:

$$Factor_{ij} = \frac{Tonnage\ flow\ between\ FAF\ Zones\ i\ and\ j}{Sum(Tonnage\ flow\ of\ all\ SWTAZ\ pairs\ with\ in\ FAF\ zones\ i\ and\ j)} \qquad (4.20)$$

The estimated factors are multiplied to the estimated flows to match with the FAF flow at zonal level.

Challenges Faced

The disaggregation at the SWTAZ level was challenging since the possible number of origin-destination (O-D) pairs increased from 6097 to 77.96 millions. After disaggregation we found that, many of the OD pairs had very small amount of tonnage associated with them. To take care of the issue, we undertook a flow-apportioning scheme by selecting threshold percentiles. All the selected flows less than the threshold are removed. The sum of the deleted flows is apportioned to the retained O-D pairs by weightage of the predicted flows. This ensured that total tonnage of flows is retained and no tonnage of flow is lost. The summary of the number of predicted flows in comparison with the predicted flows within the country are as given in Table.

Table 4-79: Number of Unique Export and Import Flows Compared to Flows within the Country

Year	2011		2015		2020		2025		2030		2035		2040	
# unique OD pairs	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports	Flows within the U.S.	Exports and Imports
FCC1	479,918	328,458	484,495	446,506	485,921	446,483	487,582	446,498	487,582	446,493	487,582	446,488	487,582	446,689
FCC2	131,179	89,081	131,209	97,204	131,541	97,196	131,429	97,204	131,429	97,206	131,429	97,202	131,429	97,203
FCC3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FCC4	762,438	564,307	759,899	634,863	761,639	634,983	763,302	634,943	763,302	635,006	763,302	634,955	763,302	634,914
FCC5	1,052,655	709,577	1,052,852	816,364	1,060,097	816,363	1,064,837	816,380	1,064,837	816,501	1,064,837	816,304	1,064,837	816,308
FCC6	689,503	411,195	696,742	548,000	697,400	548,082	700,009	548,044	700,009	548,046	700,009	548,012	700,009	548,049
FCC7	415,759	353,122	415,596	352,972	418,979	352,163	420,792	352,135	420,792	352,127	420,792	352,118	420,792	352,165
FCC8	1,205,650	843,049	1,193,314	1,026,074	1,201,189	1,026,075	1,206,579	1,026,097	1,206,579	1,026,086	1,206,579	1,026,075	1,206,579	1,056,070
FCC9	138,310	96,302	138,548	81,338	140,059	81,334	141,699	80,285	141,699	81,336	141,699	81,342	141,699	81,337
FCC10	2,872,014	2,279,795	2,884,333	1,899,712	2,927,408	1,899,704	2,940,504	1,899,678	2,940,504	1,899,703	2,940,504	1,899,674	2,940,504	1,899,699
FCC11	669,634	444,667	669,914	418,499	673,541	418,322	674,183	418,317	674,183	418,268	674,183	418,288	674,183	418,287
FCC12	155,696	117,585	155,603	87,466	153,854	86,323	151,479	86,319	151,479	86,320	151,479	94,854	151,479	96,112
FCC13	5,915,290	3,664,237	5,735,921	3,158,583	5,743,855	3,158,264	5,748,644	3,158,549	5,748,644	3,158,609	5,748,644	3,158,603	5,748,644	3,158,655

Table 4-80: FCC Wise Total Flow for Each Prediction Year

FCC Code	FCC Type	Total tonnage flow (in 1000 tons)						
		2011	2015	2020	2025	2030	2035	2040
FCC1	Agricultural Products	358.84	238.88	301.54	378.15	463.62	572.15	722.88
FCC2	Minerals	233.46	297.62	319.09	340.68	366.29	396.25	433.34
FCC3	Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FCC4	Food	1785.40	1651.44	2045.02	2564.05	3152.84	3921.95	5082.28
FCC5	Nondurable Manufacturing	778.05	791.59	1056.77	1377.28	1784.82	2336.17	3142.58
FCC6	Lumber	150.91	271.41	328.68	400.24	473.55	563.43	701.31
FCC7	Chemicals	4813.29	4190.16	3682.83	4261.49	4845.94	5549.07	6618.79
FCC8	Paper	821.80	808.15	925.74	1069.92	1198.80	1351.30	1545.06
FCC9	Petroleum	2876.98	2799.31	2444.09	2269.81	1966.64	1833.09	1660.05
FCC10	Other Durable Manufacturing	2274.09	2888.46	3444.19	4047.67	4743.96	5609.19	6796.05
FCC11	Clay and Stone	984.49	1521.99	1889.54	2317.49	2850.59	3547.63	4519.18
FCC12	Waste	1857.11	1773.87	2281.42	3044.32	3829.10	4874.92	6755.03
FCC13	Miscellaneous Freight & Ware House	0.04	0.06	0.08	0.10	0.12	0.15	0.19

Table 4-81: FAF Regional Share of Inflows

Region	2012	2015	2020	2025	2030	2035	2040
Miami	36.43%	41.70%	42.00%	42.73%	43.51%	44.50%	45.66%
Tampa	34.34%	29.85%	27.77%	27.19%	26.61%	25.78%	24.90%
Orlando	2.01%	2.29%	2.53%	2.56%	2.64%	2.70%	2.70%
Jacksonville	11.53%	11.32%	12.20%	12.18%	12.16%	12.16%	12.15%
Rest of FL	9.59%	9.58%	9.55%	9.05%	8.68%	8.43%	8.03%
Rest of the U.S.	6.10%	5.26%	5.94%	6.29%	6.40%	6.44%	6.55%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Total Flows (in tons)	**16934452**	**17232945**	**18718982**	**22071173**	**25676257**	**30555285**	**37976727**

Table 4-82: FAF Regional Share of Outflows

Region	2012	2015	2020	2025	2030	2035	2040
Miami	35.19%	38.56%	40.66%	41.30%	41.93%	42.89%	44.10%
Tampa	22.77%	16.52%	16.67%	16.58%	16.26%	15.76%	15.49%
Orlando	1.17%	0.91%	1.07%	1.22%	1.34%	1.45%	1.60%
Jacksonville	13.01%	12.34%	13.04%	12.73%	12.46%	12.25%	11.96%
Rest of FL	9.34%	8.37%	8.59%	8.35%	7.93%	7.57%	7.25%
Rest of the U.S.	18.53%	23.29%	19.97%	19.83%	20.08%	20.09%	19.61%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Total Tonnage (in tons)	**16934452**	**17232945**	**18718982**	**22071173**	**25676257**	**30555285**	**37976727**

Table 4-83: FAF Regional Share of Total flows (Inflow + Outflow)

Region	2012	2015	2020	2025	2030	2035	2040
Miami	35.81%	40.13%	41.33%	42.02%	42.72%	43.69%	44.88%
Tampa	28.55%	23.18%	22.22%	21.88%	21.44%	20.77%	20.20%
Orlando	1.59%	1.60%	1.80%	1.89%	1.99%	2.07%	2.15%
Jacksonville	12.27%	11.83%	12.62%	12.46%	12.31%	12.21%	12.05%
Rest of FL	9.47%	8.97%	9.07%	8.70%	8.31%	8.00%	7.64%
Rest of the U.S.	12.31%	14.28%	12.96%	13.06%	13.24%	13.26%	13.08%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

CHAPTER V: APPROACHES FOR ESTIMATING COMMODITY SPECIFIC TRUCK ORIGIN-DESTINATION (OD) FLOWS

5.1 FUSING THE TRUCK OD FLOWS ESTIMATED FROM ATRI DATA WITH COMMODITY FLOWS FROM TRANSEARCH DATA

The OD matrix of truck flows from ATRI provides the information about the total truck OD flows without detail on the commodity being carried. On the other hand, the Transearch data provides the tonnage flows as well as truck flows for each commodity. If a relationship is developed between the truck OD flows estimated from the ATRI data and the commodity flows from the Transearch data (for different industry sectors), by appropriately fusing the two different data sources, one might be able to utilize those relationships to develop truck OD flows for different industry sectors.

5.1.1 Methodology to Fuse Truck OD Flows Estimated from ATRI Data with Commodity Flows from Transearch Data

In this project, to fuse the Transearch commodity flow and ATRI truck OD flow data sources, a linear regression model is developed between the commodity flows from the former data source and the truck flows from the latter data source, as shown in Equation (5.21) below. Such a model may be used to estimate the truck conversion factors (TCF) and payload factors for each commodity. TCF represents the average number of trucks required to carry a unit ton of a commodity and payload factor represents the average number of tons of a commodity that a truck can carry. Essentially, TCF is the inverse of the payload factor. The estimated TCFs may be multiplied with the commodity flows reported in the Transearch data to obtain the commodity specific truck flows.

$$(Truck\ flow)_{ij} = \alpha_0 + \sum_{k=1}^{14} (\beta_k\ (commodity\ weight)_{ijk}) \qquad (5.21)$$

Where,

i = origin TAZ

j = destination TAZ

k = Commodity group

$(\text{Truck flow})_{ij}$ =Total annual truck flow from TAZ "i" to TAZ "j"

$(\text{Commodity weight})_{ijk}$ = Tonnage flow of a commodity "k" from TAZ "i" to TAZ "j"

α_0 = Constant

β_k= Truck conversion factor (tons / truck) for commodity "k"

In the above equation, the information on the left-hand side variable (truck flows) comes from the truck OD flows estimated from the ATRI data and the information on the right-hand side variables (commodity flows) come from the Transearch data. The coefficients on the commodity flow variables (i.e., the betas) are the TCFs to be estimated.

There is one limitation of this approach, which arises from the incompatibility of the two data sources: Transearch and ATRI. Specifically, it is important to note here that the OD flows reported in the Transearch data are flows of goods from their production origins to their consumption destinations. Therefore, the commodity flows in the Transearch data do not include intermediate stops (for commodity transfer) between the production origin and consumption destination. On the other hand, the truck OD flows estimated from the ATRI data represent the travel-origin and travel-destinations of commodity flows (as opposed to production origin and consumption destinations). Because of these differences, the truck flows in the ATRI data are likely to be larger than the truck flows implied by the Transearch data. This incompatibility will likely lead to unreliability of this approach in yielding TCFs or payload factors, as demonstrated in the subsequent subsections of this section.

5.1.2 Results from Fusing the Truck OD Flows Estimated from ATRI Data with Commodity Flows from Transearch Data

To implement the method described in Section 2.4.1.1 to fuse ATRI truck flows with Transearch commodity flows, we first aggregated both the data sources to a common zonal system. The truck OD flows estimated from ATRI are available at the FLSWM TAZ level as well as the county level. The Transearch commodity flows are available at the county-level as well as the FLSWM TAZ-level within Florida and at a more aggregate spatial resolution outside Florida. Specifically, the Transearch commodity flows are reported for 386 spatial zones outside Florida. The reader is referred to Figure 5-49 for a visual depiction of the zonal systems for which the ATRI truck OD flows and the Transearch commodity flows are reported (note that the figure depicts only the zones in the southeastern United States). To bring both datasets to a common zonal system, a county-level spatial resolution is used in Florida (i.e., 67 counties) and a total of 386 zones are used to represent the rest of the United States, Canada, and Mexico. This adds up to a total of 453 zones.

Recall that, in addition to commodity flows, the Transearch data reports truck flows. To compare the compatibility of the Transearch and ATRI data, we compared the truck flows reported by Transearch to the truck flows estimated from ATRI data. To do so, we computed the zonal-level trip productions and trip attractions (for all the 453 zones) from the truck flow datasets from both Transearch and ATRI datasets. Figure 5-50 provides such a comparison for each county in Florida. It can be observed from the figure that the truck flows reported in Transearch data are smaller in magnitude than to those estimated from ATRI data for most counties in the state, including Duval, Hillsborough, Lake, and Polk counties which contain many freight distribution centers and warehouses. On the other hand, for a few counties such as Miami Dade and Palm Beach, the truck flows in Transearch data are larger in magnitude than those estimated from ATRI. A plausible explanation for these differences, as discussed in Section 2.4.1.1, is that the Transearch data reports the commodity flows from production origins to consumption destinations without any detail on the intermediate stops (such as distribution centers or warehouses) for a commodity or potential empty backhauls. Whereas the truck flows estimated from the ATRI data include the travel origin and travel destination locations (thereby including the flows through intermediate stops) without regard to the production origin and consumption destinations. Figure 5-51 and Figure 5-52 represent the percentage differences in the county level daily productions and attractions, respectively, of the truck OD flows estimated from ATRI data with respect to the truck OD flows reported in Transearch data. These figures also lead to similar observations that the truck OD flows estimated from the ATRI data are generally larger in magnitude than those reported in the Transearch data. Such incompatibilities will likely make it difficult to extract meaningful relationships between the truck OD flows estimated from the ATRI data and the commodity flows reported in the Transearch data.

Following the methodology discussed in a earlier section, a linear regression model was estimated to relate the Transearch commodity flows within Florida to the ATRI truck flows within Florida. The model results are shown in Table 5-84. It can be observed from the table that the estimated coefficients (and payload factors) for several commodity groups – nondurable manufacturing, chemicals, and miscellaneous fright – have a negative sign. Such negative signs are nonsensical making it difficult to infer how many trucks does it take to transport 1000 tons of those commodities. Similarly, the coefficient estimates for the commodity groups, agricultural products, food, paper, waste are statistically insignificant at 95% confidence interval suggesting high variance (i.e., uncertainty) in these estimates. All these nonsensical results could be due to the incompatibility issues between the two datasets discussed earlier. Therefore, we decided not to use this approach to estimate commodity-specific truck flows in this project.

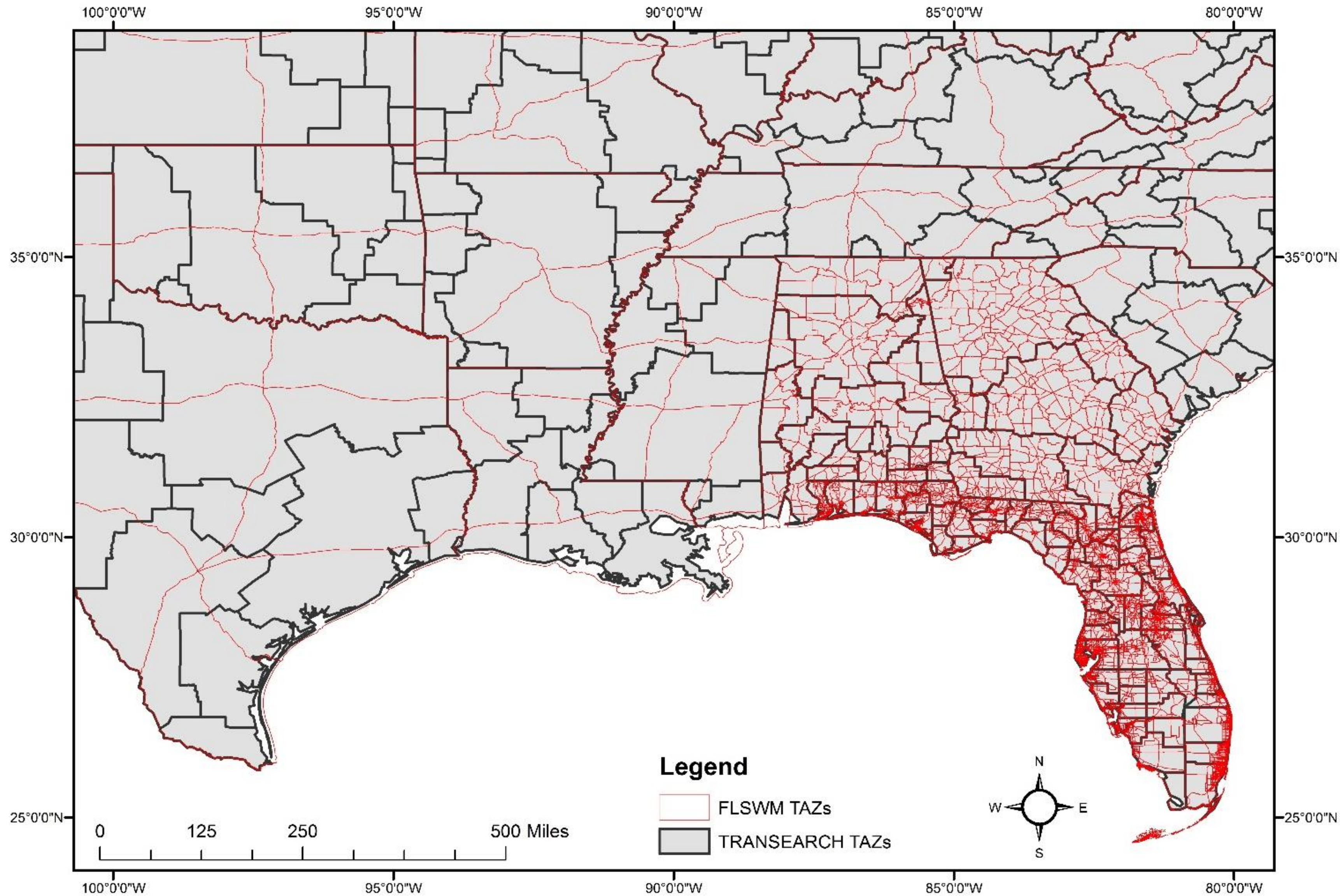


Figure 5-49: Representation of Transearch and FLSWM TAZs in the Southeastern United States

