CFIRE

Assessing Sustainable Freight Policies

CFIRE 07-04
May 2014

National Center for Freight & Infrastructure Research & Education
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Technical Report Documentation Page

1. Report No. CFIRE 07-04	2. Government Accession No.	3. Recipient's Catalog No. **CFDA 20.701**
4. Title and Subtitle **Assessing Sustainable Freight Policies**		5. Report Date May 2014
		6. Performing Organization Code
7. Author/s Seyed Mehdi Mahmoudifard, Sanghyeon Ko, and Kouros Mohammadian		8. Performing Organization Report No. **CFIRE 07-04**
9. Performing Organization Name and Address National Center for Freight and Infrastructure Research and Education (CFIRE) University of Wisconsin-Madison 1415 Engineering Drive, 2205 EH Madison, WI 53706		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. **DTRT06-G-0020; 428K956**
12. Sponsoring Organization Name and Address Research and Innovative Technology Administration U.S. Department of Transportation 1200 New Jersey Ave, SE Washington, D.C. 20590		13. Type of Report and Period Covered **Final Report (11/1/2012 – 5/31/2014)**
		14. Sponsoring Agency Code

15. Supplementary Notes
Project completed for USDOT's RITA by CFIRE.

16. Abstract
The main aim of the study was to examine transportation demand management strategies related to long haul freight. It investigates freight movements and truck vehicle miles traveled (TVMT) changes in response to certain transportation policies, including a national-level and two local policies. In the first scenario, the effects of Panama Canal expansion project and expected shifting of demands between ports on truck volumes of the interstate highway system are studied. This essentially results in a new freight origin and destination matrix that was consequently assigned to the highway network. Such a network analysis reveals the changes in the entire truck network and the congested areas, as well as the total Truck Mileage Traveled. In addition, establishing truck consolidation centers scenario was considered in that shipments that are less than truck load are banned from entering a specific region. The results show that such policies can potentially reduce the total Truck Mileage Traveled, and therefore generating less emission. The last policy prescription was to implement a truck curfew policy in Chicago region. The study examines the effects of such policies and presents sensitivity analysis with respect to each scenario.
Furthermore, the study presents an efficient method for disaggregating Freight Analysis Framework (FAF) data. FAF provides estimates of tonnages and values for different types of commodities between states and major metropolitan areas. This database establishes a good resource for analyzing the movements and behavior of freight in the U.S. However FAF data is aggregated and transportation planners and decision makers need to disaggregate the data to obtain more detailed picture of freight movements in the U.S. The study successfully disaggregates FAF data into county level.

17. Key Words **Freight Policies, Freight Analysis framework, Sustainability**	18. Distribution Statement **No restrictions. This report is available through the Transportation Research Information Services of the National Transportation Library.**		
19. Security Classification (of this report) **Unclassified**	20. Security Classification (of this page) **Unclassified**	21. No. Of Pages 43	22. Price **-0-**

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Table of Contents

List of Tables

List of Figures

1. Introduction

Climate change and its potential impacts on all aspects of human life have been increasingly highlighted in recent years. It is believed that human activities and natural events are the reasons for global warming (*1*). This is mainly attributed to the ever increasing “greenhouse” gases (GHG) such as Carbon Dioxide (CO_2), while it is known that transportation is responsible for about 28% of the total GHG. Furthermore, as shown in Figure 2, 49% of this total emission is related to trucks` movements; among which 21% are heavy duty trucks and 28% are light duty trucks (2).

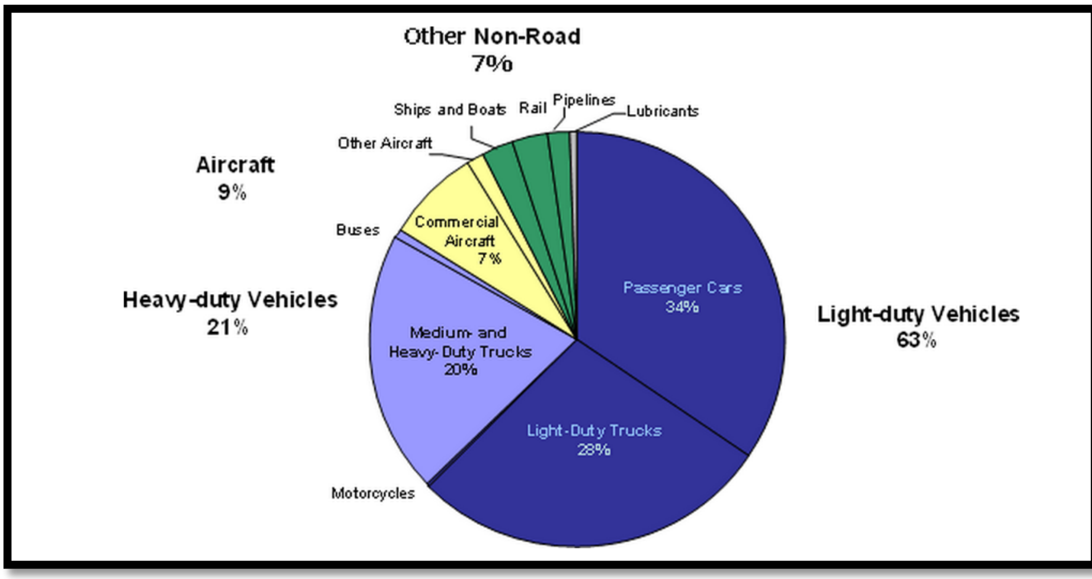

FIGURE 1: U.S. TRANSPORTATION GREENHOUSE GAS EMISSIONS BY SOURCES IN TERA GRAMS CO_2 EQUIVALENT, 2006

(US-DOT (2))

Various sectors of the economy contribute to GHG emissions. As shown in Figure 2, in the state of Illinois, emission related to transportation accounts for 25% of total emissions. Like many other US states, the most important greenhouse gas in Illinois is CO_2 which encompasses 89% of the total GHG emissions (Figure 3). The second most emitted gas is Illinois is N_2O with a 5% of total share (*3*).

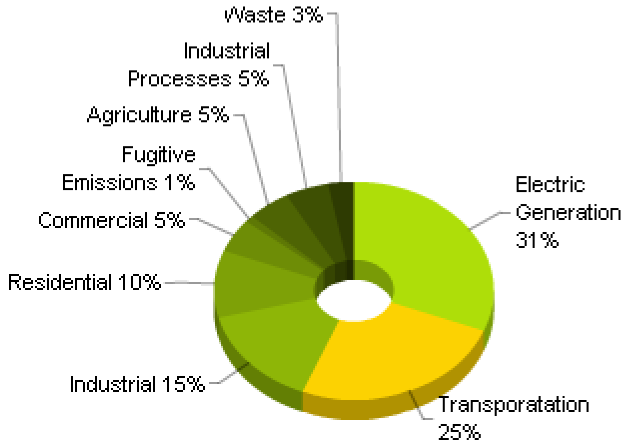

FIGURE 2: ILLINOIS GHG EMISSIONS BY ECONOMIC SECTOR (3)

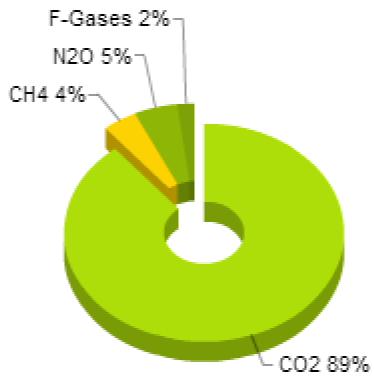

FIGURE 3: ILLINOIS GHG EMISSIONS BY TYPE (3)

While the concern about the ever increasing transportation related emissions draws more attention to the efficiency of the transportation system, freight movement which is dominantly by truck mode has been continuously increasing in the U.S. (4). Additionally, Truck mode is considered to have significant effects on various other economic activities. However, compared to passenger travel demand models, less attention has been given to freight transportation system. Scarcity and exclusivity of data are said to be the reasons for not using more advanced techniques to model freight transportation system (5).

One can postulate that significant reduction in GHG emissions cannot be achieved due to marginal and secondary impacts of any policy with the direct goal of reducing GHG emissions; however, due to the scale of the problem, even a simple action that can reduce the emission is considered as a step forward and essential towards the bigger goal of a more sustainable transportation system.

This study investigates the potential impacts of implementing three alternative policies in the field of freight movements with the goal of evaluating their effectiveness with respect to Truck Vehicle Miles Traveled (TVMT) and subsequently their potential emissions reductions.

2. Background

Freight data sources, while imposing different aggregation levels, present a variety of attributes that in many cases are not consistent. This usually becomes a reason to identify the source characteristics and to combine several data sources for modeling and analyzing different aspects of commodity movements. There are three major sources of freight movement data that are typically considered in transportation studies. The most frequently used, and of course most expensive one, is TRANSEARCH. This dataset contains freight movement information for 50 states and 3,145 U.S. counties in that the main input data is Motor Carrier Data Exchange Program (6). It also provides the O-D matrix for all U.S. counties. One of the main limitations of TRANSEARCH is its cost for academic research. The dataset is also limited to four modes of rail, truck, domestic water and air shipments. The next dataset is Commodity Flow Survey (CFS) which presents the shipment information in 50 states and Washington DC in an origin-destination format (7). However, in this dataset, some industries are not considered, including services, transportation, construction, and retail industries. These kinds of limitations make CFS an incomplete dataset because it only covers about 54% of the total freight shipment tonnage. Furthermore, in some cases, there are also empty cells when the O-D matrix is carefully examined. This is due to lack of data or small sample size that makes these cells empty.

The third source of data is Freight Analysis Framework (FAF) which is released by Federal Highway Administration (FHWA). The most recent version of FAF dataset is its third version which is a revised and advanced version of CFS 2007 that also offers information for the empty cells (8). FAF integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation.

With data from the 2007 Commodity Flow Survey and additional sources, FAF version 3 (FAF3) provides estimates of tonnage, value, and domestic ton-miles by region of origin and destination, commodity type (see Table 1), and modes (see Table 2) for 2007 (the most recent year) as well as the future years through 2040. Commodities in FAF are classified according to Standard Classification of Transported Goods (SCTG).

Table 1: FAF3 Commodity Codes

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

Table 2: FAF3 Modes of Transportation

Code	Mode	Description
1	Truck	Includes private and for-hire truck. Does not include truck that is part of ***Multiple Modes and Mail*** or truck moves in conjunction with domestic air cargo.
2	Rail	Includes any common carrier or private railroad. Does not include rail that is part of ***Multiple Modes and Mail***.
3	Water	Includes shallow draft, deep draft, Great Lakes and intra-port shipments. Does not include water that is part of ***Multiple Modes and Mail***.
4	Air (includes truck-air)	Includes shipments typically weighing more than 100 pounds that move by air or a combination of truck and air in commercial or private aircraft. Includes air freight and air express. Does not include shipments weighing 100 pounds or less which are typically classified with ***Multiple Modes and Mail***. In the case of imports and exports by air, domestic moves by ground to and from the port of entry or exit are categorized with ***Truck***.
5	Multiple Modes and Mail	Includes shipments by multiple modes and by parcel delivery services, U.S. Postal Service, or couriers. This category is not limited to containerized or trailer-on-flatcar shipments.
6	Pipeline	Includes crude petroleum, natural gas, and product pipelines. Note: Does include flows from offshore wells to land which are counted as ***Water*** moves by the U.S. Army Corps of Engineers. Does not include pipeline that is part of ***Multiple Modes and Mail***.
7	Other and Unknown	Includes movements not elsewhere classified such as flyaway aircraft, and shipments for which the mode cannot be determined.
8	No Domestic Mode	Includes shipments that have an international mode, but no domestic mode and is limited to import shipments of crude petroleum transferred directly from inbound ships to a U.S. refinery at the zone of entry. This is done to ensure a proper accounting of import flows, while avoiding assigning flows to the domestic transportation network that do not use it.

