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Final Draft Report

FAF^3 FREIGHT TRAFFIC ANALYSIS

Submitted to

Oak Ridge National Laboratory

Submitted by

Battelle

March 23, 2011

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CHAPTER 1: INTRODUCTION

1.1 Background

The Federal Highway Administration (FHWA), in cooperation with other U.S. Department of Transportation (DOT) modal administrations having freight responsibilities, developed the first Freight Analysis Framework (FAF) in 2002. Since its inception, the FAF freight database has gone through several updates and has been used in a variety of transportation analyses including highway capacity and bottleneck assessments, truck size and weight studies, evaluations of the benefits of strategic investments in transportation infrastructure, impacts of changes in road-pricing policies, multimodal freight policy analysis, impacts of toll proposals on shipper choice decisions, and the impact on national freight movement of natural and manmade disasters (e.g., the I-40 bridge collapse in Oklahoma in 2002; the I-95 bridge at Bridgeport, Connecticut in 2004; the impact on freight movement due to Katrina in 2005, the Collapse of the I-35W bridge in Minneapolis in 2007; and others).

Given its importance to national and state freight flow analysis, the FAF version 3 (FAF^3) commodity flow data are being updated and enhanced by the Oak Ridge National Laboratory (ORNL) for FHWA to estimate the dollar value and tons of shipments between 123 regions used in the 2007 Commodity Flow Survey (CFS) and eight international trade regions. These flows are broken down by type of commodity and mode of transport. The FAF^3 commodity flow data are benchmarked to calendar year 2007, with a forecast for the year 2040. However, for the highway mode, the commodity flows and other non-freight traffic for years 2007 and 2040 need to be assigned to an updated, 2007 representative version of the FAF Highway Network, upon which various traffic analyses can be performed by FHWA staff and contractors. Therefore, the FAF version 2 highway network database and its inclusive traffic assignments needed to be updated using the FAF^3 network data products and approach.

1.2 Objectives of the FAF^3 Project

To update and improve the FAF^2 database, FHWA recently developed the next generation FAF^3 freight origin-destination (O-D) database using the 2007 CFS and other public data sources. Intended in part to address issues and lessons learned from the FAF^1 and FAF^2 projects, some of the primary objectives of the development of the FAF^3 data were to

- Provide data and analytical capability to support various Federal needs related to policy and legislative issues for the new planning horizon
- Provide leadership to develop, maintain, and update data to meet the growing demand for freight data and minimize the gap among FHWA, State DOTs and metropolitan planning organizations (MPOs)
- Update the FAF database with 2007 CFS data
- Make FAF^3 data more transparent to all public and private users outside the U.S. DOT.

1.3 Objectives of FAF^3 Freight Traffic Analysis

This study is directed at conducting a national highway freight analysis designed to estimate the base year 2007 and the 2040 forecasted FAF truck flow and assess the system-wide congestion related performance elements of the nation's highway systems. The overall objectives of the FAF^3 Freight Traffic Analysis are to prepare:

- Updated FAF^3 highway network coverage data with Highway Performance Monitoring System (HPMS) 2008 data elements essential for freight network assignment
- Update empty trucks percentage
- Revise tonnage allocation by commodity and by trip length by vehicle type
- Use demand responsive dynamic disaggregating for FAF^3 truck O-D for subsequent freight network assignment
- Develop a database of freight truck flows (freight assignment) on the highway network for the base year and forecasted year
- Develop a database of highway congestion, travel time, and delay for each FAF^3 highway network segment
- Produce FAF^3 maps depicting national freight flows and congestion for the years 2007 and 2040.

1.4 Overview of the Methodology

The overall methodology of the Freight Traffic Analysis research project covers seven general areas:

1. FAF^3 network update and integration of 2008 HPMS database
2. Pre-assign non-FAF^3 traffic counts to the FAF^3 highway network
3. Update if necessary, truck trips, payload, and passenger car equivalency factors
4. Virtual FAF O-D disaggregation
5. Assign FAF^3 Flows (2007 and 2040) to the highway network
6. Estimate segment-specific network performance for 2007 and 2040
7. Documentation.

These seven building blocks are illustrated in Figure 1-1.

The estimates of link specific network truck flows and the capacity-related performance of the FAF highway network are based on the supply and demand characteristics of freight traffic flows for 2007 and 2040. Figure 1-1 illustrates the various Task components.