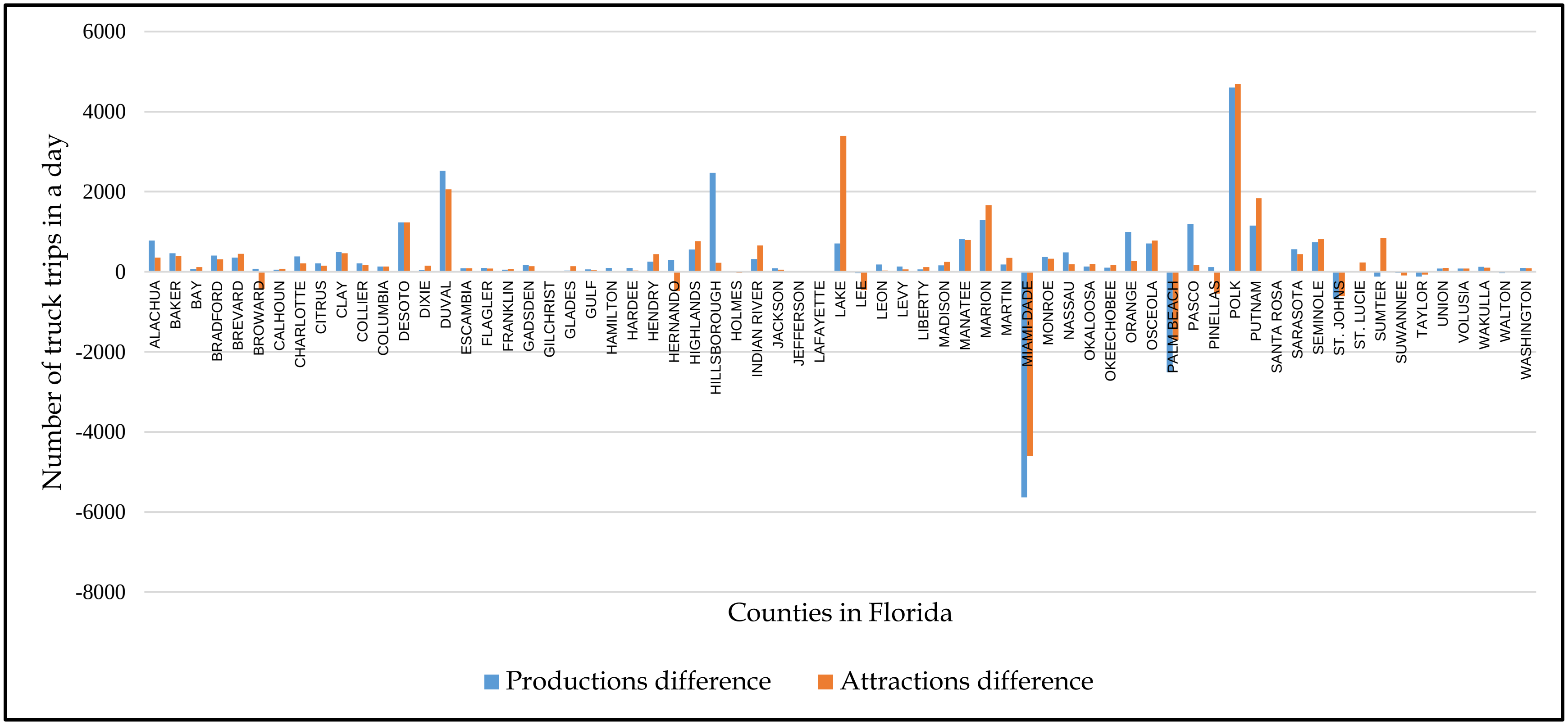


Figure 5-50: Differences in the County Level Daily Truck Trip Productions and Attractions in Estimated OD Matrix of Truck Flows and Truck Flows Reported in Transearch Data

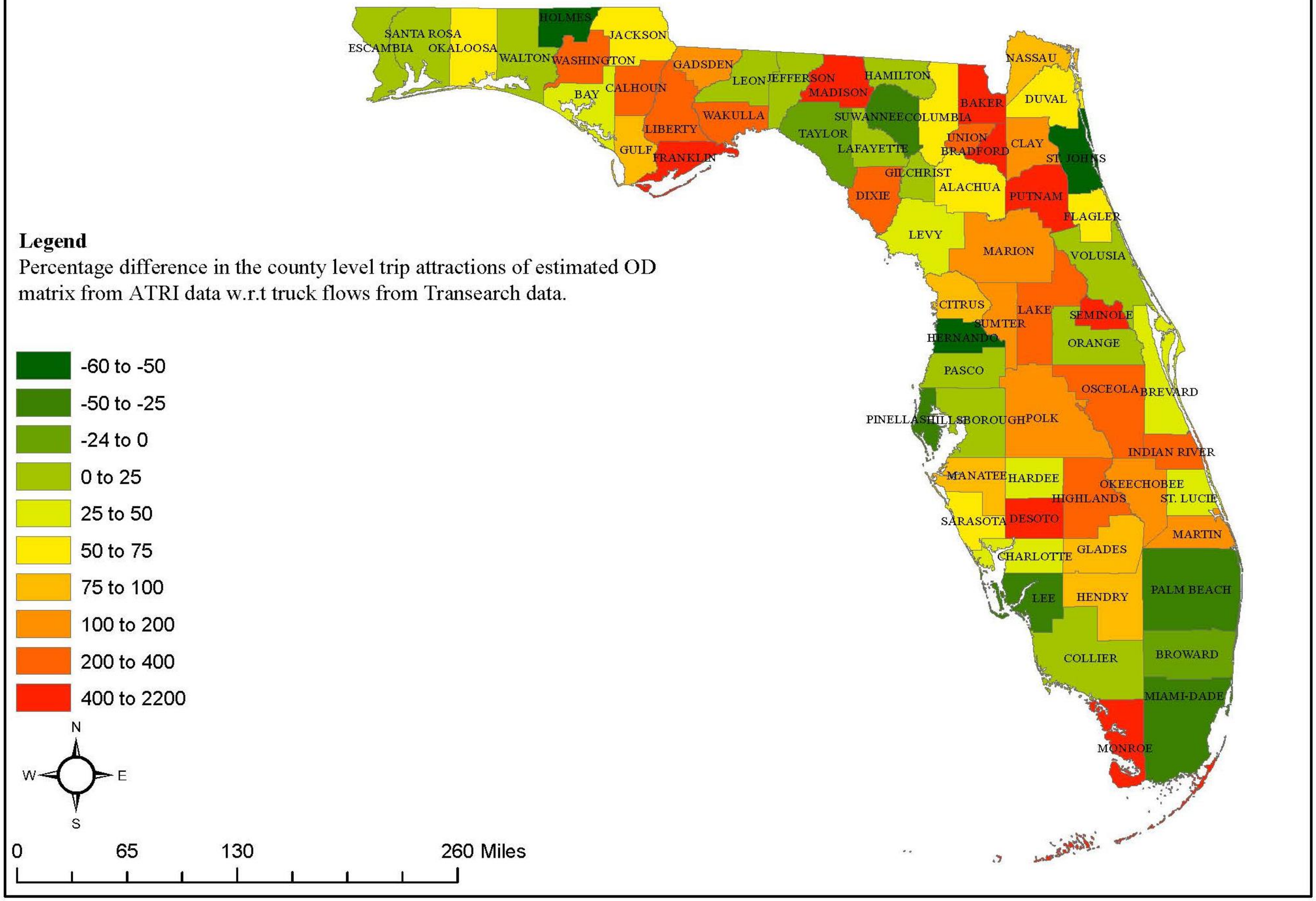


Figure 5-51: Percentage Difference in the County Level Daily Truck Trip Attractions of Estimated OD Matrix from ATRI Data with respect to Truck Flows Reported in Transearch Data

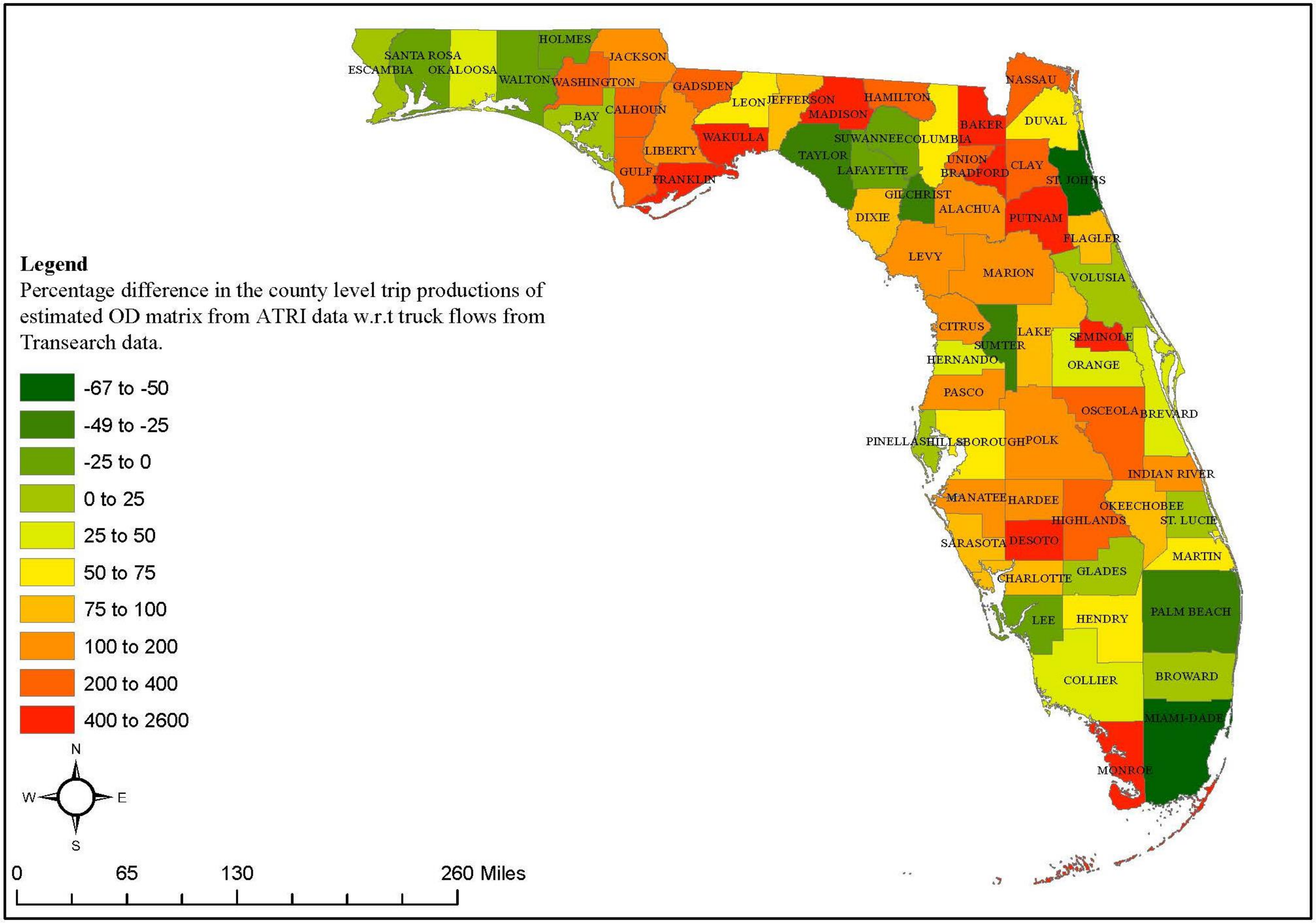


Figure 5-52: Percentage Difference in the County Level Daily Trip Productions of Estimated OD Matrix from ATRI Data with respect to Truck Flows Reported in Transearch Data

Table 5-84: Estimated Payload Factors for All Commodities Transported within Florida Using Transearch Data and Estimated OD Flow Matrix from ATRI 2010 Data

FCC CODE	Explanatory Variable	Estimated coefficient	Estimated pay load (tons/ truck)	t-statistic
	Constant	2816.12	--	10.29
1	Agricultural products	-0.001	-687.95	-0.85
2	Minerals	0.011	90.16	3.99
4	Food	0.030	33.49	1.67
5	Nondurable manufacturing	-4.338	-0.23	-14.01
6	Lumber	0.150	6.65	2.70
7	Chemicals	-0.474	-2.11	-3.59
8	Paper	0.208	4.80	1.69
9	Petroleum products	0.106	9.45	11.26
10	Other durable manufacturing	0.852	1.17	7.91
11	Clay and stone	0.334	2.99	24.66
12	Waste	0.020	48.78	0.61
13	Miscellaneous freight	-1.527	-0.65	-13.90
14	Warehousing	0.086	11.68	22.57
Adjusted R-square		0.551		

5.1.3 Fusing the Truck OD Flows Estimated from ATRI Data with Commodity Flows from Transearch Data

5.1.3.1 Applying Payload Factors to Commodity Flows from Disaggregated FAF Data

The second approach to develop truck OD flows for different commodity groups (or industry sectors) is to apply commodity-specific payload factors to the disaggregated FAF data on commodity flows – disaggregated to a county-level or TAZ-level spatial resolution. For the reasons discussed above, this approach is better than applying payload factors directly to the Transearch commodity data or to derive payload factors by fusing Transearch commodity flow data with ATRI truck flow data. In this section, we describe different approaches to develop commodity-specific payload factors, including a brief review of the approaches and data sources used in the literature, and present the final set of payload factors derived for use in this project.

5.1.3.2 Development of Commodity Specific Payload Factors

Payload factors from various studies in the literature

Data sources that are commonly used to obtain payload factors for different commodities are the Vehicle Inventory and Usage Survey (VIUS) and the Commodity Flow Survey (CFS). VIUS was conducted by the U.S. Bureau of census from 1963 to 2002 at a 5-year interval to measure the physical and operational characteristics of the truck population in the U.S. The physical characteristics include truck type, engine type, empty truck weight, truck length, number of axles, etc. and the operational characteristics include the type of use, operator classification, annual miles driven, typically carried commodities, gas mileage, and annual miles driven. The CFS data is the primary source of national and state-level data on domestic freight shipments by American establishments in various industries. The data includes information on the types, origins and destinations, values, weights, modes of transport, distance shipped, and ton-miles of commodities shipped. Data from the VIUS or CFS surveys specific to the analysis region are typically considered for obtaining the payload factors of the region.

For Florida's, Quick Freight Response Manual II-based legacy freight model, commodity-specific payload factors available in the (which were in turn obtained from the VIUS data) were utilized. As shown in Table 5-85, these payload factors differ by the distance between the origin and destination.

Table 5-85: Payload Factors Considered in Florida's Legacy Freight Model

Commodity	Payload factors					
	On Road Average	Less than 50 miles	50 to 100 miles	100 to 200 miles	200 to 500 miles	Greater than 500 miles
Agricultural products	16.36	9.20	18.14	21.95	19.48	17.79
Minerals	20.82	20.62	17.50	21.07	N/A	23.00
Coal	18.23	8.64	18.60	22.29	21.10	21.23
Food	8.68	3.58	5.05	18.10	6.22	14.79
Nondurable manufacturing	14.03	4.70	25.19	22.39	28.32	24.16
Lumber	15.11	11.32	9.90	19.86	17.00	18.48
Chemicals	16.59	11.61	20.75	19.62	23.46	18.66
Paper	21.04	19.55	25.52	27.32	21.85	17.33
Petroleum products	11.38	5.12	6.97	18.72	19.21	17.23
Other durable manufacturing	18.47	15.82	20.31	19.97	22.71	22.40
Clay and stone	12.90	10.28	17.03	16.15	23.07	21.03
Waste	12.44	6.90	7.21	20.89	19.29	18.43
Miscellaneous freight	9.07	9.02	6.53	23.91	3.34	11.56
Warehousing	14.21	9.97	12.02	20.57	19.61	18.80

Source: Beagan, et al (2007)

According to the NCHRP Report 606 (titled Forecasting Statewide Freight Toolkit), payload factors for different commodities in the Florida Intermodal Statewide Highway Freight Model (FISHFM) are established using the Florida-specific data from the VIUS. Commodity-specific payload factors are estimated for different OD distance categories. Considering that the payload factors for a commodity typically increase with OD distance, a growth function shown in equation (5.22) is used to smooth the payload factors over distance. The resulting payload factors are shown in Table 5-86.

$$\text{Payload factor} = \exp(\beta_0 + \beta_1 * distance) \tag{5.22}$$

Table 5-86: Florida-specific Payload Factors Reported in NCHRP Report 606 (Forecasting Statewide Freight Toolkit)

Commodity	Payload factors				
	Less than 50 miles	50 to 100 miles	100 to 200 miles	200 to 500 miles	Greater than 500 miles
Agricultural products	13.59	16.04	18.92	22.32	26.34
Minerals	19.35	20.92	22.63	24.46	26.45
Coal	19.35	20.92	22.63	24.46	26.45
Food	12.19	14.92	18.28	22.38	27.40
Nondurable manufacturing	3.94	5.79	8.51	12.51	18.38
Lumber	10.8	14.12	18.46	21.14	31.57
Chemicals	10.93	13.29	16.15	19.63	23.87
Paper	15.53	17.99	20.85	24.16	27.99
Petroleum products	24.58	24.99	25.40	25.82	26.24
Other durable manufacturing	6.32	8.92	12.58	17.76	25.07
Clay and stone	19.57	21.29	23.16	25.20	27.41
Waste	12.45	14.99	18.06	21.76	26.21
Miscellaneous freight	7.79	10.49	14.13	19.02	25.62
Warehousing	8.25	9.93	11.95	14.38	17.30

Source: Cambridge Systematics, et al (2008)

The commodity-specific payload factors reported in Table 5-85 and Table 5-86 can potentially be applied to the disaggregated FAF commodity flows for estimating the commodity-specific truck OD flows within, into, and outside Florida.