Concerning the spatial representation, FAF defines its regions according to consolidated metropolitan statistical areas (CMSAs), metropolitan statistical areas (MSAs), states or remainder of states, so the zones could be as big as a state. In the third version (i.e., FAF3), there are 123 domestic FAF zones in the U.S. For example, the state of Illinois includes three FAF zones of 171, 172, and 179 which encompass a total of 102 counties. It is clear that these large zones are not appropriate for testing freight policies. Disaggregating these three FAF zones into 102 counties would help decision makers to better understand the nature of the inter-state freight movements. This will also enable users to enhance their vision through freight flows and its distribution into the network.

Disaggregation into county level has been done by several other states including California, New Jersey, Florida, and Wisconsin. Most of these studies disaggregate FAF data according to industrial aspects of each county or TVMT data. In the California study, a very simple factor is used to disaggregate the data. This factor was the ratio of TVMT of each county to the mother

FAF region. This ratio was used for both the attraction and production parts (9). However, the method does not consider the effects of empty trucks that are moving in the network. While this method seems to be straightforward and simple to apply, one may find it to be inaccurate. In a similar attempt in New Jersey, they used TVMT and other economic factors to disaggregate FAF data (10). They also mentioned that if there would be a bridge between North American Industry Classification System (NAICS) and SCTG in terms of attraction, the results would be more accurate. Using the supplier selection and commodity consumption, such a bridge can be produced to get better results from the disaggregation of FAF.

In a study in the state of Florida, employment and industrial aspects of each county were considered as the main factors for disaggregating the FAF data. Researchers used the three digit NAICS, population and total employment data to carry out the analysis. They also compared the results with the TRANSEARCH dataset (11). In another study for the state of Wisconsin, all methods of disaggregation were investigated and finally they presented a case study to apportion machinery commodities in the county level.

3. Data

Several different data sources are used in this study including Freight Analysis Framework (FAF), County Business Pattern (CBP), Input-Output tables, and other supplementary datasets. This section briefly introduces those data sources.

3.1. Illinois FAF Data Review

Illinois consist of three FAF zones. These zones are Chicago (zone 171), St. Louis (zone 172), and remainder of Illinois (zone 179). Collectively they encompass a total of 102 counties. Figure 4 and Table 3 show these zones and the counties in each zone. Although in this study, disaggregation process is performed for the entire state of Illinois, due to the specific focus of the study, the analysis is concentrated on 6 counties of Cook, DuPage, Kane, Lake, McHenry, and Will. These counties are all in FAF-171.

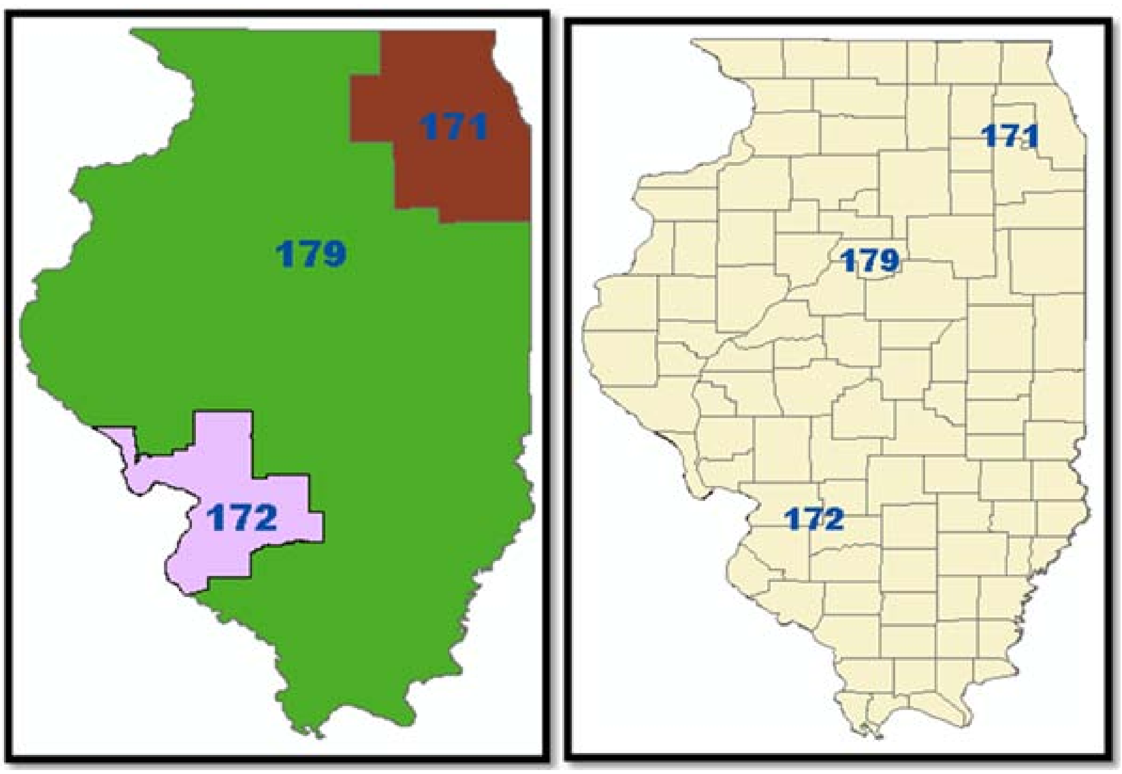

FIGURE 4: ILLINOIS FAF3 ZONES

Table 3: Illinois Counties Comprising FAF3 Zones

FAF Zone	County	Population	Area sq mi	FAF Zone	County	Population	Area sq mi
171	Cook	5,194,675	946	179	Jefferson	38,827	571
171	DeKalb	105,160	634	179	Jo Daviess	22,678	601
171	Du Page	916,924	334	179	Johnson	12,582	346
171	Grundy	50,063	420	179	Knox	52,919	716
171	Kane	515,269	521	179	LaSalle	113,924	1,135
171	Kankakee	113,449	678	179	Lawrence	16,833	372
171	Kendall	114,736	321	179	Lee	36,031	725
171	Lake	703,462	448	179	Livingston	38,950	1,044
171	McHenry	308,760	604	179	Logan	30,305	618
171	Will	677,560	837	179	Macon	110,768	581
172	Bond	17,768	380	179	Marion	39,437	572
172	Calhoun	5,089	254	179	Marshall	12,640	386
172	Clinton	37,762	474	179	Mason	14,666	539
172	Jersey	22,985	369	179	Massac	15,429	239
172	Macoupin	47,765	864	179	McDonough	32,612	589
172	Madison	269,282	725	179	McLean	169,572	1,184
172	Monroe	32,957	388	179	Menard	12,705	314
172	St. Clair	270,056	664	179	Mercer	16,434	561
179	Adams	67,103	857	179	Montgomery	30,104	704
179	Alexander	8,238	236	179	Morgan	35,547	569
179	Boone	54,165	281	179	Moultrie	14,846	336
179	Brown	6,937	306	179	Ogle	53,497	759
179	Bureau	34,978	869	179	Peoria	186,494	620
179	Carroll	15,387	444	179	Perry	22,350	441
179	Cass	13,642	376	179	Piatt	16,729	440
179	Champaign	201,081	997	179	Pike	16,430	830
179	Christian	34,800	709	179	Pope	4,470	371
179	Clark	16,335	502	179	Pulaski	6,161	201
179	Clay	13,815	469	179	Putnam	6,006	160
179	Coles	53,873	508	179	Randolph	33,476	578
179	Crawford	19,817	444	179	Richland	16,233	360
179	Cumberland	11,048	346	179	Rock Island	147,546	427
179	DeWitt	16,561	398	179	Saline	24,913	383
179	Douglas	19,980	417	179	Sangamon	197,465	868
179	Edgar	18,576	624	179	Schuyler	7,544	437
179	Edwards	6,721	222	179	Scott	5,355	251
179	Effingham	34,242	479	179	Shelby	22,363	759
179	Fayette	22,140	716	179	Stark	5,994	288
179	Ford	14,081	486	179	Stephenson	47,711	564
179	Franklin	39,561	412	179	Tazewell	135,394	649
179	Fulton	37,069	866	179	Union	17,808	416
179	Gallatin	5,589	324	179	Vermilion	81,625	899
179	Greene	13,886	543	179	Wabash	11,947	224
179	Hamilton	8,457	435	179	Warren	17,707	543
179	Hancock	19,104	795	179	Washington	14,716	563
179	Hardin	4,320	178	179	Wayne	16,760	714
179	Henderson	7,331	379	179	White	14,665	495
179	Henry	50,486	823	179	Whiteside	58,498	685
179	Iroquois	29,718	1,116	179	Williamson	66,357	424
179	Jackson	60,218	588	179	Winnebago	295,266	514
179	Jasper	9,698	494	179	Woodford	38,664	528

Freight Flow in *Illinois*

Extracted from FAF3, freight movements by different modes for the state of Illinois are compared in Table4 for the base year 2007 and future year 2040. Similar percentages of freight distributions for all modes are observed for both years with the same rank orders, where the truck is the main mode. It is shown that the truck mode is increased from 2007 to 2040 for interstate shipments. This data was later used for network assignment and further analysis in TransCAD software.

Table 4: Shipments by Weight for 2007 and 2040 (Thousands of Tons) for Illinois

2007						
Mode	Intrastate		Outbound		Inbound	
	Tonnage	%	Tonnage	%	Tonnage	%
Truck	488537.8	85.1	138045.9	40.0	153002.6	44.3
Rail	12120.7	2.1	65060.7	18.9	108921.5	31.5
Water	15702.6	2.7	51452.4	14.9	17598.4	5.1
Air (include truck-air)	0.0084	0	235.9	0.07	371.9	0.1
Multiple modes & mail	4437.9	0.7	50136.4	14.5	17488.5	5.1
Pipeline	48948	8.5	34323	9.9	45509.7	13.2
Other and unknown	3762.8	0.6	5701	1.7	2621.7	0.8
Total	573510	100.0	344955.2	100.0	345514.3	100.0
2040						
Mode	Intrastate		Outbound		Inbound	
	Tonnage	%	Tonnage	%	Tonnage	%
Truck	559311	87.1 ↑	241519.5	45 ↑	259496.8	47.8 ↑
Rail	53453.3	8.31 ↓	82834.8	15.4 ↓	127772.8	23.5 ↓
Water	20571.2	3.2 ↑	73037.3	13.6 ↓	38032.8	7 ↑
Air (include truck-air)	0.0126	0	871.3	0.2 ↑	1683.6	0.3 ↑
Multiple modes & mail	4420.1	0.7	117834.5	22 ↑	48997.6	9 ↑
Pipeline	659.8	0.11 ↓	13752.1	2.6 ↓	61959.5	11.4 ↓
Other and unknown	3896.8	0.61 ↑	6544.6	1.2 ↓	4689.7	0.9 ↑
Total	642312.3	100.0	536394.2	100.0	542632.7	100.0

As shown in the Table 4, for short distance shipments (e.g., Intrastate), truck is the dominant mode of shipment. Trucks are also considered as the dominant mode for long distance shipments, both inbound and outbound, although with lower mode share. Outbound commodity flows from Illinois totaled 345 million tons in 2007. Trucks carried a total of this tonnage (138 million tons, or 40 percent). Table 4 also shows that 44% of the inbound shipments in 2007 were by truck mode. Examining the forecasted values for the year 2040 also reconfirms the importance of truck mode. Although FAF forecasts are extrapolation of the current trends, they do not reflect major shifts in future capacity limitations, the national economy or changes in transportation costs and technology. However, as a brief aspect of future freight movement, FAF forecasts could be useful.

3.2. County Business Pattern Data

In this study we have utilized County Business Pattern (CBP) data along with Input-Output tables for disaggregation of FAF data into county level.

The annual County Business Patterns (CBP) is an annual series that provides subnational economic data by industry. The dataset includes the number of establishments, employment during the week of March 12, first quarter payroll, and annual payroll. The dataset has been shown to be useful for researching the economic activities of small areas; analyzing economic changes over time; and as a benchmark for other surveys, and statistical series. Market researchers have utilized CBP for analyzing market potential, measuring the effectiveness of sales and advertising programs. Many government agencies also use CBP for administration and planning purposes.

The CBP dataset also includes ZIP Code Business Patterns (ZBP) data which contains the number of establishments by employment-size classes and by detailed industry in the U.S.

3.3. Input-Output Tables

The U.S. Bureau of Economic Analysis (BEA) provides information about economic activities. Annual industry accounts are combinations of the integrated gross-domestic-product (GDP) by industry and annual input-output (I-O) accounts. This annual industry accounts publish data of the U.S. economic structures in detail compromising the annual contributions of private industries and governments to the Nation's GDP, the annual flow of goods and services used in the production processes of industries, and the final uses that comprise GDP in BEA`s national income and product accounts (NIPAs).

The North American Industry Classification System of the United States (NAICS) is provided to define various industries. It covers 61 private industries as well as 4 government classifications. This publication is usually available after 11 months from the end of the reference year.

The GDP-by-industry accounts contain estimated values which are added by industry, for 20 private industry groups and 2 government classifications. From this added value, the contribution of each industry group to the National's GDP can be estimated. This can be calculated as the difference between an industry's gross output (sales or receipts and other operating income, commodity taxes, and inventory change) and its intermediate inputs (energy, raw materials, semi-finished goods, and purchased services). Published data also contain an industry's gross output and intermediate inputs including compensation of employees, gross operating surplus, and taxes on production and imports less subsidies, in current U.S. dollars. Also, industries publish chain-type price and quantity indexes of gross output, intermediate inputs, and value. Furthermore, the publication contains each industry group's GDP contribution with the percent change.

The GDP-by-industry accounts allow us to overview the U.S. economic structure and importance of GDP contributions from industries, including:

- Changes of labor and capital shares
- Changes of production, capacity, and production across industries
- Comparisons of price changes across industries

4. Methodology

4.1. FAF disaggregation

As noted before, the Freight Analysis Framework (FAF) provides estimates of tonnages and values for different types of commodities that are moved between states and major metropolitan areas. This database establishes a good resource for analyzing the movements of freight in the United States. However FAF data is provided only in aggregate level in FAF zone level where each zone could be as large as a state. Over the past few years, transportation planners and decision makers have considered various approaches to disaggregate the data into a smaller geography in order to obtain more detailed picture of freight movements. The most recent version of FAF data, called FAF3, encompasses the necessary data elements that are required in this study.

<u>Firm synthesize</u>

Commodity Generation and Consumption

Data is expensive and in many studies data collection is considered as the most costly task of each project. In case of freight movements, many analysts use available data sources, while others suggest gathering new and more detailed data. There is also the option of using commercial databases such as Transearch. In this project we will use publicly available datasets such as FAF3. However, the main question here is whether and how we can disaggregate this database into a smaller geography (e.g., county level). To do that, one should investigate how a county can attract a specific type of commodity or how it may generate that. It should be noted that an industry may produce just one type of commodity but at the same time it may need different types of commodities to consume.

The CBP data provides each county`s employment and businesses data. In addition, there are few datasets presenting a bridge between NAICS industries and corresponding commodities that each industry produces. So if one plans to examine the production of various commodities in each county, there should not be a serious problem. However, there is no detailed cross-tab for the attraction part and before such analysis is performed; a cross-tab should be produced for the commodity attraction of the Input-Output (I-O) accounts. In such databases, there are different types of information; including the information on the type of industries that make or use certain type of commodities. It should also provide information on the values of other commodities needed to produce a unit output within an industry. To further complicate the problem, it should be noted that the I-O account dataset uses its own classification code for the industry and commodity types, which are different from those used in CBP. As a result, the analyst first needs to develop a relation between SCTG commodities and I-O commodities, as well as between NAICS industry codes and I-O account Industry codes.

Since it is easier to obtain the production of each industry, there is a cross-walk table that shows which industry makes what type of commodities, in terms of both NAICS and I-O account codes. Therefore, we should be able to use such data and come up with a relationship between SCTG commodity codes and I-O account commodity codes. Then, utilizing the make and use table we can have a crosstab for the consumption part with both codes. Figures 5 and 6 illustrate this process.

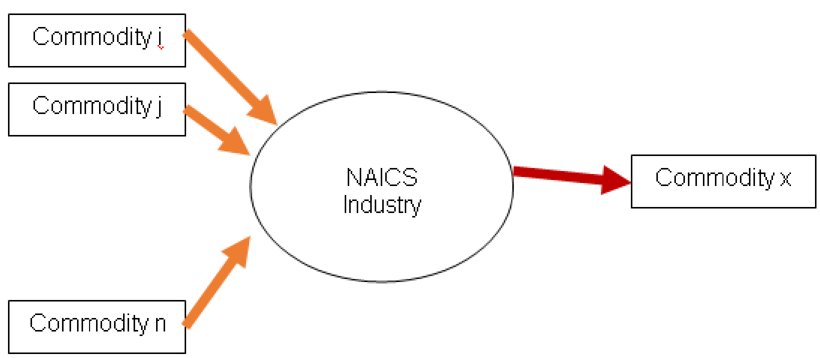

FIGURE 5: CONSUMPTION AND PRODUCTION PROCESS

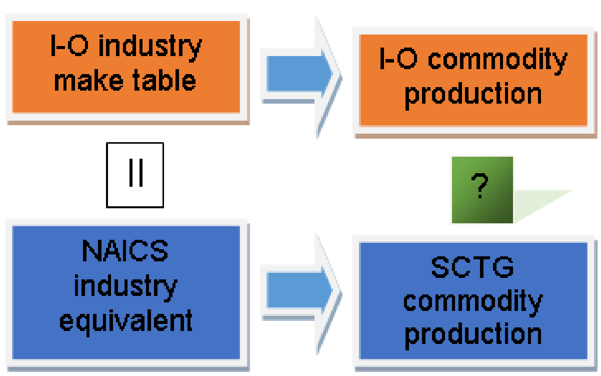

FIGURE 6: INTERACTION BETWEEN DIFFERENT DATABASE CODES

Methodology for Disaggregating FAF data in Illinois

Different methods of disaggregation of FAF data that are proposed in the literature are constrained by the availability of data. It should be noted that the consumption of a commodity does not only depend on the industrial aspects of the region. In fact, many other factors should be considered. For example food consumption can be seen as more related to regional population than any other industrial factors. Thus, the analysis would not be complete if only the employment and industrial data are considered. In this study each type of commodity is apportioned logically with respect to available data and the choice of appropriate criteria. We have adopted the following procedure for disaggregating the FAF data in the state of Illinois.

First, industries are mapped to their corresponding commodities according to the Input-Output (IO) data and the BEA dataset. In addition to the employment data and in order to make the disaggregation more accurate, few other local data like Farm Land use, Population, livestock production and mineral production data were obtained and considered in the analysis. Then, apportioning the data was performed by considering all the available data as presented in table 5.

Table 5: Apportioning Criteria for Each Commodity

SCTG	Production criteria	Attraction criteria
1,2,3,6,7,9	farm land use	population
4	livestock data	livestock data
5	livestock data	population
8, 11, 12, 13, 14, 20, 21, 23, 24, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 43	D8*	D8*
10, 16, 17, 18, 27	D8*	Population
15,19	minerals data (The Illinois Coal Industry)	D8*
22	farm land use	farm land use
25,26	land use for forests	population
99	population	population

*: NAICS 6-digit commodity specific industry employment

4.2. Converting Tonnage to Trucks

States collect local data on number of trucks passing particular section of their network. However, there are no special data on how many trucks are transporting certain amount of goods between specific origins and destinations. The FAF data contains the forecasts of freight tonnage movements between FAF zones with no information on the number of trucks. As a result, a procedure was developed to solve this issue.

A dataset from Vehicle Inventory and Use Survey (VIUS) of 2002 was the primary data source for developing the Tons-To-Trucks allocation procedure. This database contains information about physical and operational characteristics of different types of trucks. The procedure could be illustrated in five steps (12) which are also shown in Figure 7:

- identify the primary truck configurations and major truck body types;
- allocate commodities to truck configurations that are used to transport those commodities;
- estimate the average payloads by vehicle group and body type;
- convert the commodity tons to the equivalent number of trucks; and
- estimate the percentage of the empty truck trips.

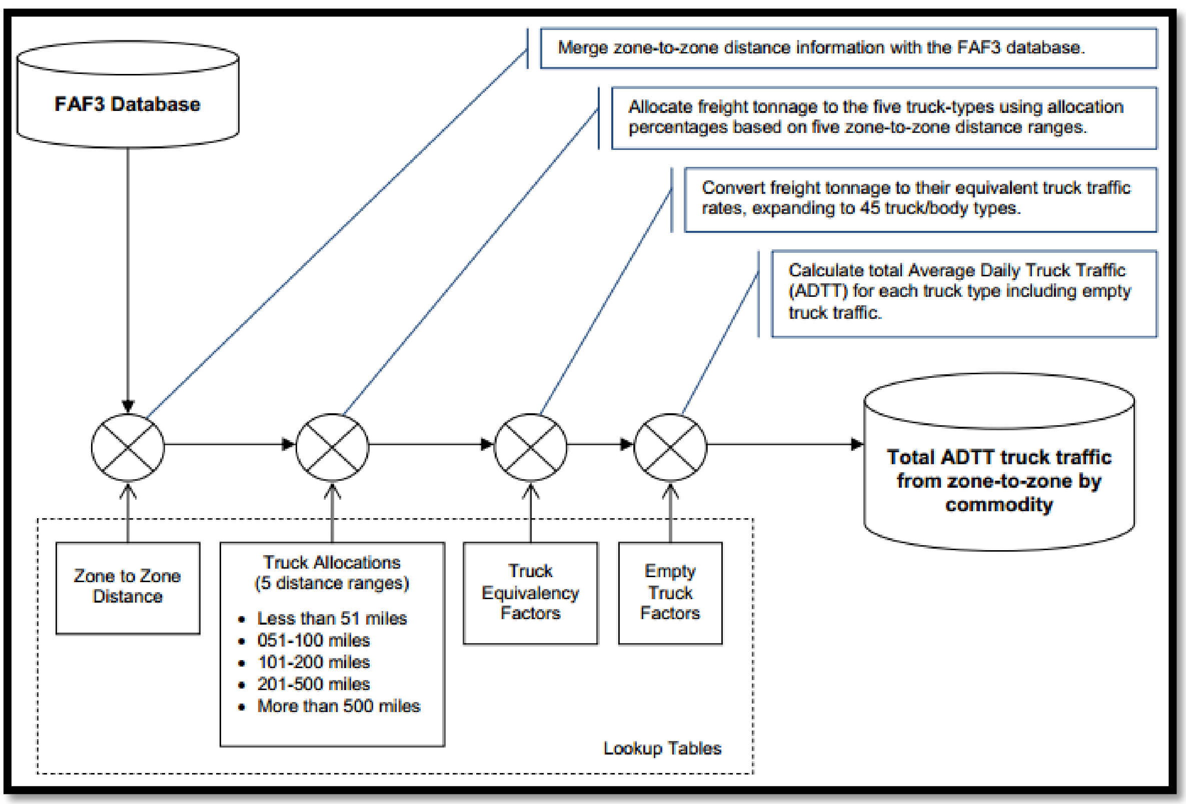

FIGURE 7: TRUCK CONVERSION FLOW DIAGRAM

(Source: Battelle, 2011 (12))

In order to identify the major truck types in terms of number of axles, one can use the AXLE_CONFIG variable that is available in VIUS dataset. There are 5 categories of truck configurations: 1-Single unit trucks; 2-Truck plus trailer combinations; 3-Tractor plus semitrailer combinations; 4-Tractor plus double trailer combinations; and 5-Tractor plus triple trailer combinations.