Three more studies in this regard are reviewed in Appendix A. These are briefly discussed here. Areekamol et al. (2014), utilized payload factors from VIUS 2002 to allocate the commodity weight to the number of trucks by specific body type. Similarly, Zhang et al. (2003) used VIUS data to determine the vehicle capacity by truck type as well as vehicle distribution by commodity group. The number of trucks for transporting a specific commodity is determined by dividing the assigned commodity tonnage by average load for the specific commodity. Krishnan and Hancock (1998) combined all commodity categories together and a single analysis procedure was adopted for estimating freight traffic on major roads in Massachusetts from interstate commodity flow data. (The reader is referred to APPENDIX A for more details).

Development of payload factors by using truck flows and commodity flows within Florida reported in the Transearch data

As mentioned earlier, Transearch data for Florida includes both commodity flows (in tonnage, volume, and dollar value) as well as truck flows for the commodities transported by the truck mode. One can use both these data sources to develop commodity-specific relationships, using statistical regression equations, between truck flows and commodity flows. Equation (5.23) shows the relationship between truck flows for estimating commodity-specific TCFs and payload factors. As can be observed from the equation, the relationships can be allowed to be different for different OD distance categories.

$$T_{ijk} = \alpha_{0k} + \alpha_k * w_{ijk} + \left(\sum_{p=2}^{5} \alpha_k^p * d_{ij}^p \right) * w_{ijk} \tag{5.23}$$

Where,

T_{ijk} = Annual truck flow from TAZ "i" to TAZ "j" carrying a commodity "k"

w_{ijk} = Annual tonnage flow of a commodity type "k" from TAZ "i" to TAZ "j"

α_{0k} = Constant specific to a commodity "k"

α_k = Truck conversion factor (TCF) for commodity "k" for OD pair in the distance category less than 50 miles.

α_k^p = TCF for commodity "k" for OD pair in the distance category "p" relative to the base category's TCF. Therefore, the TCF for that OD pair is $\alpha_k^p + \alpha_k$.

- ⇨ Payload factor for a commodity "k" for OD pair in the distance category "p" except for distance less than 50 miles = $1/(\alpha_k^p + \alpha_k)$.

  Payload factor for a commodity "k" for OD pair in the distance category less than 50 miles = $1/(\alpha_k^p + \alpha_k)$.

d_{ij} = Average distance between TAZ "i" and TAZ "j" in miles,

d_{ij}^2 = 1 if 50 < d_{ij} < 100 miles and 0 otherwise,

d_{ij}^3 = 1 if 100 < d_{ij} < 200 miles and 0 otherwise,

d_{ij}^4 = 1 if 200 < d_{ij} < 500 miles and 0 otherwise, and

d_{ij}^5 = 1 if d_{ij} > 500 miles and 0 otherwise.

Table 5-87 below reports the results of the TCFs and payload factors estimated from the statistical regression models, as in Equation (18), between the truck flows and commodity flows reported in the Transearch data.

Table 5-87: Truck Conversion Factors (TCF) and Payload Factors (in Parenthesis) Estimated from Regression between Truck and Commodity Flows in the Transearch Data

FCC	TCF for 'Less than 50 miles' category	TCF for '50 to 100 miles' category	TCF for '100 to 200 miles' category	TCF for '200 to 500 miles' category	TCF for 'greater than 500 miles' category	Average TCF
Agricultural products	0.048 (20.68)	0.048 (20.68)	0.052 (19.16)	0.055 (18.25)	0.048 (20.68)	0.05 (19.89)
Minerals	0.041 (24.31)	0.041 (24.31)	0.041 (24.31)	0.041 (24.31)	0.041 (24.31)	0.041 (24.31)
Food	0.043 (23.01)	0.043 (23.08)	0.044 (22.92)	0.044 (22.91)	0.043 (23.01)	0.043 (22.99)
Nondurable manufacturing	0.06 (16.74)	0.06 (16.74)	0.06 (16.74)	0.06 (16.54)	0.061 (16.36)	0.060 (16.62)
Lumber	0.039 (25.44)	0.04 (25.23)	0.04 (25.26)	0.04 (25.14)	0.041 (24.48)	0.04 (25.11)
Chemicals	0.046 (21.9)	0.048 (20.79)	0.048 (20.82)	0.046 (21.7)	0.046 (21.9)	0.047 (21.42)
Paper	0.041 (24.12)	0.041 (24.12)	0.052 (19.12)	0.051 (19.47)	0.041 (24.12)	0.045 (22.19)
Petroleum products	0.041 (24.23)	0.042 (23.69)	0.041 (24.23)	0.041 (24.23)	0.041 (24.23)	0.041 (24.12)
Other durable manufacturing	0.07 (14.19)	0.069 (14.42)	0.059 (16.88)	0.057 (17.55)	0.07 (14.19)	0.065 (15.45)
Clay and stone	0.063 (15.77)	0.064 (15.66)	0.063 (15.83)	0.06 (16.62)	0.063 (15.77)	0.063 (15.93)
Waste	0.046 (21.87)	0.046 (21.95)	0.046 (21.87)	0.046 (21.87)	0.046 (21.87)	0.045 (21.89)
Miscellaneous freight	0.049 (20.56)	0.049 (20.56)	0.049 (20.56)	0.049 (20.56)	0.049 (20.56)	0.049 (20.56)
Warehousing	0.063 (15.85)	0.052 (19.11)	0.049 (20.3)	0.049 (20.46)	0.049 (20.46)	0.052 (19.23)

Payload factors recommended for this project

A comparison of average values of payload factors from Quick Response Freight Manual's Florida Freight Model and the payload factors estimated from Transearch data are given in Figure 5-53. It can be observed that the commodity specific payload factors estimated using the Transearch 2011 data are generally higher than those used previously in the literature using VIUS data from 2002. The truck sizes and configurations have undergone significant changes over a decade period between 2002 and 2011 (for example, increased weight capacity of newer trucks), a reason why the payload factors estimated from the Transearch 2011 are greater than those derived from the 2002 VIUS data. Therefore, we recommend using the payload factors reported in Table 5-87 (which are derived from Transearch 2011 data) for this study.

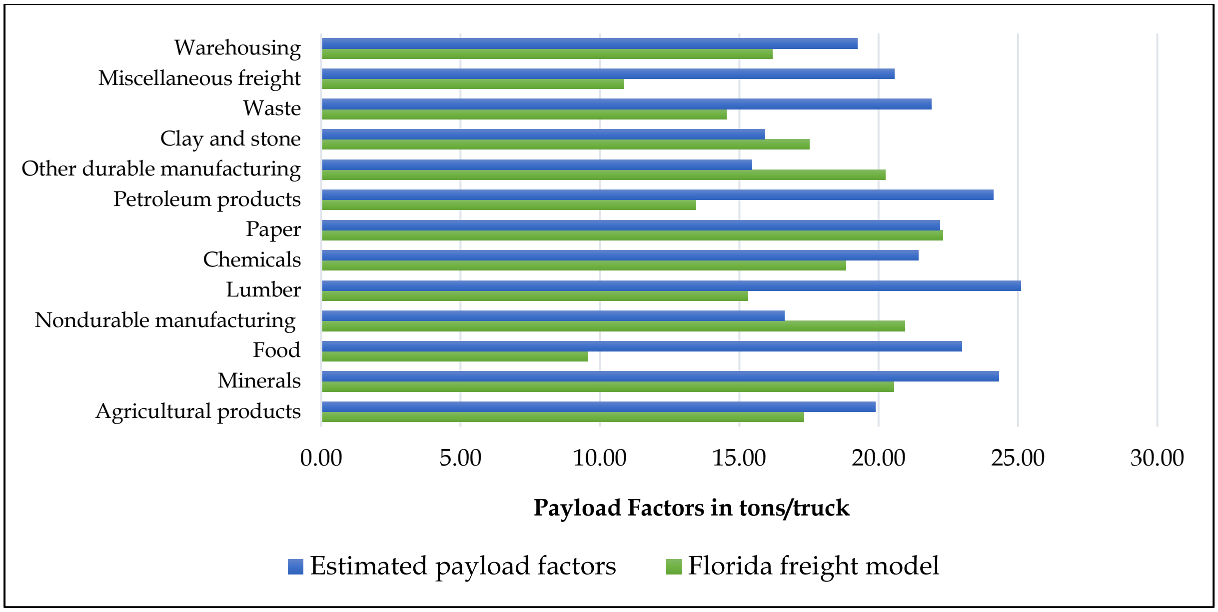


Figure 5-53: Comparison of Payload Factors from Florida Freight Model (Quick Response Freight Manual) and the Payload Factors Estimated from Transearch 2011 Data

5.2 ESTIMATION OF ORIGIN-DESTINATION MATRICES OF TRUCK FLOWS

Trucks back hauling from areas with a significant imbalance in the consumption and production of goods consist of a notable proportion of empty or partially loaded trucks. These back-hauling trucks cause monetary loss to the trucking industry in terms of fuel, workforce, time and other resources. Apart from the wastage of resources, empty or partially loaded back hauling contribute to an increase in air pollution, congestion, and damage to the pavement. Furthermore, an increase in the supply chain costs adversely affects the overall economic growth of an area. Being one of the largest consumer and visitor markets in the United States, Florida makes an excellent example of the freight imbalance with a large consumer market and comparatively smaller production base. The overall inbound tonnage to Florida is nearly 80 percent higher than the outbound tonnage causing a significant number of empty or partially loaded back hauls and is one among the major challenges faced by the state (Florida trade and logistics study, 2010).

A possible solution to address the empty back hauling truck flow is through formulating policies targeting the trade imbalance in a region which includes the development of production centers and attracting imports to the region's sea ports. However, to devise any such policy, it is important for the policy makers to have a clear idea about the spatial distribution of the empty truck flows. Along with the information about whether a truck is empty or not, it is equally important to know to what extent a truck is filled (i.e., empty, partially filled, and filled). This will help the policy makers to devise appropriate strategies.

Some practical insights to the challenges involved in modeling the empty trips using the traditional freight demand models are given by Holguin-Veras and Thorson (2003). While trip based models fail to make any distinction between the loaded and empty trucks, the commodity based models cannot estimate the empty truck flows accurately (Holguin-Veras and Thorson, 2003). Studies (Holguin-Veras and Thorson, 2003; Holguín-Veras and Thorson, 2003; Holguín-Veras et al., 2010; Jansuwan et al., 2017) have tried to use statistical models where the empty flows were modeled as a function of loaded truck flows. Holguín-Veras and Patil (2008), integrated a commodity-based demand model based on a gravity model and a statistical model estimating empty trips and developed a freight origin–destination synthesis that includes both loaded and empty truck trips. Studies based on these statistical models require extensive data collection from OD surveys, which is a major drawback (Mesa-Arango et al., 2013).

These shortcomings can be overcome by integrating distinct data sets by formulating a hybrid approach using optimization techniques (Jansuwan et al., 2017). Some of the earlier pioneering works in this area are by Crainic et al. (1993) and Crainic and Laporte (1997). Later, Mesa-Arango et al. (2013) formulated an optimization function to minimize the overall system cost while ensuring the truck flow conservation for both loaded and empty trips. The method is advantageous when limited, or no data is available. Chow et al. (2014) used a nonlinear inverse optimization technique similar to the work by Guelat et al. (1990) for the freight assignment at different network equilibrium conditions. These models are an extension of the traffic assignment problem that includes commodity, and commercial vehicle flows with transfer costs.

To the best of authors' knowledge, no study in the freight modeling literature has estimated the truck flows by weight categories. This study bridges this gap and contributes to the freight literature by developing a model which makes use of available data sources related to freight flow. In the present data driven era, an abundance of data and its complexity is also an issue, which is handled efficiently in the proposed methodology. Furthermore, the study estimates the truck flows in a finer granularity (at the newest FLSWM zonal level) using the loaded truck flows at finer TAZ level and the empty flow model used in Holguín-Veras and Patil, 2008.

This paper demonstrates a suitable easy to use method for integrating all the available datasets for a region. Datasets include the truck flows on links with or without their weight information, origin-destination matrices of truck and commodity flows, and the path flows for the truck traffic from the assignment stage in the four-step freight demand model. The paper applies the proposed methodology and results in different scenarios are compared and validated with the observed data. The paper also discusses (a) the categorization of trucks e.g. empty truck or partially loaded trucks or fully loaded trucks, (b) the attractions and productions of empty truck trips within Florida and productions of empty truck trips to other states in the United States, and (c) the practical aspects of the proposed method. The following section explains the proposed optimization procedure used to estimated truck trips by different weight categories. Followed by the implementation of the optimization procedure for Florida, the comparison of results in different scenarios and the validation between estimated value and observed value are presented. The final section summarizes and concludes the study.

5.2.1 Methodology

This section aims to fuse the observed truck flow data from multiple sources (including commodity mass and truck counts from the sampled links and all relevant OD pairs) to produce the best estimation of weight-categorized truck flows at different resolutions over the studied region. We propose a convex optimization model to estimate the weight-categorized truck counts for the sample links and OD pairs that best match the observations from all these sources. The objective function of this model is set to minimize the summation of the squared errors between the estimated and the observed truck flows for both weight-categorized truck counts and associated commodity masses. Flow conservation constraints are applied to ensure the estimated OD flows are consistent with the estimated link flows. Proper weight factors are multiplied to each error term to balance the effects of the different data sizes and error magnitudes from these multiple data sources.

One insightful result from this model is the empty truck OD flows over the studied region, which may often have relatively coarse resolution due to the input data limitation. Per the engineering needs of the investigated problem, we also propose a disaggregation approach that breaks county-level empty truck OD flows into relatively fine TAZ (Traffic Analysis Zone) level empty truck OD flows. This disaggregation approach is built upon the model proposed by Holguín-Veras and Patil, 2008 assuming that the whole truck flow from an origin to a destination to is proportional to the empty truck flow in the reverse direction with a constant factor across a local area (e.g., between two counties).

5.2.1.1 Estimation of Truck Flows by Different Weight Categories

Our proposed model estimates the truck flows by weight categories assuming the conservation of commodity and truck flows at road link and OD pair levels. For the convenience of the reader, the variables and parameters in the model are listed in Table 5-88.

Table 5-88: Description of Notations Used in the Model Formulation

Notation	Description
A'_w	set of links used by the truck flows between an OD pair $w \in W$
A^T	set of links for which only total truck counts are available
A^{WS}	set of links for which truck counts by weight categories are available
A	set of all links, $A = A^{WS} \cup A^T$
$C_1, C_2, C_3, C_4, C_5, C_6$	optimization weightage factors for different error terms
$\mathcal{L}$	weight categories for trucks, $\mathcal{L} = \{1, 2, \ldots, l, \ldots, L\}$
$\bar{m}_{la}$	average gross weight of category l trucks passing through link in $a \in A^{WS}$, $l \in \mathcal{L}$
$\bar{m}_w$	average of all commodity flows between OD pair $w \epsilon W^C$
m_{la}	total gross weight of category l trucks passing through link $a \in A^{WS}$, $l \in \mathcal{L}$
m_w	commodity flow between an OD pair $w \in W^c$
	truck flows on link $a \in A^T$
n_{la}	number of category l trucks passing through link $a \in A^{WS}$, $l \in \mathcal{L}$
n_w	truck flow between an OD pair $w \in WT$
$\bar{n}_a$	average of all truck flows on link $a \in A^T$
$\bar{n}_{la}$	average number of category l trucks passing through the links in A^{WS}, $l \in \mathcal{L}$
$\bar{n}_w$	average of all truck flows between OD pairs in WT
P_{wa}	percentage of truck flows between an OD pair $w \in W$ going through the link $a \in A_w$
v_0	weight of empty truck
v_l	average commodity weight carried by a category l truck, where $l \in \mathcal{L}$
v_{lg}	vla average gross weight of a category l truck, $v_{lg} = v_l + v_0$, where $l \in \mathcal{L}$
W^C	set of OD pairs for which the commodity flows are available
W^T	set of OD pairs for which the truck flows are available
W_a	set of OD pairs contributing to the truck flows on a link $a \in A$
W	set of all OD pairs, $W = W^C \cup W^T$
x_{la}	number of category l trucks passing through link $a \in A$, $l \in \mathcal{L}$
y_{lw}	number of category l trucks flowing between OD pair $w \in W$, $l \in \mathcal{L}$
ε_{la}	error term for category l trucks passing through link $a \in A$, $l \in \mathcal{L}$

Truck flows between OD pairs W and on links A are estimated. We define $W^C \subset W$ as the set of OD pairs for which the commodity flows are available, which can be made available for a region using commodity flow databases provided by both public and proprietary agencies, and $W^T \subset W$ as set of OD pairs for which the truck flows are available, which can be obtained from the traffic assignment step from a regional four step travel demand model or from other data sources. So that the set of all OD pairs W is the union of W^T and W^C ($W = W^c \cup W^T$).

Without loss of generality, truckloads are divided into several categories $l \in \mathcal{L}$ to get a better model fitness. It is important to note that the consideration of finer weight categories can lead to computation complexity and may over fit the data. v_l is the average commodity weight carried by a category l truck and v_{lg} is the average gross weight of a category l truck, which means $v_{lg} = v_l + v_0$, where v_0 is the average weight of empty truck.

$A^{WS} \subset A$ is defined as the set of links for which truck counts by weight categories are available and $A^T \subset A$ as set of links for which only total truck counts are available. So that A will be the union of A^T and A^{WS}, $\text{A} = A^T \cup A^{WS}$. Again, A'_w denotes the set of links used by the truck flows between an OD pair $w \in W$ and W_a is the set of OD pairs contributing to the truck flows on a link $a \in A$. P_{wa} is the percentage of truck flows between an OD pair $w \in W$ going through the link $a \in A_w$. So, the truck flows on a link $a \in A_w$ should be consistent with the sum of the truck flows of all OD pairs going though link a. Due to possible errors between the estimated truck count x_{la} and that calculated from OD flows y_{lw} and assignment percentages P_{wa}, we add an error term variable ε_{la} to balance the equation. Therefore, constraint is shown in equation (5.24).

$$\sum_{w \in W} y_{lw} P_{wa} = x_{la} + \varepsilon_{la}, \forall\, l \in \mathcal{L}\,, a \in A'_w, \tag{5.24}$$

where x_{la} is decision variable that describes the estimated number of category l trucks on link $a \in A$ and y_{lw} is the decision variable that describes the estimated number of category l trucks on OD pair $w \in W$. Meanwhile, m_w denotes the commodity flow between an OD pair $w \in \mathrm{W}^{\mathrm{C}}$ and $\bar{m}_w$ as average of all commodity flows between OD pairs in W^{C}. We define n_w as truck flow between an OD pair $w \in \mathrm{W}^{\mathrm{T}}$ and $\bar{n}_w$ as average of all truck flows between OD pairs in W^{T}. m_{la} is the total gross weight of a category l truck passing through link $a \in A^{WS}$, and $\bar{m}_{la}$ as the average gross weight of category l trucks going through link $a \in A^{WS}$. n_{la} is the number of category l trucks passing through link $a \in A^{WS}$ and $\bar{n}_{la}$ as average number of category l trucks passing through link $a \in A^{WS}$. Finally, n_a is the truck flows on link $a \in A^T$ and $\bar{n}_a$ is the average of all truck flows on link $a \in A^T$.

The procedure used in this research is a convex optimization model that tries to minimize a function that is the sum of the difference between observed truck counts at WIM stations for multiple weight category and the estimated trucks counts for multiple weight categories, difference between observed total truck counts and estimated truck counts, difference between estimated commodity flow between OD pairs and estimated commodity flow between OD pairs and the difference between the truck flows between the OD pair and the observed truck flows between the OD pairs. We define variables x_{la} as number of category l trucks passing through link $a \in A, \; l \in \mathcal{L}$ and variables y_{lw} as number of category l trucks flowing between OD pair $w \in W, \; l \in \mathcal{L}$. For simplicity of the notation, we denote variables as $x \coloneqq \{x_{la}\}_{l\in\mathcal{L},a\in A}$, $y \coloneqq \{y_{lw}\}_{l\in\mathcal{L},w\in W}$ and $\varepsilon \coloneqq \{\varepsilon_{la}\}_{l\in\mathcal{L},a\in A}$. Then this problem can be formulated as:

$$\begin{aligned} min_{x,y,\varepsilon} & \underbrace{\left[\sum_{l\in\mathcal{L}}\sum_{a\in A^{WS}} C_1(n_{la} - x_{la})^2\right]}_{\substack{Conservation\ of\ link\ flows\\ at\ WIM\ sites}} + \underbrace{\left[\sum_{a\in A^T} C_2\left(n_a - \sum_{l\in\mathcal{L}} x_{la}\right)^2\right]}_{\substack{Conservation\ of\ link\ flows\\ at\ TTM\ sites}} \\ & + \underbrace{\left[\sum_{l\in\mathcal{L}}\sum_{a\in A^{WS}} C_3\left(m_{la} - x_{la}v_{lg}\right)^2\right]}_{Conservation\ of\ mass\ at\ WIM\ sites} + \underbrace{\left[\sum_{w\in W^c} C_4\left(m_w - \sum_{l\in\mathcal{L}} y_{lw}\, v_l\right)^2\right]}_{\substack{Conservation\ of\ mass\\ at\ an\ OD\ pair\ level}} \\ & + \underbrace{\left[\sum_{w\in W^T} C_5\left(n_w - \sum_{l\in\mathcal{L}} y_{lw}\right)^2\right]}_{\substack{Conservation\ of\ truck\ flows\\ at\ an\ OD\ pair\ level}} + \underbrace{\left[\sum_{w\in W^T} C_6\, \varepsilon_{la}^2\right]}_{\substack{Sum\ of\ estimation\\ errors\ \varepsilon_{la}}}, \end{aligned} \tag{5.25}$$

subject to Constraints (1) (Equation 5.25) and $x_{la}, y_{lw} \geq 0, \forall\, l \in \mathcal{L}, a \in A, w \in W.$

To balance the unit and the order of magnitude of five parameters in the objective function, we normalized the error terms in the following way:

$$C_1 = c_1 / \sum_{l\in\mathcal{L}}\sum_{a\in A^{WS}} (n_{la} - \bar{n}_{la})^2 \tag{5.26}$$

$$C_2 = c_2 / \sum_{a\in A^T} (n_a - \bar{n}_a)^2 \tag{5.27}$$

$$C_3 = c_3 / \sum_{l\in\mathcal{L}}\sum_{a\in A^{WS}} (m_{la} - \bar{m}_{la})^2 \tag{5.28}$$

$$C_4 = c_4 / \sum_{w\in W^C} (m_w - \bar{m}_w)^2 \tag{5.29}$$

$$C_5 = c_5 / \sum_{w \in W^T} (n_w - \bar{n}_w)^2 \tag{5.30}$$

$$C_6 = c_6 / \left\{ \sum_{l \in \mathcal{L}} \sum_{a \in A^{WS}} (n_{la} - \bar{n}_{la})^2 + \sum_{a \in A^T} (n_a - \bar{n}_a)^2 \right\} \tag{5.31}$$

The procedure attempts to estimate the truck flows for specific truck load categories between OD pairs in such a manner that the resulting traffic count at links, commodity flows between OD pairs, and truck flows between OD pairs closely match with observed variables. The c values – error weighing factors in the optimization process allow us to give weight according to nature of data used for the optimization procedure.

The estimated truck counts at different truck-weight (or truckload) categories may be evaluated by comparing the estimated truck traffic volumes and the observed truck traffic volumes at different locations for a set of validation data that was not used for optimization process.

Apart from evaluating the results for three main categories of weight, the estimated truck counts are also evaluated for its reasonableness by considering more disaggregated categories of truck weights. The total truck counts at links, commodity flows and the truck flows between OD pairs are also evaluated using same measures of performance for more disaggregated weight categories. This will ensure the efficacy of model for various applications.

5.2.1.2 Disaggregation of Estimated Truck Flows

What's more, after obtaining the estimated empty truck flows between OD pairs y_{0w}, we further consider to estimate the truck flows in a finer granularity (at the Statewide TAZ level) using the loaded truck flows at finer TAZ level and the empty flow model used in Holguín-Veras and Patil, 2008. In each OD pair, the origin and destination are divided into finer zones and we get the finer OD pairs $k, k \in w$. We define a_k as the observed loaded truck flows and $\bar{b}_k$ as the estimated empty truck flows between OD pair k. Further, we define $\bar{k}$ as the OD pair in a reverse direction of OD pair k and $\bar{w}$ as the OD pair in a reverse direction of OD pair w. We set p_w to denote the parameter that we use to estimate empty truck flows of OD pair k as a proportion p_w of the corresponding loaded truck flows of OD pair $\bar{k}$. Therefore, the estimated empty flow between an OD pair $\bar{k}$ can be calculated in the following way:

$$\bar{b}_{\bar{k}} = p_w * a_k, \forall k \in w, \forall \bar{k} \in \bar{w}, \forall w, \bar{w} \in W \tag{5.32}$$

Then the sum of estimated empty truck flows $\sum_{\bar{k} \in \bar{w}} \bar{b}_{\bar{k}}$ should be equal to the estimated empty truck flows between OD pair $\bar{w}$,$y_{0\bar{w}}$. So, we have

$$\sum_{\bar{k}\in\bar{w}} \bar{b}_{\bar{k}} = y_{0\bar{w}}, \forall\bar{w} \in W \tag{5.33}$$

Therefore, the estimated empty truck flows in finer OD pair can be obtained by using equation (5.32) and (5.33) and eliminating parameter p_w:

$$\bar{b}_{\bar{k}} = y_{0\bar{w}} * a_k / \sum_{k\in w} a_k \tag{5.34}$$

5.2.2 Florida Case Study

5.2.2.1 Data Description

Truck counts on a link by weight category (n_{la})

Weigh-In-Motion (WIM) data for the 2011 year was obtained from the Florida Department of Transportation (FDOT). It contains 24.50 million truck records from within Florida. Twenty-nine (29) WIM stations were operational in 2011, and some of the stations had the capability to measure the truck weight in both the traffic directions. This made up to Fifty-three (53) links corresponding to WIM stations which are available for the model estimation and validation.

Total truck counts on a link (n_a)

Telemetered Traffic Monitoring Site (TTMS) truck counts for the year 2010 are used in the estimation of OD matrix of truck flows in the study by Zanjani et al. (Zanjani et al., 2015). TTMS data has 353 links available for the model estimation and validation. The information is used in the form of average daily truck traffic.

Truck flows between an OD pair (n_w)

Zanjani et al. used the GPS data for the trucks in the year 2010 jointly provided by American Transportation Research Institute and Federal Highway Administration (FHWA) and the counts from TTMS sites to estimate Florida centric OD matrix of truck flows at both county level and Statewide TAZ level resolution (Zanjani et al., 2015). The optimization procedure in this study uses this estimated OD matrix of truck flows at county level resolution.

Commodity flows between an OD pair (m_{la})

Tonnage flow obtained from Transearch, developed by IHS Global Insight Inc. for the year 2011. a proprietary, carrier-centric comprehensive freight database for the state of Florida is used for the optimization procedure. The database provides Florida-centric data on the commodity flow between 379 zones inside the country with commodity flows at the county-level resolution in Florida.

Path flows between an origin-destination pair (P_{wa})
The path flows are a percentage of truck flows on paths between an OD pair. The percentage of path flows on the links with WIM sites and TTMS sites are extracted from the OD flows estimated from ATRI data for the year 2010. The path flows are obtained from the traffic assignment step using Cube software, from the truck OD estimation study by Zanjani et al. (2015).

Empty truck weight
From the WIM data corresponding to the Florida, it was observed that the heavy-duty trucks (class 8 and above according to FHWA trucks classification) constitute 80% of the total truck traffic. Heavy duty trucks usually consist of two units, tractor unit, and trailer unit. The individual empty weight of tractor and trailer varies depending on the manufacturer. According to a survey conducted in 2014 by American Transportation Research Institute (ATRI), the majority of fleets operated truck-tractors, and the most prevalent trailer types were 53-foot and 28-foot trailers respectively. The data shows the shift from previously used trailer specifications to 53-foot trailers. Around 70% of total tractor-trailer combination used 53-foot trailers followed by 20% of 48-foot trailers and 10% of other trailers. Using this proportion and the information from the manufacturers on the range of weights for truck-tractor units, the weight of an empty truck can range from 21-kilo pounds to 37-kilo lbs. So different empty weights within the given range were tested, and an optimum value for the empty truck was chosen which provided better predictions.

Optimization parameter settings
In the optimization procedure, we have tried two sets of truck-weight/truckload categories (set 1 and set 2) and four scenarios with different values of optimization weightages (c_1, c_2, c_3, c_4, c_5), as listed in Table 5-89 and Table 5-90, respectively.

Table 5-89: Type of Truck-Weight (or Truckload) Categories

Category No.	Weight range in kips (kilo pounds)	
	Set 1	Set 2
1	≤ 35	≤ 35
2	35 - 60	35 - 40
3	> 60	40 - 45
4	--	45 - 50
5	--	50 - 55
6	--	55 - 60
7	--	> 60

Table 5-90: Scenarios with Different Values for Optimization Weights (c)

Weightage coefficients	Scenario 1	Scenario 2	Scenario 3	Scenario 4
c_1	1	10	100	1
c_2	1	10	100	1
c_3	1	10	100	1
c_4	1	1	1	10
c_5	1	1	1	10
c_6	1	10	100	1

In the optimization process, three weight categories are used. They are 0-35 kips, 35-60 kips, and 60 kip or above. Again, the categorization is based on the weight ranges considering the typically empty, partially loaded, and fully loaded trucks. In addition to these broad weight categories, the results analyzed for finer categories with 5kip intervals are also considered for the optimization procedure, for a better quality of fitting.

5.2.2.2 Results

This section presents the results from the optimization procedure, in which the truck flows with multiple truckload (or weight) categories between the OD pairs is estimated at county level resolution for the state of Florida. The average simulation time of the model is 25sec for three categories of truckload (i.e., weight categories) and 75sec for seven categories of truckload.

In this study, two sets of truck-weight (or truckload) categories 'Set1' and 'Set2' as given in Table 5-89 were analyzed for the four scenarios given in Table 5-90. Different empty weights within the range of 21 kips to 37 kips were tested in all the 4 scenarios for two truck-weight categories, and an optimum value for the empty truck was chosen as 28kips which provided better predictions. The different sets of 'c' values as shown in Table 5-90 were then used for the analysis. For all the four optimization weightage scenarios in the two types of truck-weight categories, the mean of absolute error to mean (MAEM) is calculated as shown in Equation (5.35).

$$MAEM(\hat{\theta}) = \frac{E\left[\left|\hat{\theta} - \theta\right|\right]}{\bar{\theta}} \qquad (5.35)$$

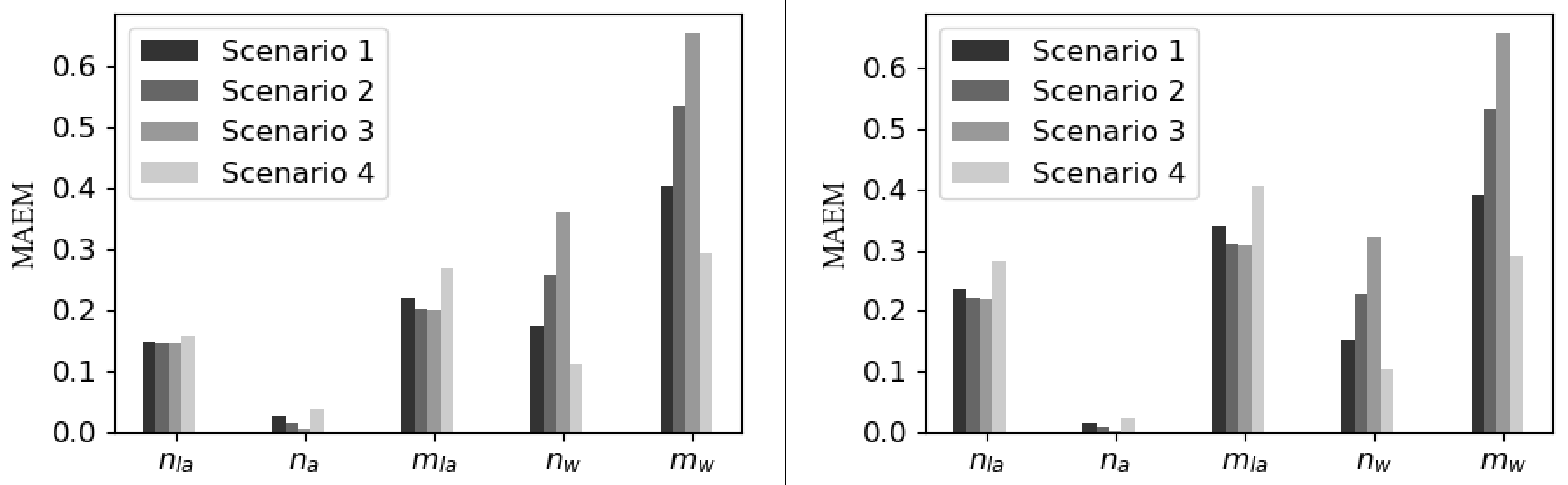
where $E\left[\left|\hat{\theta} - \theta\right|\right]$ is the expected value of $\left|\hat{\theta} - \theta\right|$, $\hat{\theta}$ is the estimated value, θ is the observed value, and $\bar{\theta}$ is the mean of observed values.

Figure 5-54 shows the results of MAEM values for all four scenarios of weightage scheme for both sets of truck-weight categories. According to the MAEM values, the model with 'Set1' truck-weight categorization performed better than the model 'Set2' truck-weight categorization, as can be observed from Figure 5-54.

Therefore, the 'Set1' truck-weight categorization is chosen for further analysis. Another finding is regarding the values of optimization weightages given for different error terms in the optimization model. Weightages of the error terms 'c_1', 'c_2', and 'c_3' correspond to the observed truck counts at WIM sites and TTM sites and weights at WIM sites respectively. Likewise, 'c_4' and 'c_5' correspond to the estimated OD matrices of truck trips and commodity flows. From the results obtained, it is clear that the set of weightages with higher values corresponding to the observed data were more satisfactory when compared to the results obtained with higher values of weightage to the estimated data. That is, better results were obtained when greater confidence was placed on observed data than on estimated data inputs to the optimization formulation. Narrowing down the results to each of the parameter estimates,

Figure 5-55 shows the 45-degree result of estimated data (from the optimization procedure) vs. observed data. It shows the following four comparisons: (1) estimated truck traffic volumes vs. observed truck traffic volumes at TTM sites, (2) estimated truck weights vs. observed truck weights at WIM sites, (3) estimated truck OD flows vs. observed truck OD flows, and (4) estimated commodity OD flows vs. observed commodity flows.