The five truck type categories are further divided into several body types with each category having a weight limit. The body types may also represent the type of commodities that the truck can transport.

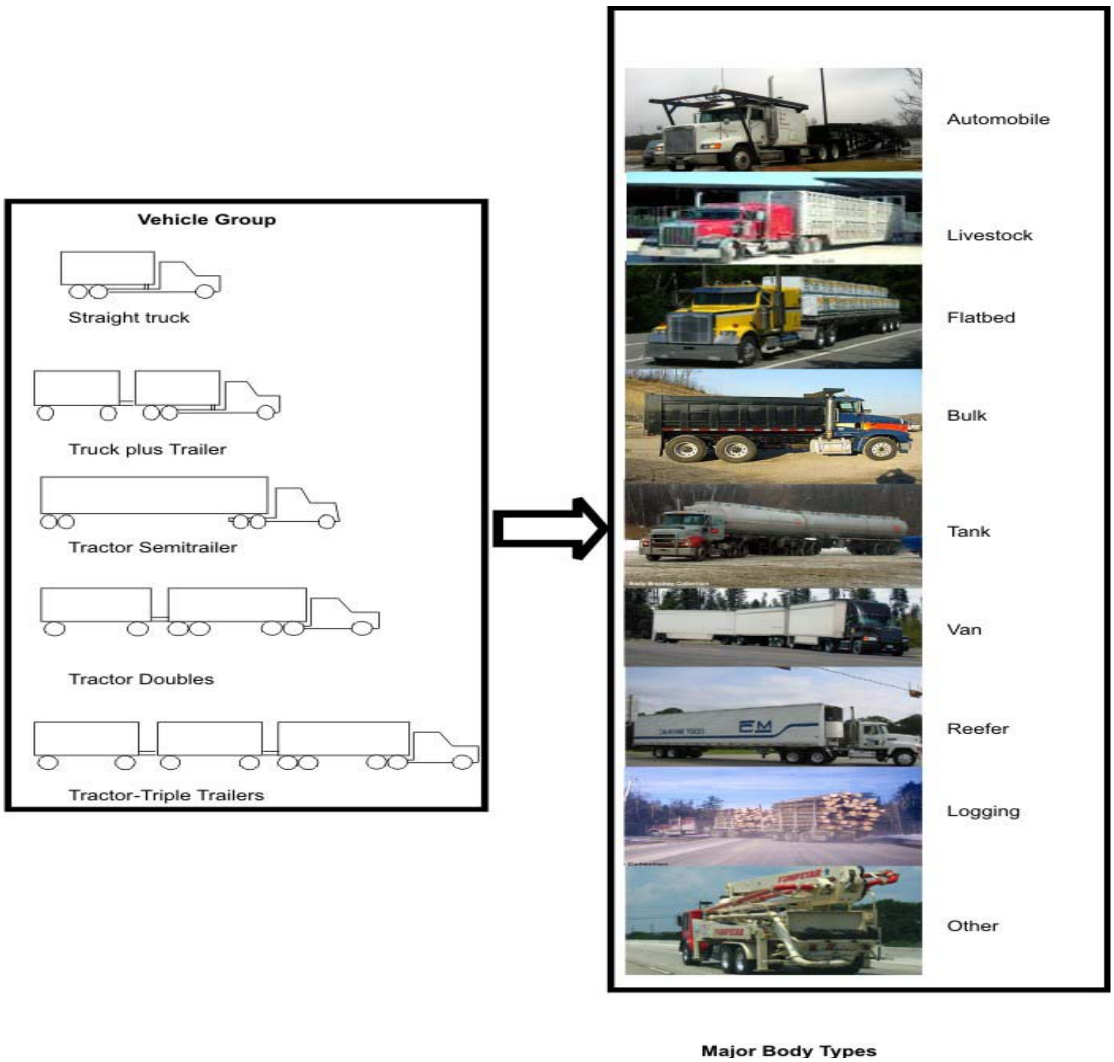

FIGURE 8: SELECTED MAJOR BODY TYPES

(Source: Battelle, 2011 (12))

Considering the fact that not all trucks are fully loaded and there are empty trucks in the network, in order to analyze the network more accurately, the percentage of empty trucks (or less than full load trucks) should be also taken into consideration. By analyzing the VIUS dataset and considering the percentage of miles that a truck is operating without load, the number of empty trucks has been estimated (12).

Table 6: Summary of Empty Trucks Percentage
(Source: Battelle, 2011 (12))

Body Type	Percent of Empty Trucks (%)				
	Straight Truck	Truck + Trailer	Tractor Semitrailer	Tractor Double Trailer	Tractor Triple Trailer
Automobile			28		
Livestock			42	34	
Bulk	44	28	43	40	12
Flatbed	29	34	32	40	7
Tank	35	37	43	44	
Van	25	16	21	10	14
Reefer	20	17	19	26	
Logging	49	44	44	28	
Other	22	12	51		
National Average	**29**	**24**	**27**	**24**	**19**

4.3. Adjusting Networks for new O-D Matrix

Federal Highway Administration (FHWA) provides FAF network which consists of the truck network links for the entire United States. The dataset also includes truck O-D matrix that are loaded on the network. There are originally 123 FAF zones and with further disaggregation of the Illinois FAF zones into county level, there are totally 222 zones in the system. As a result, the network should be adjusted and the new FAF-zone Centroids should be defined for each zone. This information is obtained from author's earlier work at UIC (13), the Freight Activity Microsimulation Estimator (FAME), in that for each FAF zone a Centroid is defined according to the zone`s network characteristics.

After defining the Centroids for each county each point is connected to the network using virtual links. These links are used just for network assignment and actually do not have specific truck volumes on them. Figure 9 shows the Centroids for the state of Illinois.

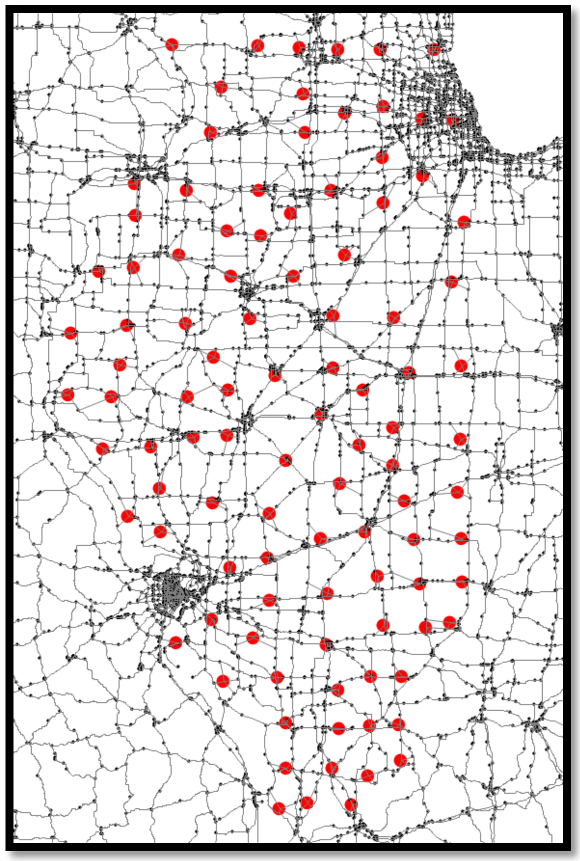

FIGURE 9: ILLINOIS CENTROIDS

4.4. Network Assignment

The FAF dataset provides forecasts of the total annual tonnages and values of commodities between transported between FAF zones. However, the process of converting the annual tonnage into daily tonnage needs major assumptions. For example, assume that an industry, say an agricultural industry, is producing *n* tons of a certain commodity during a year. Dividing this amount by 365 days a year and uniformly distributing it throughout the year would result in errors, especially in the network assignment process. Environment, economy, and seasonal effects may play roles in shipment frequency and sizes. Many industries produce and ship different amounts during different seasons and months. Additionally, converting the tonnages into truck load would result in further errors because of the process' inherent assumptions. As a result, implementing a large scale network analysis would require major assumptions and good quality data.

There are several approaches reported in the literature for a large scale freight network assignment problem. Those approaches can be categorized into two general schemes of “Non Equilibrium Traffic Assignment” (NETA), and “Equilibrium Traffic Assignment” (ETA). For example, “All or Nothing” (AON) can be considered as a NETA approach which is recommended by FHWA. On the other hand, the “User Equilibrium” (UE) method uses an iterative process to achieve a convergent solution, in which no traveler can improve his or her travel time by switching routes. In another ETA approach, the “Stochastic User Equilibrium” (SUE) is considered as a generalization form of UE assuming that travelers are not optimizers and do not have perfect information concerning network attributes. This assumption is probably closer to the reality of passenger travelers’ behavior (but not freight where routes are likely to be optimized) by allowing the network links that otherwise may not have attractiveness to have traffic flow. In other words, although less attractive routes may have lower utility of being selected, they can still receive traffic flows. Another issue of the SUE is that its rate of convergence is less than UE.

in this study, both AON and SUE assignment procedures are conducted in the TransCAD environment. Then the results of the network assignment have been compared to the FAF assignment results in order to make sure that the network is properly adjusted. It should be also noticed that FAF uses SUE assignment procedure for the year 2007 and AON approach for future prediction years, such as 2040. Figures 10 and 11 show the assignment results in terms of states Vehicle Miles Traveled (VMT) both for the aggregated and adjusted networks. The results presented in figures 10 and 11 also indicate that for most states our network analysis results matched very well with the FAF assignment results. The major difference observed in the state of Illinois is due to the fact that while the data has not been disaggregated yet, the network in this state has been significantly changed (where FAF zones are disaggregated into county level). .