Figure 5-56 uses color coding to differentiate between the WIM data used for optimization and that kept aside for validation efforts. In each panel of this figure, the estimated and observed truck traffic volumes at WIM sites are presented separately for WIM sites whose data was used in the optimization and for WIM sites whose data was kept aside for validation. Three of these panels are for the comparison of estimated and observed truck traffic volumes (at WIM sites) for each of the three truck-weight categories. The fourth panel makes such comparison for all trucks, regardless of the weight category. It is evident from all panels in the figure that the estimated truck traffic volumes in all three weight categories are close to the observed values (or at least within 25% error) for the validation sites. This highlights the efficacy of the optimization.

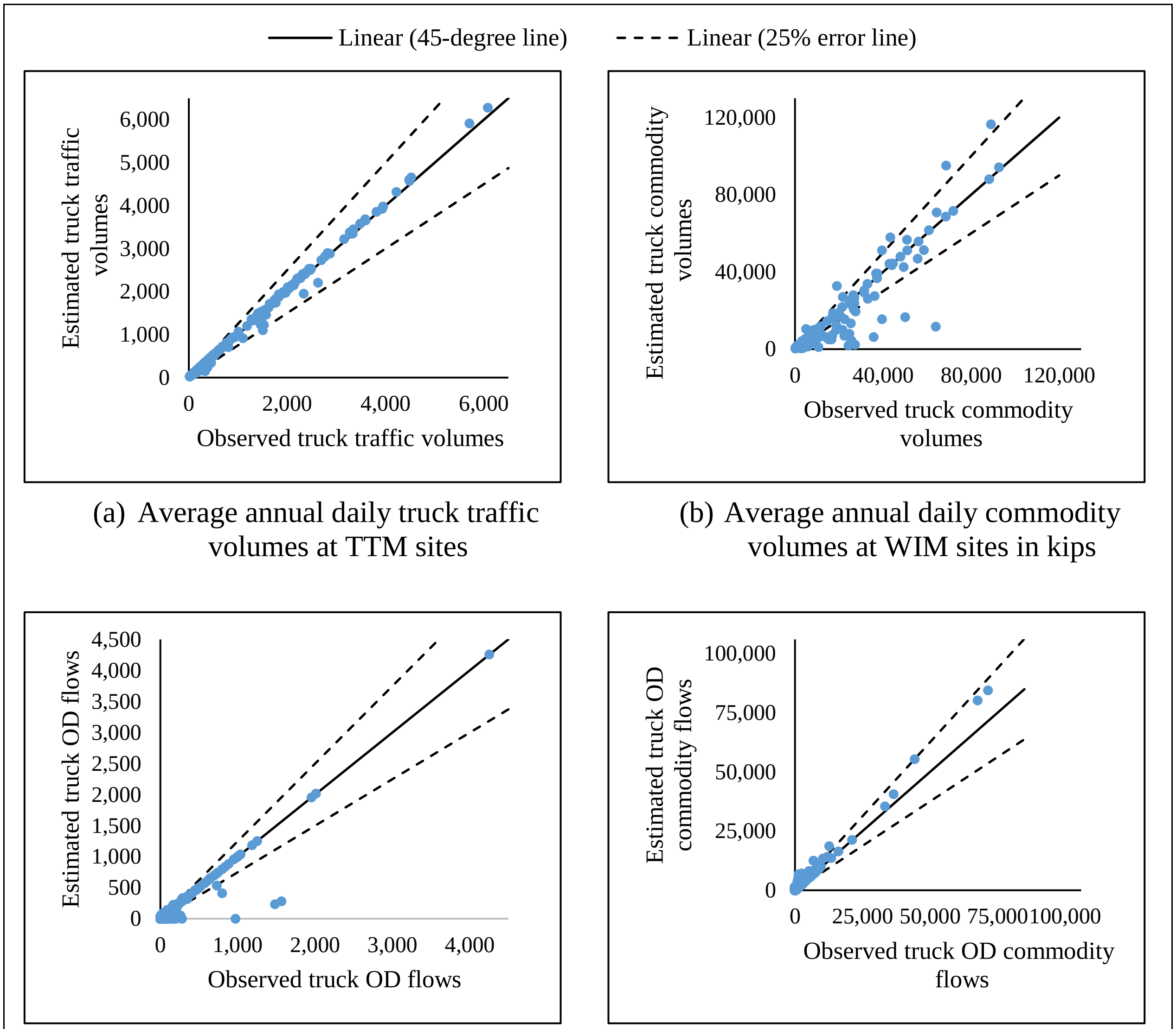


(a) Three Truck-weight Categories Model

(b) Seven Truck-Weight Categories Model

n_{la} - total number of category l trucks passing through the links
n_a - total truck flows on a link
m_{la} - total gross weight of category l trucks passing through a link a
n_w - total truck flow between an OD pair
m_w - total commodity flow between an OD pair

Figure 5-54: Mean of Absolute Error to Mean (MAEM) of Each Type of Category for 4 Scenarios of Optimization Weightages



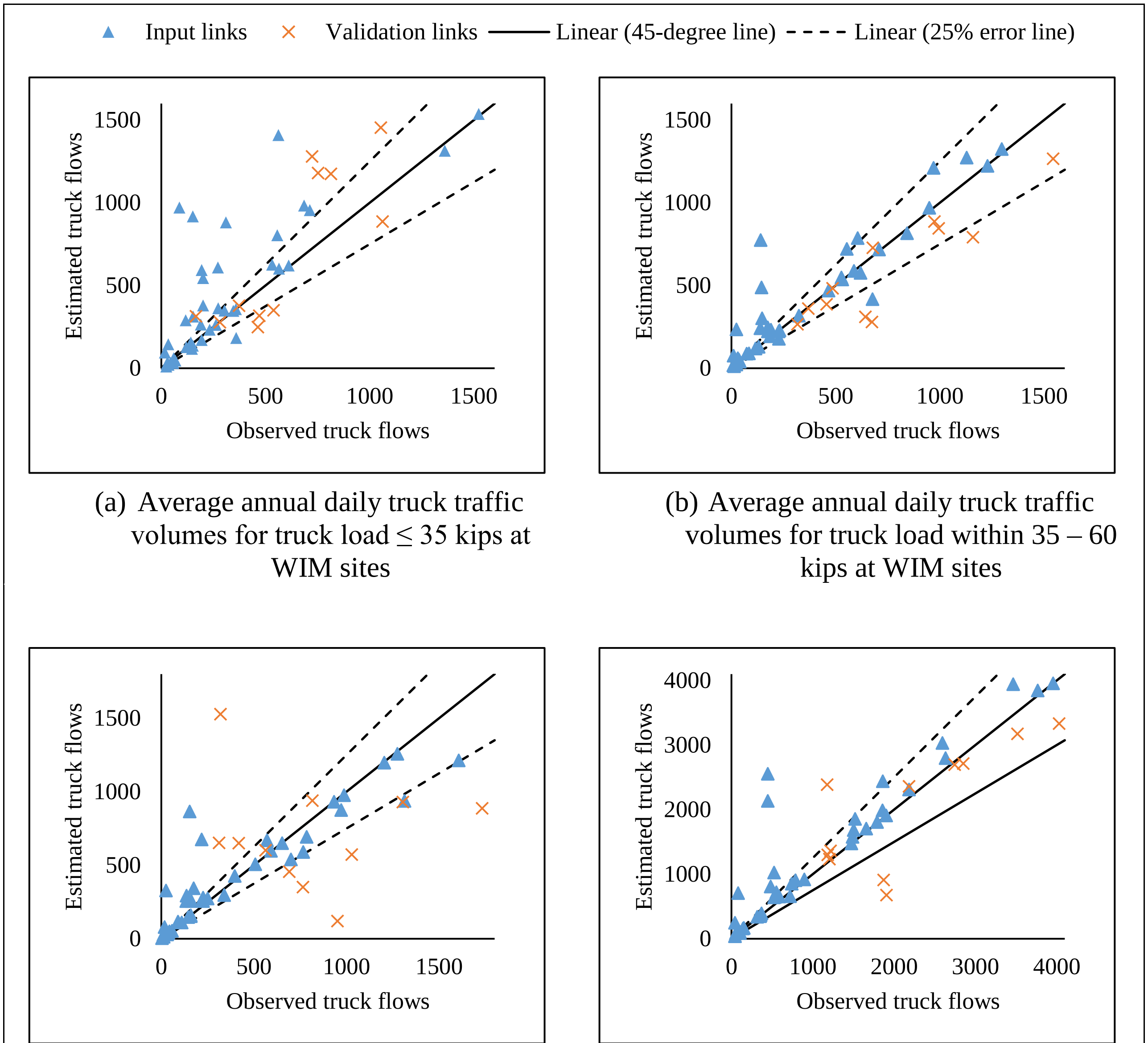
(a) Average annual daily truck traffic volumes at TTM sites

(b) Average annual daily commodity volumes at WIM sites in kips

(c) Average annual daily truck flows between an OD pair

(d) Average annual daily commodity flows between an OD pair in kips

Figure 5-55: Observed versus Estimated Truck Traffic Volumes, Truck OD Flows, and Commodity OD Flows per Day



(a) Average annual daily truck traffic volumes for truck load ≤ 35 kips at WIM sites

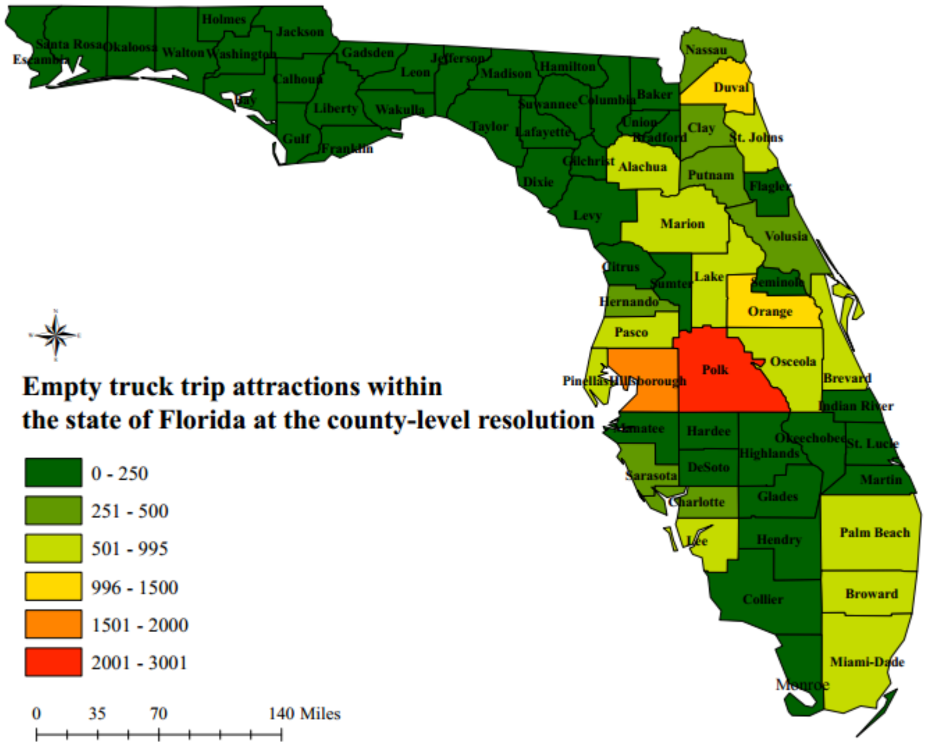
(b) Average annual daily truck traffic volumes for truck load within 35 – 60 kips at WIM sites

(c) Average annual daily truck traffic volumes for truck > 60 kips at WIM sites

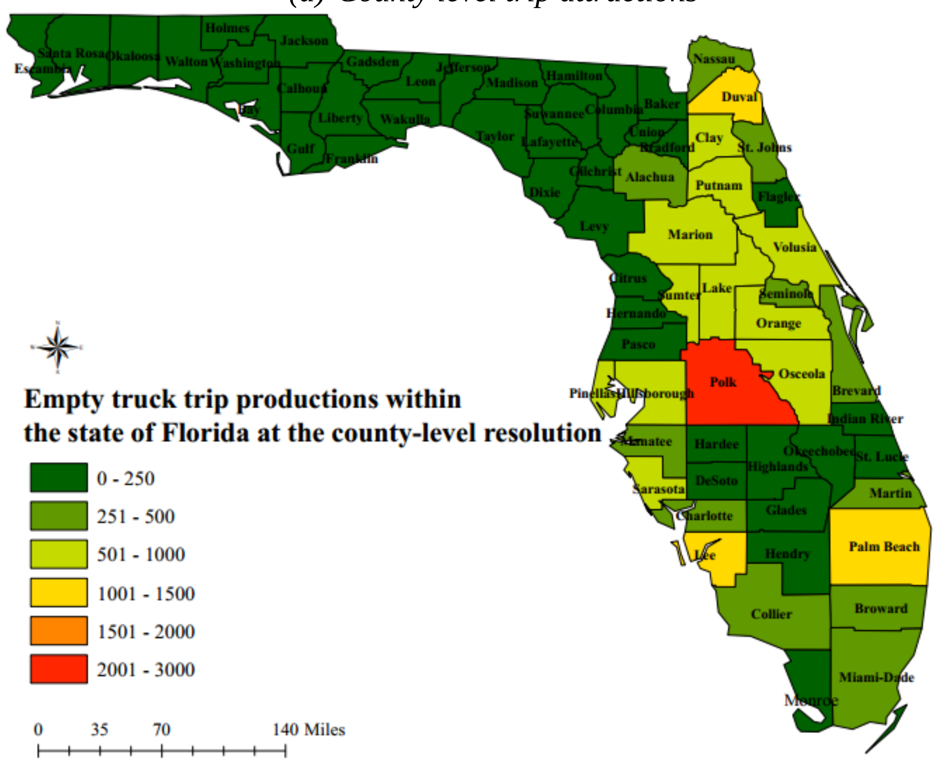
(d) Average annual daily total truck traffic volumes at WIM sites

Figure 5-56: Observed versus Estimated Average Annual Daily Truck Traffic Volumes at WIM Sites

Figure 5-57 shows the county level trip productions and attractions (excluding intra county movements) for trucks moving within Florida and with weight category one (truck load ≤ 35 kips), most of which are empty trucks. Similarly, Figure 5-58 shows the county level trip attractions and production of category 1 truck flows between Florida and other states in the U.S. One can use such results to identify the areas with high productions and attraction of empty truck flows and design appropriate policies to reduce the empty flows.

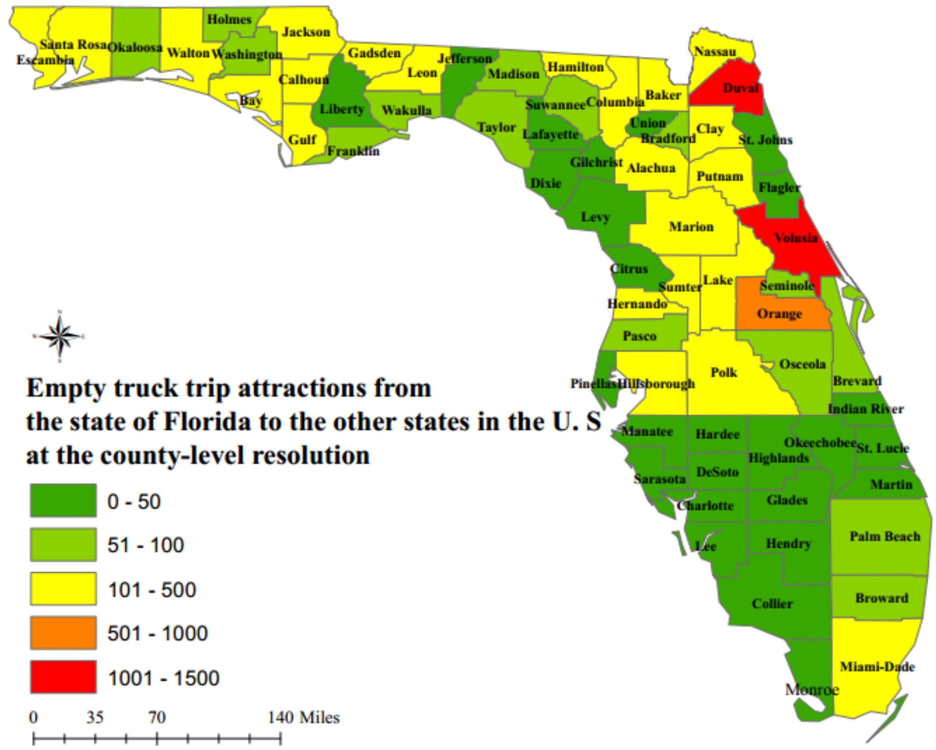


(a) County level trip attractions

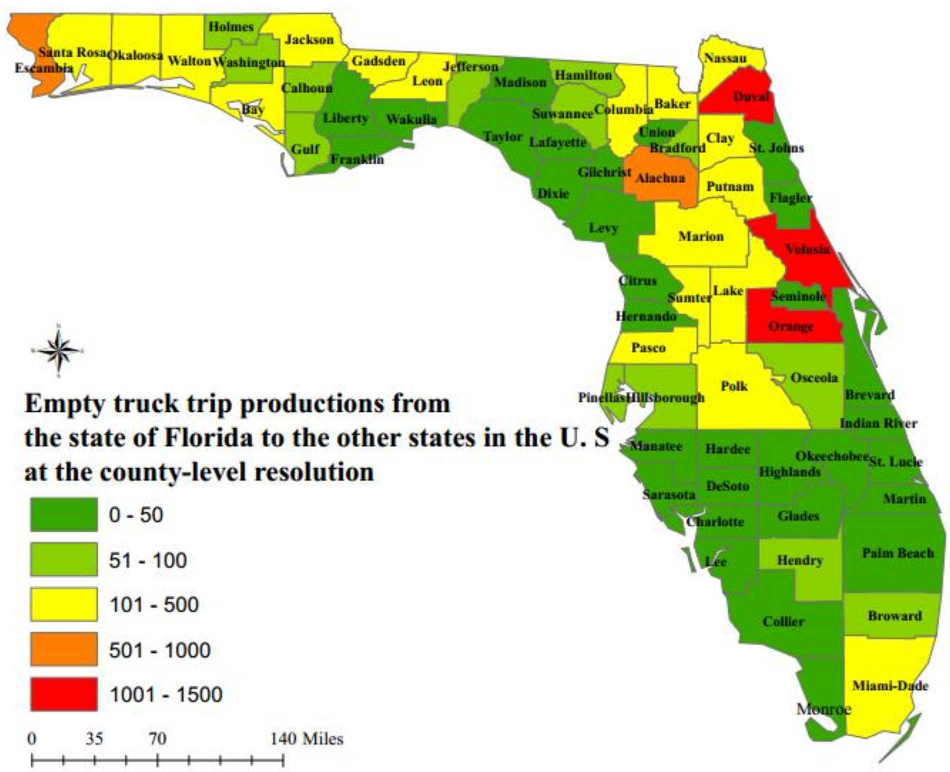


(b) County level trip productions

Figure 5-57: Estimated County Level Trip Attractions and Productions for Trucks in Category One (Truck Load ≤ 35 kip)



(a) County level trip attractions



(b) County level trip productions

Figure 5-58: Estimated County Level Trip Attractions and Productions for Trucks in Category One (Truck Load ≤ 35 kip) and Moving between Florida and Other States

Figure 5-59 shows the spatial distribution of truck flows in the weight category one (truck load ≤ 35 kips) from the state of Florida to other states in the United States. It is important to know that the link data, TTMS and WIM data used in the modeling are only in the Florida, thus Truck flows between Florida and nearby states are much reliable as compared to the flows between Florida and far away states. From Figure 5-59, it can be observed that a considerable proportion of empty trucks from Florida are destined to Alabama and Georgia. A possible explanation could be that the trucks delivering goods in Florida and leaving empty while returning may go to Alabama and Georgia to get loads. One can use such results to identify the specific OD pairs with high empty truck flows, so that appropriate strategies may be used to reduce the empty back-hauls.

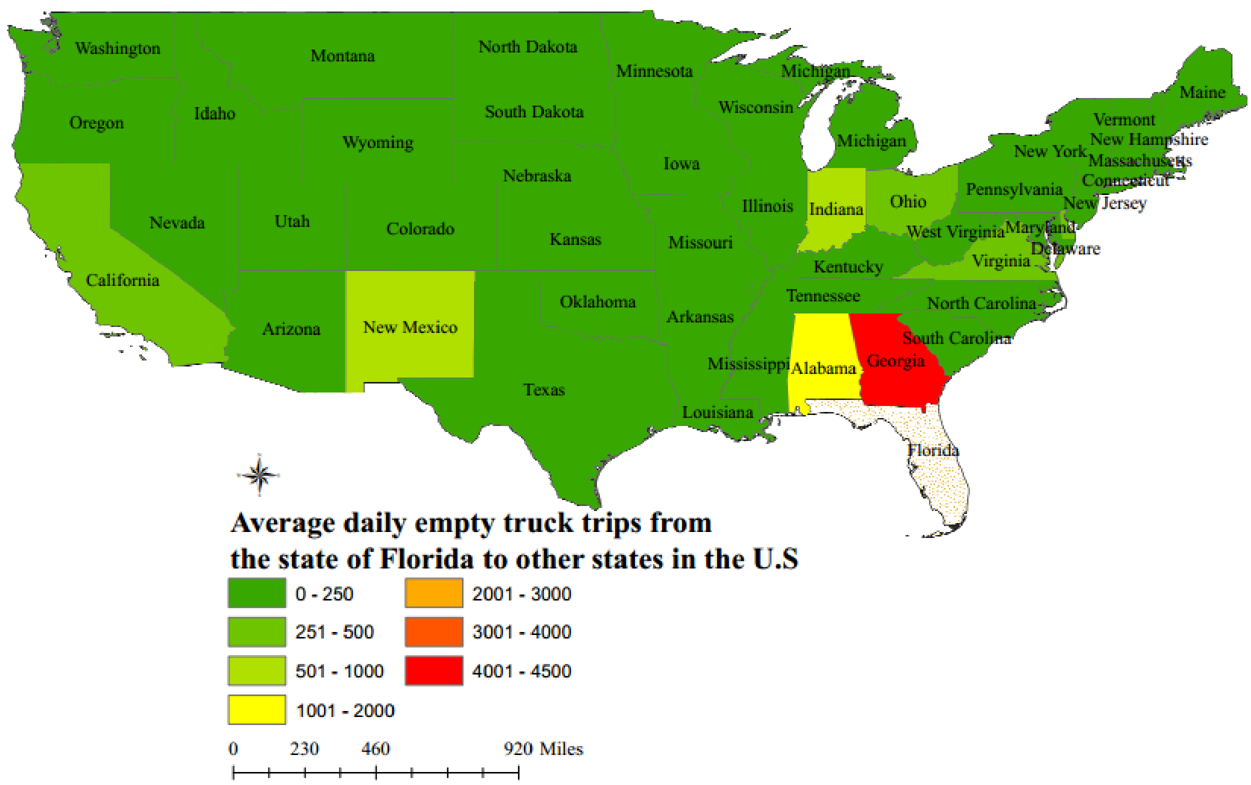
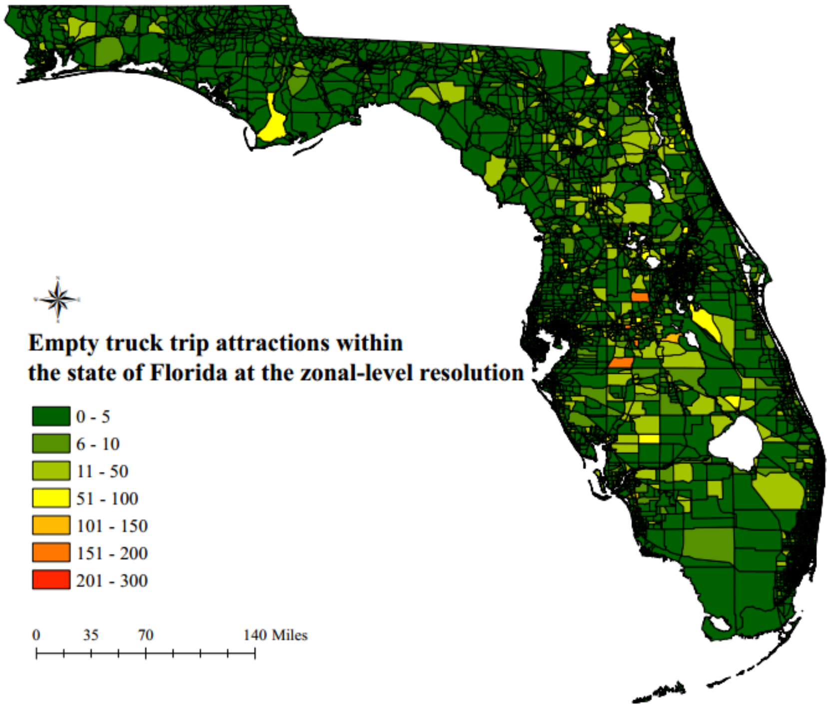
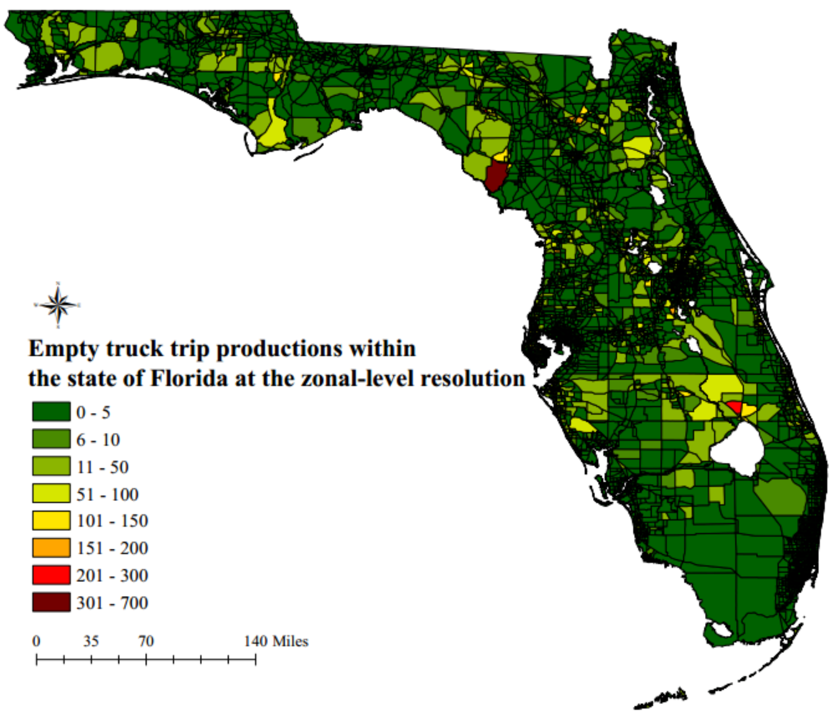


Figure 5-59: Empty Truck Flows from Florida to Other States of United States

Using the methodology described in section 4.1.2 and information on loaded truck flows at Statewide TAZ (SWTAZ) level within Florida from the Transearch data, estimated OD matrix (67×67) of empty flows within Florida at Transearch zonal level are disaggregated into the OD matrix of size 8518 × 8518 at SWTAZ level. Figure 5-60 shows the SWTAZ level attractions and productions of empty truck trips within Florida.



(a) SWTAZ level trip attractions



(b) SWTAZ level trip productions

Figure 5-60: Estimated SWTAZ Level Trip Attractions and Productions for Trucks in Category One (Truck Load ≤ 35 kip)

CHAPTER VI: CONCLUSION

6.1 INTRODUCTION

The report provides findings from two parallel efforts. The first effort is focused on developing an innovative data fusion procedure for fusing two disparate data sources of varying spatial granularity. The applicability of the model is demonstrated through a scenario analysis - how commodity flows between counties will alter in response to increase in significant determinants of freight such as population and employment. The second effort presents the development of an optimization model to estimate truck flows by different weight categories within, into, and out of a study region.

6.2 FAF AND TRANSEARCH FUSION

A major hurdle in freight demand modeling has always been a lack of adequate data on freight movements for different industry sectors for planning applications. Several data sources are available for freight planning purpose in the United States. Of these, the two most commonly adopted sources are Freight Analysis Framework (FAF) and Transearch (TS). FAF (freely available) and TS (proprietary) databases contain annualized commodity flow data that can be used in long range freight forecasting. Although both FAF and Transearch provide annual commodity flows in the United States, several differences exist between these sources, including the variability in data collection mechanism employed, and variability in the spatial and commodity type resolution. The coarser spatial resolution in FAF makes it challenging to generate reliable network flow estimates. While TS provides data at a fine spatial resolution, the supply demand nature of the database does not represent the actual transportation network path flows and requires additional analysis to realize transportation network flows. The primary objective of this part of the research project was to develop a fused database to realize transportation network flows at a fine spatial resolution while accommodating for production and consumption behavioral trends.

To achieve the goal, we undertake disaggregation of FAF flows while augmenting with production consumption based TS flows. Towards this end, we formulate and estimate a joint econometric model framework grounded in maximum likelihood approach to estimate county level commodity flows. The algorithm is implemented for the commodity flow information from 2012 FAF data for five FAF zones and 2011 TS databases for 67 counties in Florida. The fused flows are further disaggregated at the SWTAZ level using a proportional allocation framework. The fusion algorithm can be applied to obtain fused flows for future years obviating the need to purchase expensive TS dataset. We have also developed a procedure to disaggregate export/import flows following Viswanathan et al. (2008). Using the payload factor – the total tonnages are converted to truck flows.

For conducting the scenario analysis, we selected ten counties in Miami (Miami-Dade, Broward, Palm Beach), Orlando (Orange, Osceola, Seminole, and Volusia), and Jacksonville (Duval, Baker, and Clay) regions. For these counties, we increased the population by 15% and employment by 10% and estimated the change in flows using the estimates from the joint model for FCC 1 (Agricultural Product) and FCC 8 (Paper). Overall, our results show expected change in flows – a general trend towards increased flows. More specifically, for FCC 1, with increase of population and employment, Orlando region has the highest rate of flow increase. For FCC 8, for originating flows, the increase across the various counties is of similar order (~20%) with Osceola county as an exception (48%).

To be sure, the research is not without limitations. In our algorithm, only one hop paths are considered for computational tractability. It would be interesting to examine how the fused outputs are influenced by a larger choice set of paths. This is an avenue for future research.

6.3 EMPTY TRUCK FLOW GENERATION

The proposed optimization approach is applied to estimate truck OD flows by different weight categories for the State of Florida, including empty truck flows. Assuming the conservation of commodity and truck flows in a region, the optimization model minimizes an objective function with sum of squared errors to estimate truck flows with multiple truck-weight categories. The procedure attempts to estimate the truck flows for specific truck-weight categories between OD pairs in such a manner that the resulting traffic counts at different links, commodity flows between OD pairs, and truck flows between OD pairs closely match with those in the observed data, at a county level resolution. Furthermore, the estimated empty flows (where truck load is less than a threshold) are disaggregated into finer granularity to get better understanding about the empty flows. The study uses data that are readily available with the transportation agencies such as link level truck flows by weight from Weigh-in-Motion (WIM) sites, total link level truck flows from Telemetered Traffic Monitoring (TTM) sites, Origin-Destination (OD) matrix of truck flows in a region, OD matrix of commodity flows in a region, and finally the path flows for the truck traffic from the assignment stage in a four-step demand model.

The truck-weight categories considered in this study are (a) empty trucks (≤ 35kips), (b) partially loaded (35 kip-60 kip) and (c) fully loaded trucks (> 60kips). Prior to this, different categorization schemes are explored for truck-weight categories and for the determination of empty weight category. A variety of different scenarios were considered to arrive at appropriate weightages for different datasets used in the optimization program. For the final set of truck-weight categories and weightage scheme used in the study, a validation exercise was undertaken to compare the estimated truck traffic volumes and observed truck traffic volumes by weight at selected locations in the network. The validation results were satisfactory and highlighted the efficacy of the proposed method.

An interesting finding from the results is that states adjacent to Florida (Alabama and Georgia) attract more empty truck trips from Florida than other states. The estimated OD trip tables by weight category can be used for understanding the spatial distribution of empty flows and for formulating policies targeting the trade imbalance in the region.

Although the study gives satisfactory results, it can be improved in a few ways. The use of data on observed truck traffic volumes in neighboring states, improvisation to the optimization weightage factors for different error terms, and the inclusion of path flows using observed route choice patterns through the use of GPS data could improve the results.