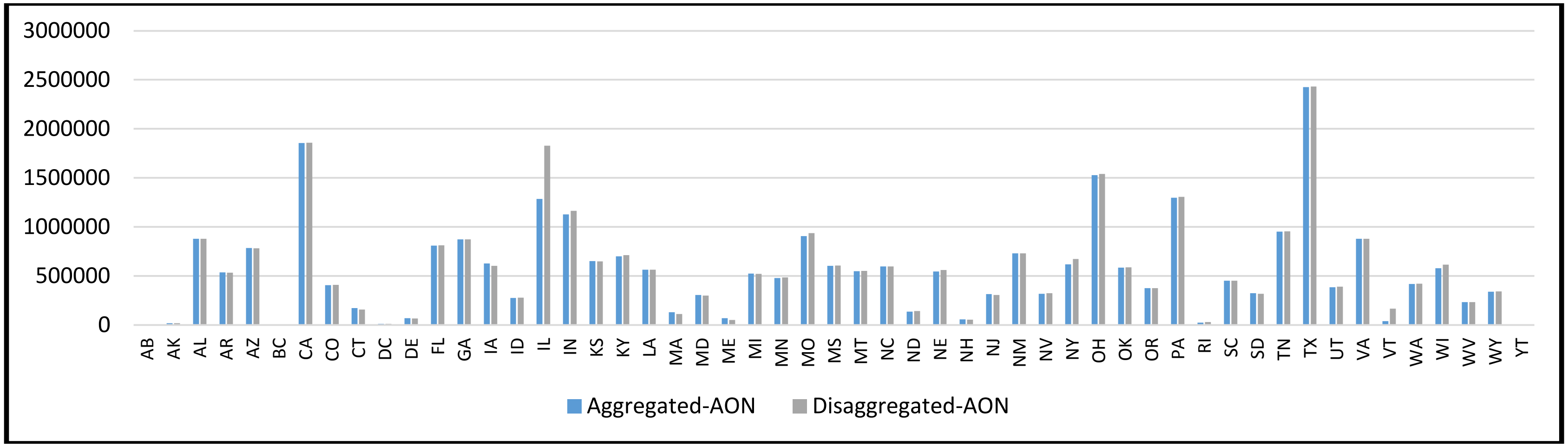

FIGURE 10: AGGREGATED VS. DISAGGREGATED AON ASSIGNMENT

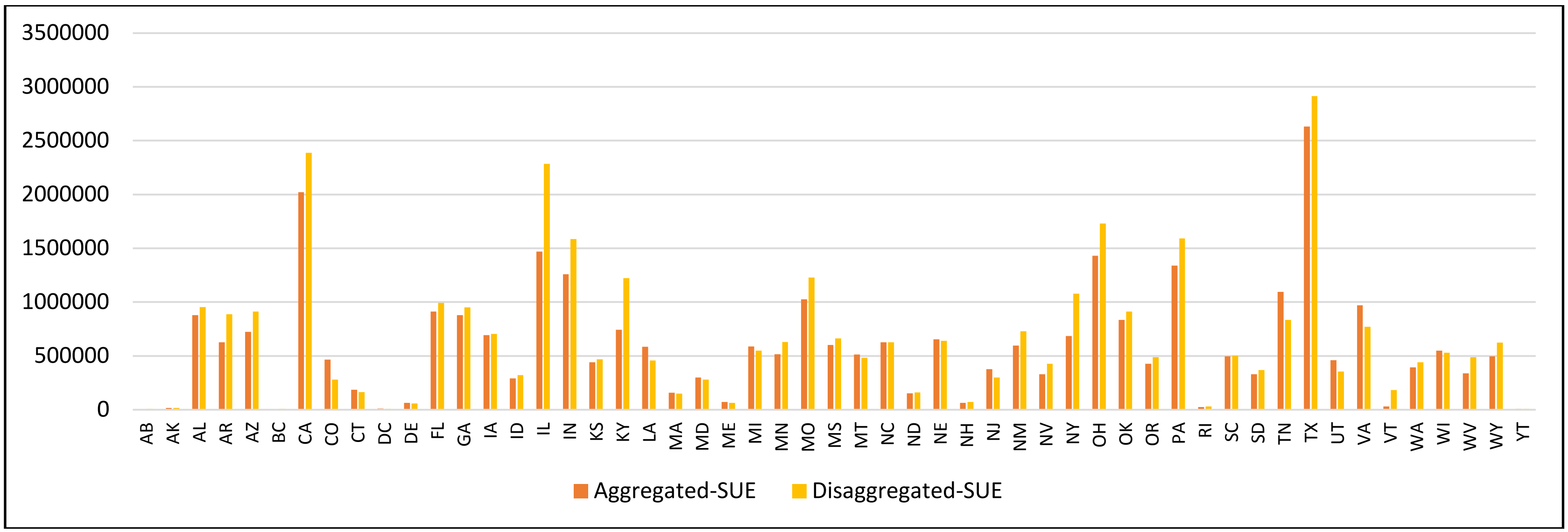

FIGURE 11: AGGREGATED VS. DISAGGREGATED SUE ASSIGNMENT

5. Developing Policy Measures

5.1. Examining Different Policies

Policies that are considered in this study can be categorized into two major groups; national and local policies. National policies are typically requiring a broader course of action adopted by the federal government in pursuit of their objectives. On the other hand Local policies are generally geared toward major goals that are implementable by cities, Metropolitan Planning Organizations (MPOs) and other local authorities.

Initially several Local and national policies were considered, including:

- **Truck Curfew**
- **Use of Consolidation Centers**
- **Off peak Hour Delivery**
- **Truck Stop Electrification for Heavy-Duty Truck**
- **The impacts of Panama Canal Expansion**

5.2. Trucks Curfew

The first local policy which was investigated involved trucks curfew. This policy assumes that trucks cannot enter specific parts of the network during some hours. This time-restriction policy is mainly applied to residential areas and includes night time operation hours. Mostly, these restriction hours are operated by local municipal agencies and vary by different areas. The aim of this policy is to improve the quality of life in residential areas by reducing the vibration and sounds that trucks make during nights.

Trucks curfew and its effect on TVMT of a region has been a question to many policy makers. People`s wellbeing and comfort from one side makes decision makers to take such policies and restrict trucks movement in some specific hours. On the other hand air quality, environmental issues, congestion and other problems bother people`s daily life. For example a truck that is on its way to the final destination and encounters a “Truck Curfew Hour” which limits the movement for some times should wait until the first legal time to proceed. This may result in increasing the peak period time in the morning. Another issue is that in these hours the truck may not turn its engine off because of cold weather around Chicago region. Working engine without moving, will cause more pollution especially in non attainment areas that need to achieve sustainable goals and reduce the emissions. Therefore, there should be a tradeoff between different goals.

In many cities, transportation engineers came to this conclusion that shifting the trucks movement into off-peak hours is an effective solution to daily truck traffic congestion. Notably, in this case trucks deliver their products in the off-peak hours and cannot enter special areas during the day. As a matter of fact they implement some kind of trucks curfew but in a different way and time.

For the purpose of this study, a region was defined by a polygon as a subarea in TransCAD environment, as shown in Figure 12. This area encompasses 6 main counties of Chicago region including Cook, DuPage, Kane, Lake, McHenry, and Will counties. Then different time periods were considered in the analyses to investigate the best time period for implementing trucks curfew.

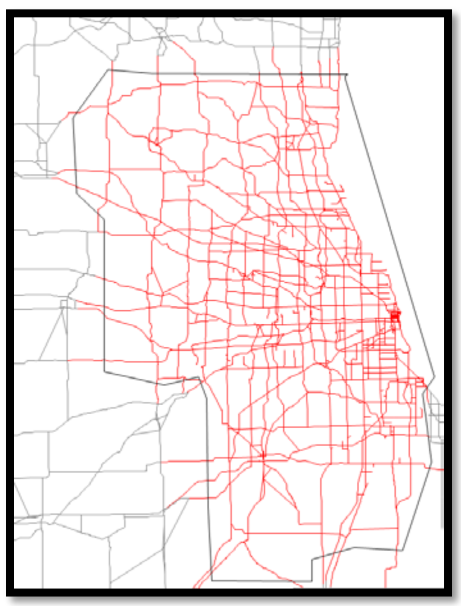

FIGURE 12: CURFEW STUDY AREA: A POLYGON

In this study the effects of trucks curfew on a special region are investigated and according to local data and disaggregated FAF data the effect of implementing such a policy are tested. In addition, where this policy is not avoidable and cities are obliged to implement it, the negative effects of the policy can be reduced by choosing the best time for implementation.

5.3. Trucks Consolidation Centers

In this policy scenario, it is assumed that the shipments that are less than truck load should be combined in consolidation centers in order to form fully loaded trucks before reaching into a specific area. Another way of looking to this policy is to imagine that a truck is loaded fully with a commodity (e.g., paper) but it should deliver it partially to Chicago and partially to another destination. So the driver can drop off the part for Chicago in a consolidation center before loading additional items to the second destination. Then the offloaded shipment in the consolidation center will be forwarded to Chicago in another truck which is not fully loaded. One can imagine that consequently the total TVMT of such a system would decrease.

The methodology for implementing this policy is somewhat new. We divided the commodities into two types: the one that should be delivered without delay or cannot be stored in the consolidation center and the second type includes those which can be stored and can accept a reasonable amount of delay. After converting the FAF total tonnage into trucks, the truck`s O-D matrix assigned onto FAF network using a stochastic user equilibrium method. The Chicago region is selected to be analyzed in TransCAD software. According to FAF tonnage conversion to trucks method, while a large portion of trucks are fully loaded, there is a significant percentage of trucks that are more than half loaded but less than full (14). Because there is not enough data about how exactly trucks are loaded, certain assumptions should be considered to examine this policy. From the generalized percentage revealed in FAF report, one can assume that trucks are about 87.5% fully loaded.

Different scenarios can be tested in this policy to achieve total TVMT in the region. First of all it should be noted that not all the trucks will participate in this policy and also there are two types of commodities, with one of the types involving commodities that cannot be delayed or stored. Considering the above-mentioned assumptions and conditions, four scenarios were tested in which the percentages of eligible trucks were considered to be 100%, 75%, 50%, or 25%.

5.4. Off-Peak Hour Delivery

In a recent effort, in the New York City, Off-Peak Hour Delivery (OHD) policy was investigated through a survey of carriers (15). In this study two different areas in the NYC are considered: Manhattan and Brooklyn. For increasing demand for off peak hour delivery, tax reduction, shipping discounts for receivers in accordance with toll discounts or financial rewards for carriers had been taken into consideration. Problems that were stated for not using the OHD policy are: for Manhattan carriers, reasons include staffing or scheduling problems (8.33%), access to delivery sites (6.77%), union regulations (6.25%), company preference (5.21%), overtime costs (4.69%) or parking/traffic problems (2.60%). In Brooklyn, the reasons were: headquarter issues (19.71%), driver issues (10.95%), hours of operations (8.03%), security issues (5.84%) and traffic issues (0.7%). Considering these results was found to be essential in order to increase the effectiveness of the policy.

5.5. Truck Stop Electrification for Heavy-Duty Truck

Electrified parking spaces (EPS) are places that provide necessary systems such as air conditioning, heating or appliances for trucks, eliminating the need for the trucks `engine to run while not moving. According to the U.S. DOT regulations, truck drivers should rest 10 hours after 11 hours riding. In cold weather or very hot weather, trucks cannot turn their engine off while they`ve stop for rest or any other reason. But with these types of facilities the power for providing heat or air conditioning comes from another source. In 2012 there were about 93 EPS in the United States.

FIGURE 13: TRUCK STOP ELECTRIFICATION FOR HEAVY-DUTY TRUCK

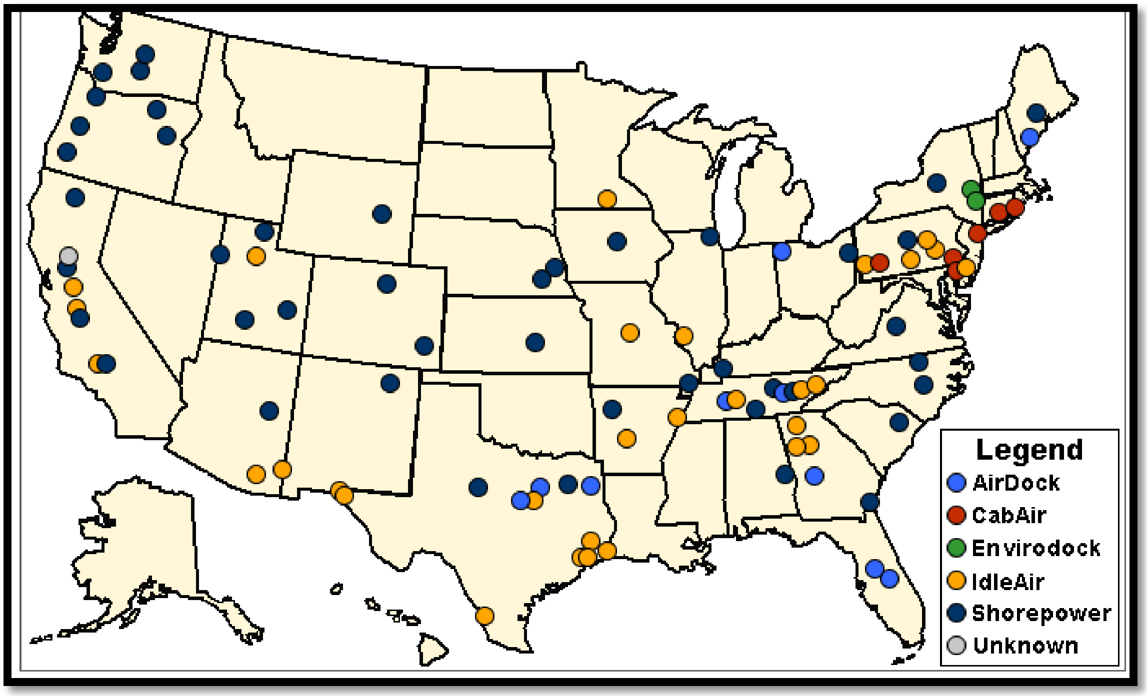

FIGURE 14: MAP OF TRUCK STOP ELECTRIFICATION SITES 2012
(Source: Office of Energy Efficiency and Renewable Energy, 2013 (16))

According to the U.S. Department of Transportation (DOT) there are about 5,000 truck stops in the United States. It has been suggested to equip these stops by the EPS system. One may argue that providing electricity itself may cause pollution from other sources (Figure 15.), so policies like this should be investigated more carefully.

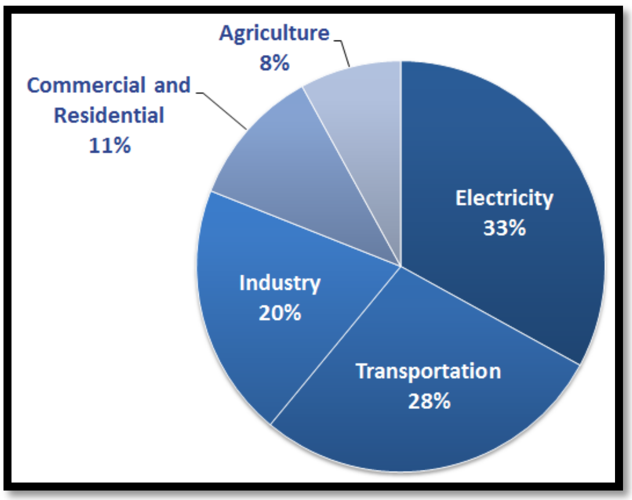

FIGURE 15: GREENHOUSE GAS EMISSIONS BY SOURCE
(Source: US DOT (2))

5.6. National policy: The Effects of Panama Canal Expansion

The capacity of Panama Canal is projected to be doubled by 2015 which will allow more and larger ships to move through this canal. It is expected that a large portion of imported shipments to the Midwest and East coast markets that are currently destined to pacific coast ports to be redirected to the Gulf and East coast ports. However, the true effects of Panama Canal expansion on the U.S. highway network and truck mode are still unknown. One may expect the total TVMT will be reduced since vessels may arrive at ports where destinations are closer. However, the network near the East coast ports is already congested.

In this scenario, the results of a recently developed model by authors are utilized in that the changes in each port`s import volumes are estimated for the case of after Panama Canal Expansion (17). In the mentioned model in order to understand the effects of Panama Canal expansion on container flow distribution to U.S. ports, capacity changes around the U.S. maritime network and containerized shipment flows which have been imported to the U.S. had been considered. In that analysis, seven Asian trading partners including China, Hong Kong, Taiwan, Macao, Mongolia, Japan, and Korea are considered. Ocean and rail shipping costs, capacity of the top 13 U.S. ports, and the potential full capacity of the Panama Canal and the port of Prince Rupert in Canada are also considered. The results of the study representing the changes in each port`s import tonnage are presented in Table 7.

Table 7: Imports by Port after Panama Canal Expansion in 2015

Ports	Before Panama Canal Expansion-2015 (millions of tons)	After Panama Canal Expansion-2015 (millions of tons)	Percent Change
LA/LB, CA	34935	29946	-14.28
Seattle, WA	3718	2244	-39.64
Oakland, CA	3012	5981	98.59
Tacoma, WA	3572	1848	-48.26
NY/NJ, NJ	7281	7757	6.54
Norfolk, VA	2044	3043	48.89
Charleston, SC	1394	1881	35.00
Savannah, GA	4006	5305	32.43
Houston, TX	2756	7240	162.72
Mobile, AL	774	3044	293.33
Miami, FL	841	1248	48.49

In order to examine the effects of Panama Canal expansion to the mid-west region, in this study, we have utilized the changes in the ports' tonnage (presented in Table 7) by updating the FAF3 data for both import and export intermodal shipments (Figure 16). Even though the listed variation is resulted from the import analysis, and imports and exports are affected with different variation rates by types of commodity, since there is no model for the export part, in this work the same rates are applied to both imports and exports.

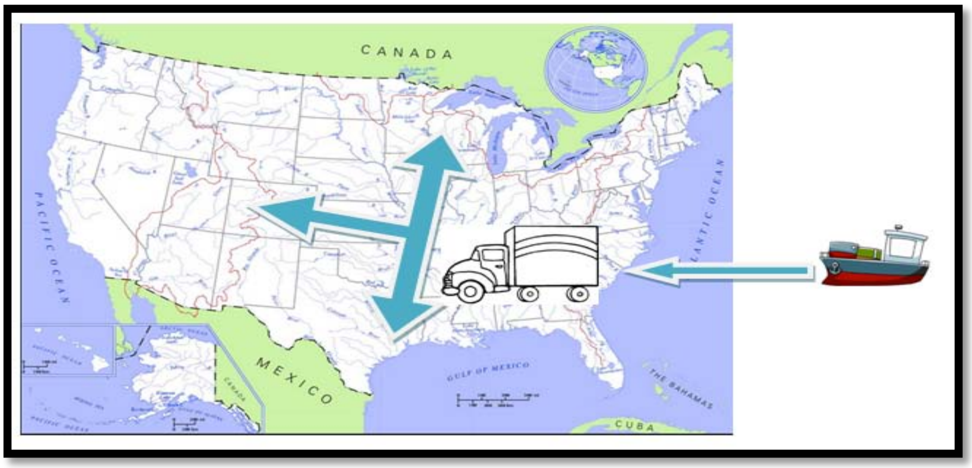

FIGURE 16: INTERMODAL SHIPMENT DIAGRAM OF THE U.S. IMPORTS

Candidate policies to be considered in this study

After careful evaluation of different policies and considering data availability and the scope of the current study, two local policies and one national policy were selected for further investigation of their effects on reducing TVMT. These include; Trucks Curfew and Consolidation Centers as local policies and Panama Canal expansion as a national policy, which are further investigated in the next chapter of this report.

The reasons for not considering the two other policies (EPS and Off- Peak Delivery) were mainly due to data limitation. Off-Peak Delivery strategy, while seemed promising, would require further work. The example provided earlier, was based on a survey in the New York City and transferring the results of the survey from NYC to Chicago would not be appropriate because of many contextual differences between Chicago and New York.

There might be also other problems in implementing this policy. For example receivers as the dominant decision maker in this process are confronting to different extra costs that need to be compensated if they are willing to accept OPD. These costs include staffing, security and lighting during OPD hours. OPD policy also is a very local phenomenon and probably FAF dataset is not an appropriate source of information for such analysis, as FAF data considers national Heavy trucks movement and OPD refers to local freight delivery.

6. Policy Analysis Results

6.1. Trucks Curfew Results

It is clear that banning trucks from entering a region not only shifts the morning peak hour congestion, but also may result in further environmental issues. In cold seasons, trucks cannot turn their engines off during night time while banned from entering the area and most likely their engine would run during the curfew time. Therefore, one may conclude that if the total number of trucks that are waiting during the curfew time is reduced, fewer engines would run and eventually less pollution would be produced.

In this study, we used the truck traffic data of FAF to the Cook County in Illinois (Chicago region) and imposed a hypothetical curfew situation where trucks are banned from entering the study area for a given period of time (5-6 hours).

After carefully examining the local trucks traffic data and considering different curfew time scenarios in a simulation setting, it was found that the best results would be achieved by a six-hour curfew implemented between 11:00 PM to 5:00 A.M. As shown in Figure 17, the percentage of trucks that are running in the network and are affected by the policy is minimized when the curfew starts at 11 pm, therefore, the policy would have the least effects on the network.

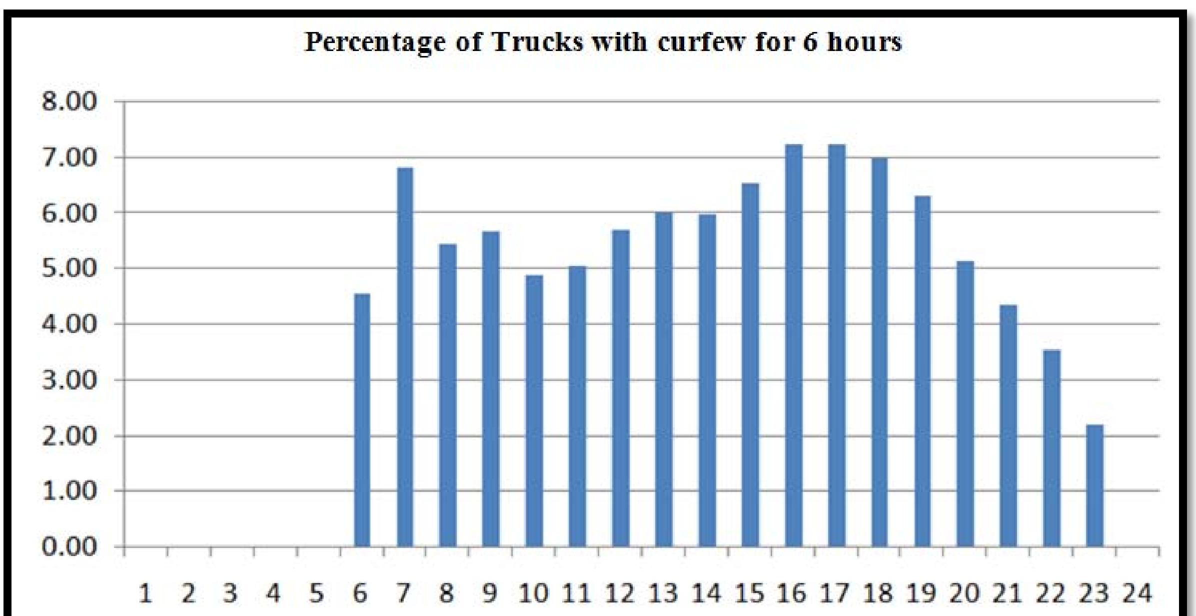

FIGURE 17: PERCENTAGE OF AFFECTED TRUCKS BY START TIME OF A 6 HOUR CURFEW

Furthermore, if the curfew time is designed for 5-hour curfew, then the best time would be between 12 A.M. to 5A.M. as shown in Figure 18. It is assumed that trucks which could not move during the curfew hours are distributed uniformly in the network during the following two hours.