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APPENDIX A: COMMODITY CONVERSION

Table A.91: Conversion of STCC Commodities to FCC Commodity Types (including subclasses)

FCC	FCC name	STCC	STCC Name
1	Agricultural products	100	Farm Products
		112	Cotton, raw
		113	Grain
		114	Oil Kernels, Nuts Or Seeds
		115	Field Seeds
		119	Misc. Field Crops
		121	Citrus Fruits
		122	Deciduous Fruits
		123	Tropical Fruits
		129	Misc. Fresh Fruits Or Tree Nuts
		131	Bulbs, roots Or Tubers
		133	Leafy Fresh Vegetables
		134	Dry Ripe Vegetable Seeds
		139	Misc. Fresh Vegetables
		141	Livestock
		142	Dairy Farm Products
		143	Animal Fibers
		151	Live Poultry
		152	Poultry Eggs
		191	Horticultural Specialties
		192	Animal Specialties
		199	Farm Prod, NEC
		800	Forest Products
		842	Barks Or Gums, crude
		861	Misc. Forest Products
		900	Fresh Fish Or Marine Products
		912	Fresh Fish Or Whale Products
		913	Marine Products
		989	Fish Hatcheries
2	Minerals	1000	Metallic Ores
		1011	Iron Ores
		1021	Copper Ores
		1031	Lead Ores
		1032	Zinc Ores
		1033	Lead And Zinc Ores Combined
		1041	Gold Ore
		1042	Silver Ore
		1051	Bauxite Or Other Alum Ores
		1061	Manganese Ores
		1071	Tungsten Ores
		1081	Chromium Ores
		1092	Misc. Metal Ores
		1400	Nonmetallic Minerals
		1411	Dimension Stone, quarry
		1421	Broken Stone Or Riprap
		1441	Gravel Or Sand
		1451	Clay Ceramic Or Refracted Minerals

FCC	FCC name	STCC	STCC Name
		1471	Chem. Or Fertilizer Mineral Crude
		1491	Misc. Nonmetallic Minerals, NEC
		1492	Water
3	Coal	1100	Coal
		1111	Anthracite
		1121	Bituminous Coal
		1122	Lignite
4	Food	2000	Food Or Kindred Products
		2011	Meat, Fresh Or Chilled
		2012	Meat, Fresh Frozen
		2013	Meat Products
		2014	Animal By-prod, inedible
		2015	Dressed Poultry, Fresh
		2016	Dressed Poultry, Frozen
		2017	Processed Poultry Or Eggs
		2021	Creamery Butter
		2023	Condensed, Evaporated Or Dry Milk
		2024	Ice Cream Or Rel Frozen Desserts
		2025	Cheese Or Special Dairy Products
		2026	Processed Milk
		2031	Canned Or Cured Sea Foods
		2032	Canned Specialties
		2033	Canned Fruits, vegetables, Etc.
		2034	Dehyd. Or Dried Fruit Or Vegetables
		2035	Pickled Fruits Or Vegetables
		2036	Processed Fish Products
		2037	Frozen Fruit, Vegetables Or Juice
		2038	Frozen Specialties
		2039	Canned Or Pres Food, Mixed
		2041	Flour Or Other Grain Mill Products
		2042	Prepared Or Canned Feed
		2043	Cereal Preparations
		2044	Milled Rice, Flour Or Meal
		2045	Blended Or Prepared Flour
		2046	Wet Corn Milling Or Milo
		2047	Dog, cat Or Other Pet Food, NEC
		2051	Bread Or Other Bakery Prod
		2052	Biscuits, Crackers Or Pretzels
		2061	Sugar Mill Prod Or By-prod
		2062	Sugar, Refined, Cane Or Beet
		2071	Candy Or Other Confectionery
		2082	Malt Liquors
		2083	Malt
		2084	Wine, brandy Or Brandy Spirit
		2085	Distilled Or Blended Liquors
		2086	Soft Drinks Or Mineral Water
		2087	Misc. Flavoring Extracts
		2091	Cottonseed Oil Or By-prod
		2092	Soybean Oil Or By-products
		2093	Nut Or Vegetables Oils Or By-products
		2094	Marine Fats Or Oils
		2095	Roasted Or Instant Coffee

FCC	FCC name	STCC	STCC Name
		2096	Margarine, shortening, Etc.
		2097	Ice, Natural Or Manufactured
		2098	Macaroni, spaghetti, Etc.
		2099	Misc. Food Preparations, NEC
5	Nondurable manufacturing	2100	Tobacco Products
		2111	Cigarettes
		2121	Cigars
		2131	Chewing Or Smoking Tobacco
		2141	Stemmed Or Re-dried Tobacco
		2200	Textile Mill Products
		2211	Cotton Broad-woven Fabrics
		2217	Cotton Broad-woven Fabrics
		2221	Man-made Or Glass Woven Fiber
		2222	Silk-woven Fabrics
		2231	Wool Broad-woven Fabrics
		2241	Narrow Fabrics
		2251	Knit Fabrics
		2271	Woven Carpets, mats Or Rugs
		2272	Tufted Carpets, rugs Or Mats
		2279	Carpets, mats Or Rugs, NEC
		2281	Yarn
		2284	Thread
		2291	Felt Goods
		2292	Lace Goods
		2293	Padding, upholstery Fill, etc.
		2294	Textile Waste, Processed
		2295	Coated Or Imprinted Fabric
		2296	Cord Or Fabrics, industrial
		2297	Wool Or Mohair
		2298	Cordage Or Twine
		2299	Textile Goods, NEC
		2300	Apparel Or Related Products
		2311	Men’s Or Boys Clothing
		2331	Women’s Or Children’s Clothing
		2351	Millinery
		2352	Caps Or Hats Or Hat Bodies
		2371	Fur Goods
		2381	Gloves, mittens Or Linings
		2384	Robes Or Dressing Gowns
		2385	Raincoats Or Other Rain Wear
		2386	Leather Clothing
		2387	Apparel Belts 23 89 Apparel, NEC
		2391	Curtains Or Draperies
		2392	Textile House furnishings
		2393	Textile Bags
		2394	Canvas Products
		2395	Textile Prod, pleated, Etc.
		2396	Apparel Findings
		2399	Misc. Fabricated Textile Products
		2500	Furniture Or Fixtures
		2511	Benches, chairs, Stools
		2512	Tables Or Desks

FCC	FCC name	STCC	STCC Name
		2513	Sofas, Couches, Etc.
		2514	Buffets, China Closets, Etc.
		2515	Bedsprings Or Mattresses
		2516	Beds, dressers, chests, Etc.
		2517	Cabinets Or Cases
		2518	Children's Furniture
		2519	Household Or Office Furniture, NEC
		2531	Public Building Or Related Furniture
		2541	Wood Lockers, partitions, Etc.
		2542	Metal Lockers, partitions, Etc.
		2591	Venetian Blinds, shades, Etc.
		2599	Furniture Or Fixtures, NEC
		3600	Electrical Equipment
		3611	Electric Measuring Instruments
		3612	Electrical Transformers
		3613	Switchgear Or Switchboards
		3621	Motors Or Generators
		3622	Industrial Controls Or Parts
		3623	Welding Apparatus
		3624	Carbon Prod For Electric Uses
		3629	Misc. Electrical Industrial Equipment
		3631	Household Cooking Equipment
		3632	Household Refrigerators
		3633	Household Laundry Equipment
		3634	Electric House wares Or Fans
		3635	Household Vacuum Cleaners
		3636	Sewing Machines Or Parts
		3639	Misc. Household Appliances
		3641	Electric Lamps
		3642	Lighting Fixtures
		3643	Current Carrying Wiring Equipment
		3644	Non-current Wiring Devices
		3651	Radio Or TV Receiving Sets
		3652	Phonograph Records
		3661	Telephone Or Telegraph Equipment
		3662	Radio Or TV Transmitting Equipment
		3671	Electronic Tubes
		3674	Solid State Semi conducts
		3679	Electronic Components
		3691	Storage Batteries Or Plates
		3692	Primary Batteries
		3693	X-ray Equipment
		3694	Electric Equip For Intern Comb Engine
		3699	Electrical Equipment, NEC
6	Lumber	2400	Lumber Or Wood Products
		2411	Primary Forest Materials
		2421	Lumber Or Dimension Stock
		2429	Misc. Sawmill Or Planing Mill
		2431	Millwork Or Cabinetwork
		2432	Plywood Or Veneer
		2433	Prefab Wood Buildings
		2434	Kitchen Cabinets, wood

FCC	FCC name	STCC	STCC Name
		2439	Structural Wood Prod, NEC
		2441	Wood Cont. Or Box Shooks
		2491	Treated Wood Products
		2492	Rattan Or Bamboo Ware
		2493	Lasts Or Related Products
		2494	Cork Products
		2495	Hand Tool Handles
		2496	Scaffolding Equip Or Ladders
		2497	Wooden Ware Or Flatware
		2498	Wood Prod, NEC
		2499	Misc. Wood Products
7	Chemicals	2800	Chemicals Or Allied Products
		2811	Industrial, Inorganic, Or Org Chemicals
		2812	Potassium Or Sodium Compound
		2813	Industrial Gases
		2814	Crude Prod Of Coal, gas, petroleum
		2815	Cyclic Intermediates Or Dyes
		2816	Inorganic Pigments
		2818	Misc. Industrial Organic Chemicals
		2819	Misc. Indus Inorganic Chemicals
		2821	Plastic Mater Or Synthetic Fibers
		2831	Drugs
		2841	Soap Or Other Detergents
		2842	Specialty Cleaning Preparations
		2843	Surface Active Agents
		2844	Cosmetics, perfumes, Etc.
		2851	Paints, Lacquers, Etc.
		2861	Gum Or Wood Chemicals
		2871	Fertilizers
		2879	Misc. Agricultural Chemicals
		2891	Adhesives
		2892	Explosives
		2893	Printing Ink
		2899	Chemical Preparations, NEC
		2800	Chemicals Or Allied Products
		2811	Industrial, Inorganic, Or Org Chemicals
		2812	Potassium Or Sodium Compound
		2813	Industrial Gases
		2814	Crude Prod Of Coal, gas, petroleum
		2815	Cyclic Intermediates Or Dyes
		2816	Inorganic Pigments
		2818	Misc. Industrial Organic Chemicals
		2819	Misc. Indus Inorganic Chemicals
		2821	Plastic Mater Or Synthetic Fibers
		2831	Drugs
		2841	Soap Or Other Detergents
		2842	Specialty Cleaning Preparations
		2843	Surface Active Agents
		2844	Cosmetics, perfumes, Etc.
		2851	Paints, Lacquers, Etc.
		2861	Gum Or Wood Chemicals
		2871	Fertilizers

FCC	FCC name	STCC	STCC Name
		2879	Misc. Agricultural Chemicals
		2891	Adhesives
		2892	Explosives
		2893	Printing Ink
		2899	Chemical Preparations, NEC
		4812	Flammable Liquids
		4814	Combustible Liquids
		4900	Hazardous Materials
		4906	Flammable Liquids
		4907	Flammable Liquids
		4908	Flammable Liquids
		4909	Flammable Liquids
		4912	Combustible Liquids
		4913	Combustible Liquids
		4914	Combustible Liquids
		4915	Combustible Liquids
		4916	Combustible Solids
		4917	Flammable Solids
		4918	Oxidizing Materials
		4919	Organic Peroxides
		4921	Poisons B, organic
		4923	Poisons B, inorganic
		4925	Irritating Materials - Etiologic Agents
		4926	Radioactive Materials
		4927	Radioactive Materials, Fissile Cl Iii
		4928	Radioactive Materials, Fissile Cl Ii
		4929	Radioactive Materials, Fissile Cl I
		4931	Corrosive Materials
		4932	Corrosive Materials
		4933	Corrosive Materials
		4934	Corrosive Materials
		4935	Corrosive Materials
		4936	Corrosive Materials
		4941	Other Regulated Materials Group A
		4944	Other Regulated Materials Group B
		4945	Other Regulated Material
		4960	Division 9 Environmentally Hazardous
		4961	Other Regulated Materials Group E
		4962	Other Regulated Materials Group E
		4963	Other Regulated Materials Group E
		4966	Other Regulated Materials Group E
8	Paper	2600	Pulp, paper Or Allied Products
		2611	Pulp Or Pulp Mill Products
		2621	Paper
		2631	Fiber, Paper Or Pulp board
		2642	Envelopes
		2643	Paper Bags
		2644	Wallpaper
		2645	Die-cut Paper Or Pulp board Products
		2646	Pressed Or Molded Pulp Goods
		2647	Sanitary Paper Products
		2649	Misc. Converted Paper Products

FCC	FCC name	STCC	STCC Name
		2651	Containers Or Boxes, paper
		2654	Sanitary Food Containers
		2655	Fiber Cans, Drums Or Tubes
		2661	Paper Or Building Board
		2700	Printed Matter
		2711	Newspapers
		2721	Periodicals
		2731	Books
		2741	Misc. Printed Matter
		2761	Manifold Business Forms
		2771	Greeting Cards, Seals, Etc.
		2781	Blank book, Loose Leaf Binder
		2791	Svc Indus For Print Trades
9	Petroleum products	1300	Crude Petrol. Or Natural Gas
		1311	Crude Petroleum
		1312	Natural Gas
		1321	Natural Gasoline
		2900	Petroleum Or Coal Products
		2911	Petroleum Refining Products
		2912	Liquefied Gases, coal Or Petroleum
		2951	Asphalt Paving Blocks Or Mix
		2952	Asphalt Coatings Or Felt
		2991	Misc. Coal Or Petroleum Products
		4904	Non Flammable Compressed Gases
		4905	Flammable Compressed Gases
10	Other durable manufacturing	1900	Ordnance Or Accessories
		1911	Guns, howitzers, mortars, Etc.
		1925	Guided Missiles Or Space Vehicle
		1929	Ammo Or Related Parts, NEC
		1931	Tracked Combat Vehicle Or Parts
		1941	Military Fire Control Equip
		1951	Small Arms, 30mm Or Less
		1961	Small Arms Ammo, 30mm Or Less
		1991	Misc. Ordnance Or Accessories
		3000	Rubber Or Misc. Plastics
		3011	Tires Or Inner Tubes
		3021	Rubber Or Plastic Footwear
		3031	Reclaimed Rubber
		3041	Rub Or Plastic Hose Or Belting
		3061	Fabricated Products
		3071	Misc. Plastic Products
		3072	Misc. Plastic Products
		3100	Leather Or Leather Products
		3111	Leather, finished Or Tanned
		3121	Industrial Leather Belting
		3131	Boot Or Shoe Cut Stock
		3141	Leather Footwear
		3142	Leather House Slippers
		3151	Leather Gloves Or Mittens
		3161	Leather Luggage Or Handbags
		3199	Leather Goods, NEC
		3300	Primary Metal Products

FCC	FCC name	STCC	STCC Name
		3311	Blast Furnace Or Coke
		3312	Primary Iron Or Steel Products
		3313	Electrometallurgical Products
		3315	Steel Wire, Nails Or Spikes
		3316	Cold Finishing Of Steel Shapes
		3321	Iron Or Steel Castings
		3331	Primary Copper Smelter Products
		3332	Primary Lead Smelter Products
		3333	Primary Zinc Smelter Products
		3334	Primary Aluminum Smelter Products
		3339	Misc. Prim Nonferrous Smelter Products
		3351	Copper Or Alloy Basic Shapes
		3352	Aluminum Or Alloy Basic Shapes
		3356	Misc. Nonferrous Basic Shapes
		3357	Nonferrous Wire
		3361	Aluminum Or Alloy Castings
		3362	Copper Or Alloy Castings
		3369	Misc. Nonferrous Castings
		3391	Iron Or Steel Forgings
		3392	Nonferrous Metal Forgings
		3399	Primary Metal Products, NEC
		3400	Fabricated Metal Products
		3411	Metal Cans
		3421	Cutlery, not Electrical
		3423	Edge Or Hand Tools
		3425	Hand Saws Or Saw Blades
		3428	Builders Or Cabinet Hardware
		3429	Misc. Hardware
		3431	Metal Sanitary Ware
		3432	Plumbing Fixtures
		3433	Heating Equip, not Electrical
		3441	Fabricated Structural Metal Products
		3442	Metal Doors, Sash, Etc.
		3443	Fabricated Plate Products
		3444	Sheet Metal Products
		3446	Architectural Metal Work
		3449	Metal Work
		3452	Bolts, Nuts, Screws, Etc.
		3461	Metal Stampings
		3481	Misc. Fabricated Wire Products
		3491	Metal Shipping Containers
		3492	Metal Safes Or Vaults
		3493	Steel Springs
		3494	Valves Or Pipe Fittings
		3499	Fabricated Metal Products, NEC
		3500	Machinery
		3511	Steam Engines, Turbines, Etc.
		3519	Misc. Internal Combustion Engines
		3522	Farm Machinery Or Equipment
		3523	Farm Machinery Or Equipment
		3524	Lawn Or Garden Equipment
		3531	Construction Machinery Or Equipment

FCC	FCC name	STCC	STCC Name
		3532	Mining Machinery Or Parts
		3533	Oil Field Machinery Or Equipment
		3534	Elevators Or Escalators
		3535	Conveyors Or Parts
		3536	Hoists, Industry Cranes, Etc.
		3537	Industrial Trucks, Etc.
		3541	Machine Tools, Metal Cutting
		3542	Machine Tools, Metal Forming
		3544	Special Dies, tools, jigs, etc.
		3545	Machine Tool Accessories
		3548	Metalworking Machinery
		3551	Food Prod Machinery
		3552	Textile Machinery Or Parts
		3553	Woodworking Machinery
		3554	Paper Industries Machinery
		3555	Printing Trades Machinery
		3559	Misc. Special Industry Mach
		3561	Industrial Pumps
		3562	Ball Or Roller Bearings
		3564	Ventilating Equipment
		3566	Mech. Power Transmission Equipment
		3567	Industrial Process Furnaces
		3569	Misc. General Industrial
		3572	Typewriters Or Parts
		3573	Electronic Data Proc Equipment
		3574	Accounting Or Calculating Equipment
		3576	Scales Or Balances
		3579	Misc. Office Machines
		3581	Automatic Merchandising Machines
		3582	Commercial Laundry Equipment
		3585	Refrigeration Machinery
		3589	Misc. Service Industry Machinery
		3592	Carburetors, Pistons, Etc.
		3599	Misc. Machinery Or Parts
		3700	Transportation Equipment
		3711	Motor Vehicles
		3712	Passenger Motor Car Bodies
		3713	Motor Bus Or Truck Bodies
		3714	Motor Vehicle Parts Or Accessories
		3715	Truck Trailers
		3721	Aircraft
		3722	Aircraft Or Missile Engines
		3723	Aircraft Propellers Or Parts
		3729	Misc. Aircraft Parts
		3732	Ships Or Boats
		3741	Locomotives Or Parts
		3742	Railroad Cars
		3751	Motorcycles, Bicycles Or Parts
		3769	Missile Or Space Vehicle Parts
		3791	Trailer Coaches
		3799	Transportation Equipment, NEC
		3800	Instruments, Photo Equipment, Optical Equip