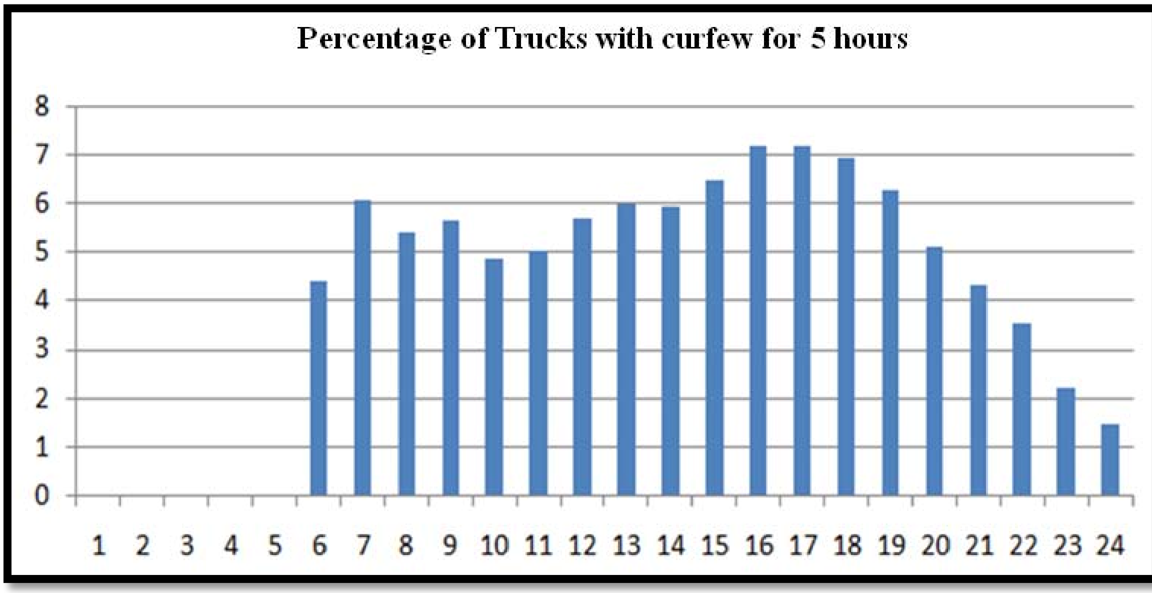

FIGURE 18: PERCENTAGE OF AFFECTED TRUCKS BY START TIME OF A 5 HOUR CURFEW

It could be observed that the difference between 5-hour and 6-hour curfew would result in affecting almost 1.46% more trucks which is translated to a 9,488 less trucks per month. That means 9,488 trucks would generate less pollution and less delay caused by the trucks curfew policy.

6.2. The Results of the Trucks Consolidation Centers Policy

The analysis was based on examining various percentages of trucks in our model to participate in a consolidating program. The analysis results show that the first scenario in which 100% of eligible trucks attend the program is very promising. It was shown that as a result of this scenario the total TVMT in the region can be reduced by about 10.27%. In the second scenario it was assumed that the percentage of participating trucks is reduced to 75% of eligible trucks. The results suggest that about 7.71% reduction in TVMT could be expected. In scenario 3 where 50%

of eligible trucks participate in the program, that the total TVMT would be decreased by 5.21%, and finally in the fourth scenario (25% of eligible trucks participating in the program), would result in only a 2.68% reduction of total TVMT. Please note that as the benchmark for comparison purpose, we have also considered the fifth case where no truck would participate in the program.

Various pollution measures and environmental impacts of the scenarios are estimated and depicted in Figures 21 to 25. In each case, scenario one represents the case in which 100% of eligible trucks participate in the policy, and consequently scenarios 2 to 5, represent 75%, 50%, 25%, and 0% participation rate in the trucks Consolidation Centers Policy, respectively.

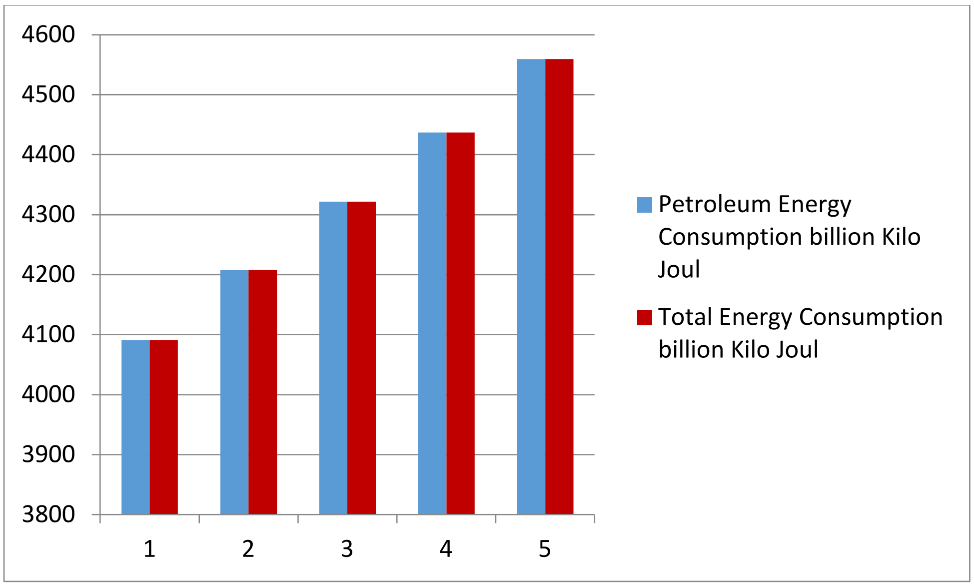

FIGURE 19: PETROLEUM ENERGY CONSUMPTION AND TOTAL ENERGY CONSUMPTION VARIATION FOR 5 SCENARIOS (BILLION KILOJOULES)

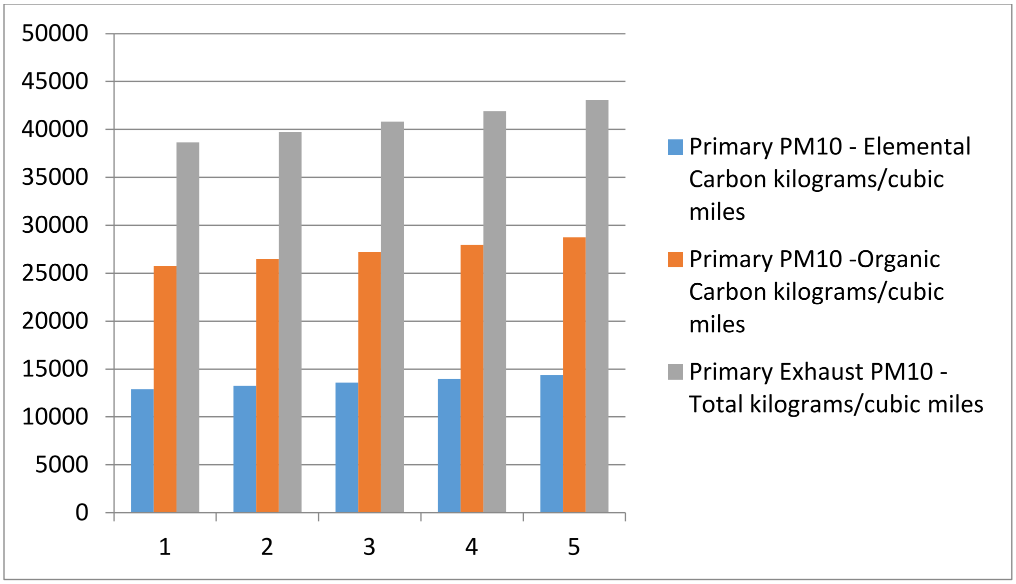

FIGURE 20: PRIMARY PM10 (ELEMTAL AND ORGANIC CARBON) AND PRIMARY EXHUST VARIATION FOR 5 SCENARIOS (KILOGRAMS/CUBIC MILES)

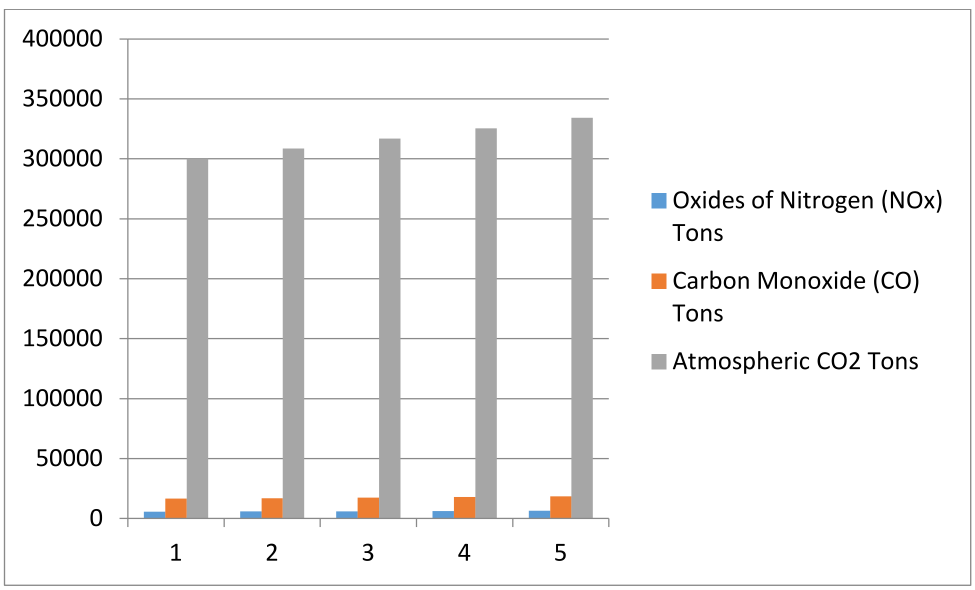

FIGURE 21: OXIDES OF NITROGEN (NOX), CARBON MONOXIDE (CO) AND ATMOSPHERIC CO2 VARIATION FOR 5 SCENARIOS (TONS)