FCC	FCC name	STCC	STCC Name
		3811	Engrg, Lab Or Scientific Equipment
		3821	Mechanical Measuring Or Control Equipment
		3822	Automatic Temperature Controls
		3831	Optical Instruments Or Lenses
		3841	Surgical Or Medical Instruments
		3842	Orthopedic Or Prosthetic Supplies
		3843	Dental Equipment Or Supplies
		3851	Ophthalmic Or Opticians Goods
		3861	Photographic Equip Or Supplies
		3871	Watches, Clocks, Etc.
		3900	Misc. Manufacturing Products
		3911	Jewelry, Precious Metal, Etc.
		3914	Silverware Or Plated Ware
		3931	Musical Instruments Or Parts
		3941	Games Or Toys
		3942	Dolls Or Stuffed Toys
		3943	Children’s Vehicle Or Parts, NEC
		3949	Sporting Or Athletic Goods
		3951	Pens Or Parts
		3952	Pencils, crayons, or Artists Materials
		3953	Marking Devices
		3955	Carbon Paper Or Inked Ribbons
		3961	Costume Jewelry Or Novelties
		3962	Feathers, Plumes, Etc.
		3963	Buttons
		3964	Apparel Fasteners
		3991	Brooms, Brushes, Etc.
		3992	Linoleum Or Other Coverings
		3993	Signs Or Advertising Displays
		3994	Morticians Goods
		3996	Matches
		3997	Furs, dressed Or Dyed
		3999	Manufactured Prod, NEC
		4901	Ammunition & Class A Explosives
		4902	Class B Explosives
		4903	Class C Explosives
11	Clay and stone	3200	Clay, concrete, glass Or Stone
		3211	Flat Glass
		3213	Laminated Safety Glass
		3221	Glass Containers
		3229	Misc. Glassware, blown Or Pressed
		3241	Portland Cement
		3251	Clay Brick Or Tile
		3253	Ceramic Floor Or Wall Tile
		3255	Refractories
		3259	Misc. Structural Clay Products
		3261	Vitreous China Plumbing Fixtures
		3262	Vitreous China Kitchen Articles
		3264	Porcelain Electric Supplies
		3269	Misc. Pottery Products
		3271	Concrete Products
		3273	Ready-mix Concrete, Wet

FCC	FCC name	STCC	STCC Name
		3274	Lime Or Lime Plaster
		3275	Gypsum Products
		3281	Cut Stone Or Stone Products
		3291	Abrasive Products
		3292	Asbestos Products
		3293	Gaskets Or Packing
		3295	Nonmetal Minerals, Processed
		3296	Mineral Wool
		3299	Misc. Nonmetallic Minerals
12	Waste	4000	Waste Or Scrap Materials
		4011	Ashes
		4021	Metal Scrap Or Tailings
		4022	Textile Scrap Or Sweepings
		4023	Wood Scrap Or Waste
		4024	Paper Waste Or Scrap
		4025	Chemical Or Petroleum Waste
		4026	Rubber Or Plastic Scrap
		4027	Stone, Clay Or Glass Scrap
		4028	Leather Waste Or Scrap
		4029	Misc. Waste Or Scrap
		4804	Waste Nonflammable Compressed Gases
		4805	Waste Flammable Compressed Gases
		4807	Waste Flammable Liquids
		4808	Waste Flammable Liquids
		4809	Waste Flammable Liquids
		4813	Waste Combustible Liquids
		4890	Regulated Waste Stream
		4891	Regulated Waste Stream
		4026	Rubber Or Plastic Scrap
		4027	Stone, Clay Or Glass Scrap
		4022	Textile Scrap Or Sweepings
		2294	Textile Waste, Processed
		4813	Waste Combustible Liquids
		4815	Waste Combustible Liquids
		4831	Waste Corrosive Materials
		4815	Waste Combustible Liquids
		4816	Waste Flammable Solids
		4817	Waste Flammable Solids
		4818	Waste Oxidizing Materials
		4821	Waste Poison B, Organic
		4823	Waste Poisonous Materials
		4825	Waste Etiologic Agents
		4829	Waste Radioactive Materials
		4831	Waste Corrosive Materials
		4832	Waste Corrosive Materials
		4835	Waste Corrosive Materials
		4836	Waste Corrosive Materials
		4845	Waste Other Regulated Materials, Group C
		4861	Waste Miscellaneous Hazardous Materials
		4862	Waste Misc. Hazardous Materials
		4863	Waste Miscellaneous Hazardous Materials
		4866	Waste Miscellaneous Hazardous Materials

FCC	FCC name	STCC	STCC Name
		4875	Waste Stream Other Regulated
13	Miscellaneous freight	4100	Misc. Freight Shipments
		4111	Misc. Freight Shipments
		4121	Special Commodities
		4192	Special Commodities
		4200	Shipping Containers
		4211	Shipping Containers
		4221	Semi-trailers Returned Empty
		4231	Empty Equipment, Reverse Route
		4300	Mail Or Contract Traffic
		4311	Mail And Express Traffic
		4321	Other Contract Traffic
		4400	Freight Forwarder Traffic
		4411	Freight Forwarder Traffic
		4500	Shipper Association Traffic
		4511	Shipper Association Traffic
		4600	Misc. Mixed Shipments
		4611	FAK Shipments
		4621	Mixed Shipments, Multi-STCC
		4700	Small Packaged Freight Shipments
		4711	Small Packaged Freight Shipments
14	Warehousing	5000	Secondary Traffic
		5021	Rail Intermodal Drayage to Ramp
		5022	Rail Intermodal Drayage from Ramp
		5031	Air Freight Drayage to Airport
		5032	Air Freight Drayage from Airport
15	Unknown	6000	Unclassified

APPENDIX B: ADDITIONAL DESCRIPTIVE ANALYSIS

As mentioned in Section 1.2.1.3.1 of this report, we include the commodity type analyses for the other four regions (Region 122, Region 123, Region 124 and Region 129) in this appendix.

Within Miami, bulk products such as non-metallic minerals (27%), gravel and crushed stone (22%), gasoline and aviation turbine fuel (11%), and natural sands (9%) comprised the top four shipped commodities.

Table B.92: Top 15 Commodities by Weight (Within Miami Region)

Commodity Type	Tonnage (%)
Nonmetallic mineral products	46,749 (26.86)
Gravel and crushed stone	37,940 (21.80)
Gasoline and aviation turbine fuel	18,443 (10.60)
Natural sands	15,462 (8.88)
Waste and scrap	12,779 (7.34)
Cereal grains	4,589 (2.64)
Other prepared foodstuffs and fats and oils	3,611 (2.07)
Animal feed and products of animal origin, (not elsewhere classified)	3,492 (2.01)
Commodity unknown	3,363 (1.93)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	3,290 (1.89)
Mixed freight	3,233 (1.86)
Machinery	2,170 (1.25)
Fuel oils	1,904 (1.09)
Other agricultural products	1,750 (1.01)
Alcoholic beverages	1,724 (0.99)

Cereal grains constituted approximately 25 percent of total tonnage shipped from Miami to other regions of Florida. Second highest commodity was waste and scrap which accounted for nearly 19 percent of total tonnage shipped.

Table B.93: Top 15 Commodities by Weight (Miami to Other Florida regions)

Commodity Type	Tonnage (%)
Cereal grains	6,589 (24.77)
Waste and scrap	5,031 (18.91)
Gravel and crushed stone	3,955 (14.87)
Nonmetallic mineral products	3,821 (14.36)
Gasoline and aviation turbine fuel	1,765 (6.63)
Fuel oils	1,165 (4.38)
Mixed freight	865 (3.25)
Other prepared foodstuffs and fats and oils	560 (2.10)
Other agricultural products	497 (1.87)
Animal feed and products of animal origin (not elsewhere classified)	468 (1.76)
Natural sands	419 (1.58)
Meat, fish, seafood, and their preparations	188 (0.71)
Wood products	131 (0.49)
Articles of base metal	106 (0.40)
Plastics and rubber	95 (0.36)

From other regions of Florida, waste and scrap was the topmost commodity shipped into Miami (33%) followed by non-metallic products accounting for 11 percent of the total weight.

Table B.94: Top 15 Commodities by Weight (Other Regions of Florida to Miami)

Commodity Type	Tonnage (%)
Waste and scrap	5,156 (33.20)
Nonmetallic mineral products	1,781 (11.47)
Other prepared foodstuffs and fats and oils	1,122 (7.23)
Mixed freight	851 (5.48)
Alcoholic beverages	714 (4.60)
Gravel and crushed stone	594 (3.82)
Fertilizers	497 (3.20)
Other agricultural products	451 (2.90)
Wood products	435 (2.80)
Base metal in primary or semi-finished form and in finished basic shapes	395 (2.54)
Basic chemicals	349 (2.25)
Miscellaneous manufactured products	315 (2.03)
Meat, fish, seafood, and their preparations	284 (1.83)
Chemical products and preparations (not elsewhere classified)	284 (1.83)
Natural sands	279 (1.80)

The top two commodities by tonnage shipped within Orlando were: non-metallic mineral products and gravel and crushed stone accounting for 33 percent and 21percent, respectively.

Table B.95: Top 15 Commodities by Weight (Within Orlando Region)

Commodity Type	Tonnage (%)
Nonmetallic mineral products	21,727 (32.63)
Gravel and crushed stone	14,233 (21.37)
Waste and scrap	6,733 (10.11)
Natural sands	6,257 (9.40)
Logs and other wood in the rough	2,629 (3.95)
Other agricultural products	2,369 (3.56)
Commodity unknown	1,847 (2.77)
Machinery	1,217 (1.83)
Other prepared foodstuffs and fats and oils	1,165 (1.75)
Mixed freight	1,067 (1.60)
Wood products	988 (1.48)
Articles of base metal	650 (0.98)
Fertilizers	633 (0.95)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	592 (0.89)
Base metal in primary or semi-finished form and in finished basic shapes	468 (0.70)

Gravel and crushed stone represented more than 50 percent (16 million tons) of the total tonnage shipped from Orlando to other regions of Florida. Second highest was waste and scrap which accounted for 1 percent of total tonnage.

Table B.96: Top 15 Commodities by Weight (Orlando to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gravel and crushed stone	16,019 (53.80)
Waste and scrap	3,512 (11.80)
Nonmetallic mineral products	1,926 (6.47)
Mixed freight	1,873 (6.29)
Other prepared foodstuffs and fats and oils	1,158 (3.89)
Wood products	904 (3.04)
Other agricultural products	641 (2.15)
Fertilizers	557 (1.87)
Chemical products and preparations, (not elsewhere classified)	528 (1.77)
Plastics and rubber	339 (1.14)
Milled grain products and preparations, bakery products	230 (0.77)
Pharmaceutical products	221 (0.74)
Base metal in primary or semi-finished form and in finished basic shapes	198 (0.67)
Miscellaneous manufactured products	196 (0.66)
Nonmetallic minerals (not elsewhere classified)	181 (0.61)

From others regions of Florida, gravel and crushed stone was the top commodity group shipped into Orlando (40%).

Table B.97: Top 15 Commodities by Weight (Other Regions of Florida to Orlando)

Commodity Type	Tonnage (%)
Gravel and crushed stone	15,207 (39.72)
Non-metallic mineral products	3,589 (9.38)
Waste and scrap	3,472 (9.07)
Fuel oils	2,400 (6.27)
Gasoline and aviation turbine fuel	2,325 (6.07)
Natural sands	1,869 (4.88)
Other agricultural products	1,446 (3.78)
Cereal grains	1,092 (2.85)
Other prepared foodstuffs and fats and oils	972 (2.54)
Wood products	888 (2.32)
Alcoholic beverages	721 (1.88)
Mixed freight	658 (1.72)
Miscellaneous manufactured products	502 (1.31)
Base metal in primary or semi-finished form and in finished basic shapes	372 (0.97)
Fertilizers	366 (0.96)

By weight, gasoline and aviation turbine fuel and gravel and crushed stone were the top two commodities moved within Tampa, each accounting for almost 19 percent of the total intraregional freight tonnage.

Table B.98: Top 15 Commodities by Weight (Within Tampa Region)

Commodity Type	Tonnage (%)
Gasoline and aviation turbine fuel	12,611 (19.31)
Gravel and crushed stone	12,470 (19.09)
Nonmetallic mineral products	9,630 (14.75)
Waste and scrap	6,179 (9.46)
Other agricultural products	2,808 (4.30)
Fuel oils	2,721 (4.17)
Fertilizers	2,573 (3.94)
Other prepared foodstuffs and fats and oils	2,047 (3.13)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	1,892 (2.90)
Commodity unknown	1,872 (2.87)
Natural sands	1,351 (2.07)
Machinery	950 (1.46)
Articles of base metal	782 (1.20)
Mixed freight	777 (1.19)
Wood products	741 (1.14)

From Tampa, gravel and crushed stone was shipped the most in quantity (23%) to other regions of Florida followed by gasoline and aviation turbine oil (15%).

Table B.99: Top 15 Commodities by Weight (Tampa to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gravel and crushed stone	7,409 (22.81)
Gasoline and aviation turbine fuel	4,775 (14.70)
Nonmetallic mineral products	3,940 (12.13)
Waste and scrap	3,390 (10.44)
Other prepared foodstuffs and fats and oils	2,151 (6.62)
Fertilizers	1,274 (3.92)
Fuel oils	1,264 (3.89)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	1,002 (3.08)
Nonmetallic minerals, (not elsewhere classified)	944 (2.91)
Motorized and other vehicles (including parts)	792 (2.44)
Mixed freight	771 (2.37)
Animal feed and products of animal origin, (not elsewhere classified)	739 (2.28)
Other agricultural products	679 (2.09)
Miscellaneous manufactured products	502 (1.55)
Milled grain products and preparations, bakery products	422 (1.30)

Mineral and kindred products and agricultural and food products comprised the top ten commodity groups transported into Tampa from other regions of Florida with Gravel and crushed stone representing the highest percentage (33%) followed by non-metallic minerals accounting for 5 million or nearly 13 percent of total tonnage shipped into Tampa.

Table B.100: Top 15 Commodities by Weight (Other Regions of Florida to Tampa)

Commodity Type	Tonnage (%)
Gravel and crushed stone	13,425 (32.86)
Nonmetallic minerals, (not elsewhere classified)	5,353 (13.10)
Fertilizers	4,013 (9.82)
Waste and scrap	3,505 (8.58)
Other agricultural products	3,021 (7.40)
Cereal grains	1,719 (4.21)
Nonmetallic mineral products	1,056 (2.59)
Natural sands	1,047 (2.56)
Other prepared foodstuffs and fats and oils	881 (2.16)
Basic chemicals	875 (2.14)
Miscellaneous manufactured products	835 (2.04)
Mixed freight	776 (1.90)
Wood products	689 (1.69)
Alcoholic beverages	610 (1.49)
Animal feed and products of animal origin, (not elsewhere classified)	410 (1.00)

Within rest of Florida, gravel and crushed stone represented the highest quantity shipped (22%) followed by non-metallic mineral products which accounted for almost 20 percent of total tonnage shipped.

Table B.101: Top 15 Commodities by Weight (Within Rem. of Florida Region)

Commodity Type	Tonnage (%)
Gravel and crushed stone	44,438 (25.29)
Nonmetallic mineral products	35,447 (20.17)
Logs and other wood in the rough	15,341 (8.73)
Waste and scrap	13,286 (7.56)
Natural sands	12,967 (7.38)
Nonmetallic minerals, (not elsewhere classified)	8,523 (4.85)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	4,675 (2.66)
Other agricultural products	4,155 (2.36)
Wood products	4,029 (2.29)
Other prepared foodstuffs and fats and oils	3,750 (2.13)
Cereal grains	3,733 (2.12)
Commodity unknown	3,335 (1.90)
Gasoline and aviation turbine fuel	2,850 (1.62)
Basic chemicals	2,349 (1.34)
Fertilizers	2,290 (1.30)

From rest of Florida, gravel and crushed stone was the top most commodity group exported to the other regions of Florida (25%). The second highest commodity shipped from this region was waste and scrap which constituted almost 12 percent of the total tonnage.

Table B.102: Top 15 Commodities by Weight (Rem. of Florida to Other Regions of Florida)

Commodity Type	Tonnage (%)
Gravel and crushed stone	13,294 (25.52)
Waste and scrap	6,427 (12.34)
Nonmetallic minerals n.e.c.*	5,376 (10.32)
Other agricultural products	4,984 (9.57)
Fertilizers	4,576 (8.79)
Natural sands	3,180 (6.11)
Cereal grains	2,625 (5.04)
Other prepared foodstuffs and fats and oils	1,1617 (3.11)
Wood products	1,604 (3.08)
Basic chemicals	1,360 (2.61)
Miscellaneous manufactured products	1,198 (2.30)
Nonmetallic mineral products	1,096 (2.10)
Mixed freight	702 (1.35)
Animal feed and products of animal origin, (not elsewhere classified)	562 (1.08)
Meat, fish, seafood, and their preparations	544 (1.04)
Live animals and live fish	469 (0.90)

Four of the top five commodities imported to the remainder of the Florida region belonged to the minerals, petroleum and waste commodity groups.

Table B.103: Top 15 Commodities by Weight (Other Regions of Florida to Rem. of Florida)

Commodity Type	Tonnage (%)
Gravel and crushed stone	10,265 (18.14)
Nonmetallic mineral products	7,176 (12.68)
Cereal grains	6,954 (12.29)
Waste and scrap	5,591 (9.88)
Gasoline and aviation turbine fuel	4,310 (7.62)
Articles of base metal	3,260 (5.76)
Mixed freight	2,576 (4.55)
Other prepared foodstuffs and fats and oils	2,098 (3.71)
Fertilizers	1,603 (2.83)
Fuel oils	1,552 (2.74)
Alcoholic beverages	1,505 (2.66)
Wood products	1,299 (2.29)
Other agricultural products	1,188 (2.10)
Animal feed and products of animal origin, (not elsewhere classified)	1,059 (1.87)
Nonmetallic minerals, (not elsewhere classified)	1,026 (1.81)
Coal and petroleum products, (not elsewhere classified) (includes natural gas)	892 (1.58)