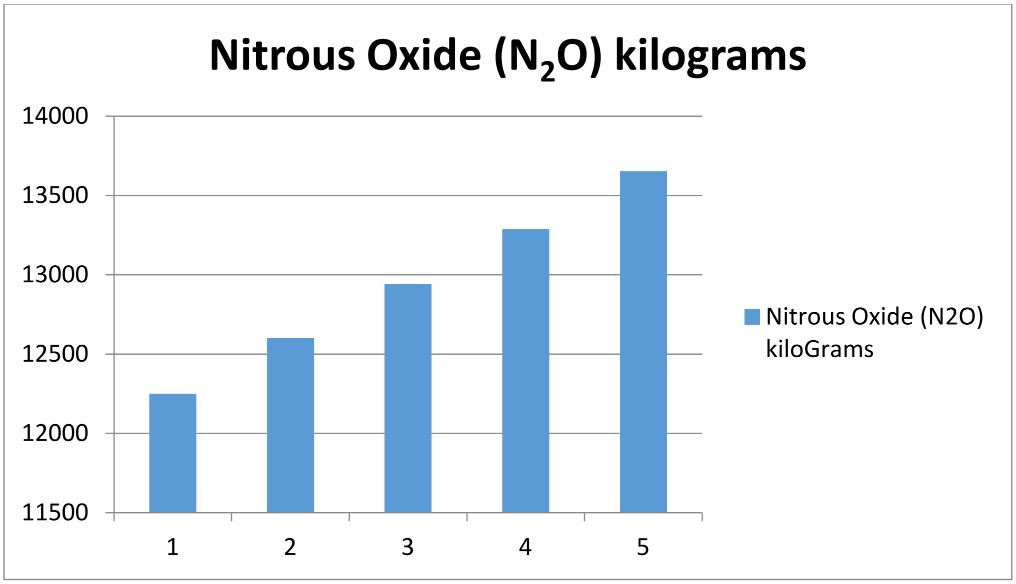

FIGURE 22: NITROUS OXIDE (N_2O) VARIATION FOR 5 SCENARIOS (KILOGRAMS)

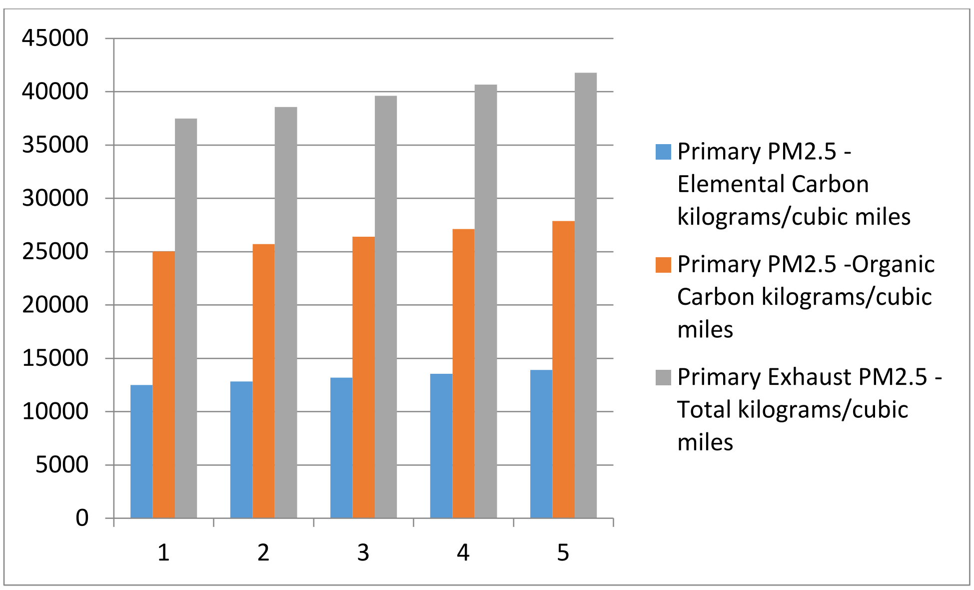

FIGURE 23: PRIMARY PM2.5 (ELEMTAL AND ORGANIC CARBON) AND PRIMARY EXHUST PM2.5 VARIATION FOR 5 SCENARIOS (KILOGRAMS/CUBIC MILES)

It should be noted that the freight consolidation scenarios that are examined in this study are simplistic and do not consider the effects of external factor which in many cases may act as the primary factor controlling the shipping decisions. For example if an industry needs to deliver 13 tons of goods the next day, it ships the truck with 13 tons. Most likely, it will not tell the customer to wait until another order is received and the truck is fully loaded. In addition, lack of information about the shipment size, truck specifications, and mode of transportation impose further constrain in the analysis, preventing us from having more detailed information.

6.3. The Results of Panama Canal Expansion Scenario

There are a lot of uncertainties around the future of Panama Canal and its expansion. For instance, what would be the effect of this expansion on the United States economy? How much increase or even decrease can be expected in total import and export of the U.S.? How does this expansion affect the entire transportation networks? When considering a major project like Panama Canal expansion, so many uncertainties would rise. For example, how would major logistics carriers, and ocean liners change their routes to the final destination? How ports would change accordingly, and adapt to the new demand? How long would it take for those firms and transportation companies to adjust to the newer routes? Further discussion of these issues and detailed modeling results can be found in Sang et al. (14), for interested readers.

In the current study, after assigning each ports expected percentage changes (Table 7) and updating the FAF3 Origin-Destination (OD) dataset, the volumes are loaded into the network assignment package and the resulted of the analysis for both cases of before and after Panama Canal expansion are shown in Figure 17 and Figure 18, assuming that the Canal would open in 2015.With all the uncertainties and major assumptions that noted earlier, the results show that after Panama Cana expansion, the total TVMT would be reduced by 4.26%. Also the results show that there is a slight shift of trucks volume to the east parts of the U.S. and a likely reduction of trucks total flow in the western region, especially in the state of California.

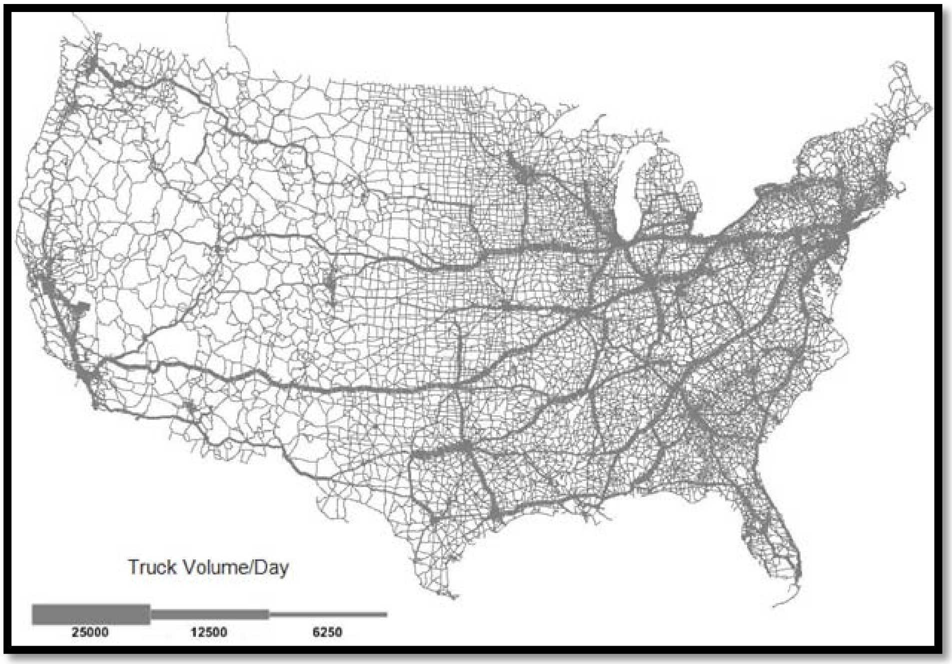

FIGURE 24: 2015 BEFORE THE PANAMA CANAL EXPANSION

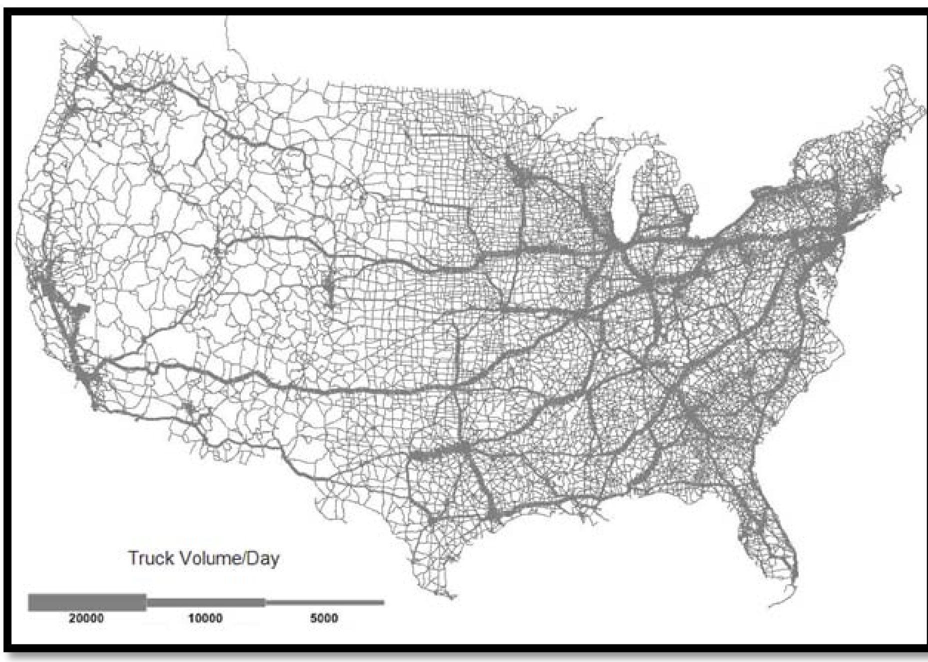

FIGURE 25: 2015 AFTER THE PANAMA CANAL EXPANSION

7. Conclusions and Future Work

This study introduced a comprehensive analysis of disaggregating FAF3 data into county level. Having more detailed information on each county would certainly help better investigating different policy scenarios. The disaggregation method is based on using publicly available local and national data and commodity supply chains, assuming that productions and consumptions of commodities do not always depend only on employment data (as used in other studies) but rather several other factors like population and land use characteristics should be also considered. Ranking the consumption of each industry from 1 to 10 and apportioning the FAF zone into each sub-county proved to be an efficient approach for the case where employment data is fully available.

This study also examined three different freight policy scenarios for truck movement. First the effects of Panama Canal expansion by 2015 was investigated on US highway network. This study showed that approximately a total reduction of 4.26% in TVMT can be expected as a result of Panama Canal expansion. The next policy considered the impact of greater use of consolidation centers and the key factors that should be considered in identifying their most effective location. It was shown that such centers can be effective in reducing TVMT by up to 10.27% in a region like Chicago. The last policy that was examined in this study, was to identify the most efficient time for a truck curfew policy. It was shown that the most effective time would be from 11:00 pm to 5:00 am.

Because of several constrains and limitation we faced during the course of the study, many prominent policies were not tested. It is suggested to collect more detailed information, preferably in form of a survey for implementing Off-Peak Delivery policy. Behavioral analysis of carriers and receivers in the Chicago region and their response to policies such as reducing tax during OPD or rewarding carriers to operate during Off Peak hours should be all investigated more accurately.

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