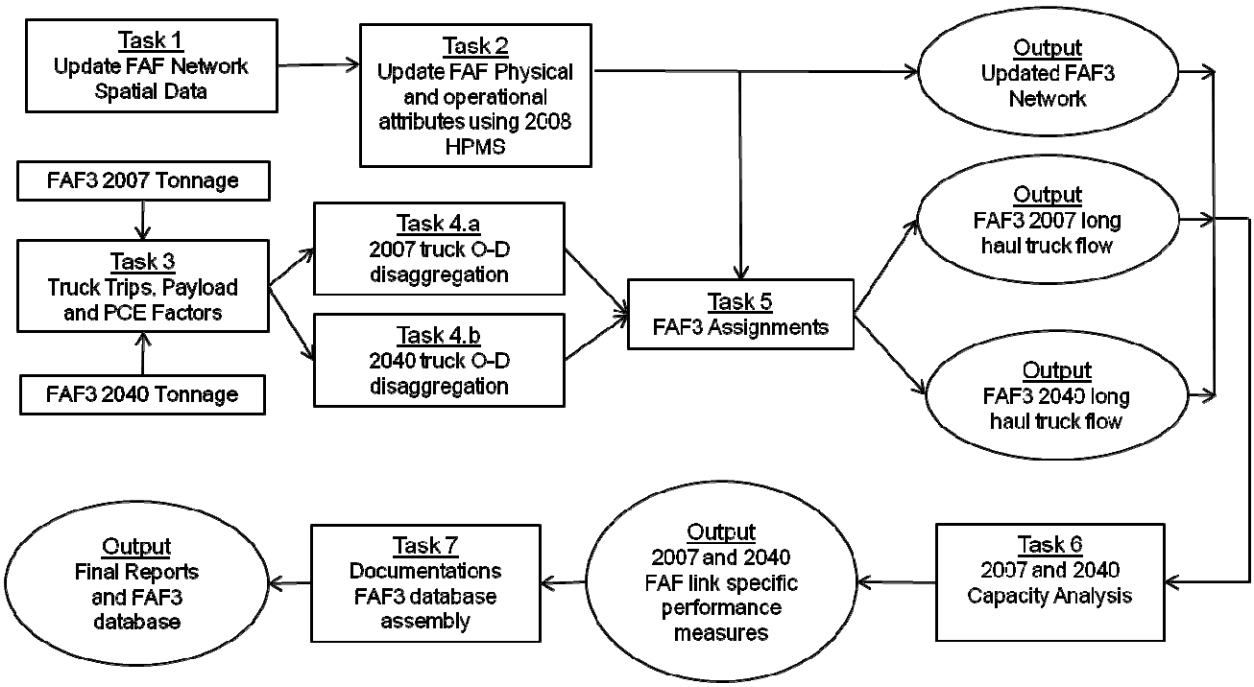

Figure 1-1. FAF Analysis Tasks

1.5 Organization of the Report

Chapter 2 discusses methodologies and steps used to develop freight highway networks using the latest version of the National Highway Planning Network (NHPN), the HPMS database, and input from other State DOT agencies. Chapter 3 describes the development of tonnage to truck conversion procedures and methodology adopted to disaggregate the 131 FAF^3 freight analysis zones to the required number of virtual loading/unloading points. Chapter 5 describes the freight assignment models and associated calibration procedures utilized for the development of base year 2007 and year 2040 network flows. Chapter 5 discusses various performance measures estimated and illustrates the results in tabular and map formats. Chapter 6 presents conclusions.

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CHAPTER 2: FAF^3 FREIGHT NETWORK UPDATE AND 2008 HPMS DATA INTEGRATION

2.1 Introduction

FAF^2 geospatial network coverage was used as the basis to update FAF network. It represents more than 447,400 miles of the nation's highways comprised of Rural Arterials, Urban Principal Arterials, and all National Highway System (NHS) routes. The following roadways are included:

- Interstate highways
- Other FHWA designated NHS routes
- National Network (NN) routes that are not part of NHS
- Other rural and urban principal arterials
- Intermodal connectors
- Rural minor arterials for those counties that are not served by either NN or NHS routes
- Urban bypass and streets as appropriate for network connectivity.

Updates from the FAF^2 to the FAF^3 network include:

- Updates to NHS designation and intermodal revisions current to version 2009.11 releases
- Additions or updates to urban bypass or other state specific highway alignment
- Integration and updating of NN and long combination vehicle (LCV) designations, state link specific truck restrictions, clearances, and hazmat route restrictions

2.2 FAF^3 Network and HPMS 2008 Data Integration Process

The 2008 HPMS database was selected for the 2007 network update to ensure base year information consistency. Typically each HPMS current year release (e.g., 2008) is based on the last year (e.g., 2007) state reported roadway inventory database. In the earlier FAF project, integration of the HPMS database to the FAF^2 network was accomplished using the state submittal linear referencing system. However, this was not possible for the 2008 HPMS database due to a change in the HPMS geographic information system (GIS) based linear referencing system (LRS) data submittal criteria. The new criteria did not maintain the original HPMS LRS criteria that were maintained with NHPN (the base network for FAF^2). To overcome this problem, the Battelle team developed an algorithm using the route primary and secondary signage, along with state milepost data, to extract and attach the relevant HPMS attributes to FAF^3 network links.

The link specific information was then further processed to minimize the attribute discrepancy at the state/or urban boundary and at other locations where link specific data gaps exist. For missing and non-sampled links, truck traffic percentages were updated using a combination of state specific functional class averages and/or correlations with adjacent link truck percentages. The 2040 values for average traffic volume and truck traffic were estimated using the state growth factor reported in the HPMS 2008 database and projected to 2040 using a linear growth algorithm. The following sections describe the work process performed to update the FAF^3 network with the 2008 HPMS database.

2.2.1 Route Matching

The HPMS and NHS data sources both provide LRS information. However, due to changes in the submittal criteria, the two data sources have not maintained a common format that would allow direct relating of their respective data. To overcome this issue, Battelle team utilize Battelle Multifaceted Analysis Tools (BMFAT), an in-house proprietary software tool that employs algorithms to relate the HPMS and NHS data using, as necessary, primary and secondary signage, mileposts, and translated LRS identifiers. The route matching flow diagram is illustrated in Figure 2-1. Table 2-1 shows LRS alignment codes.

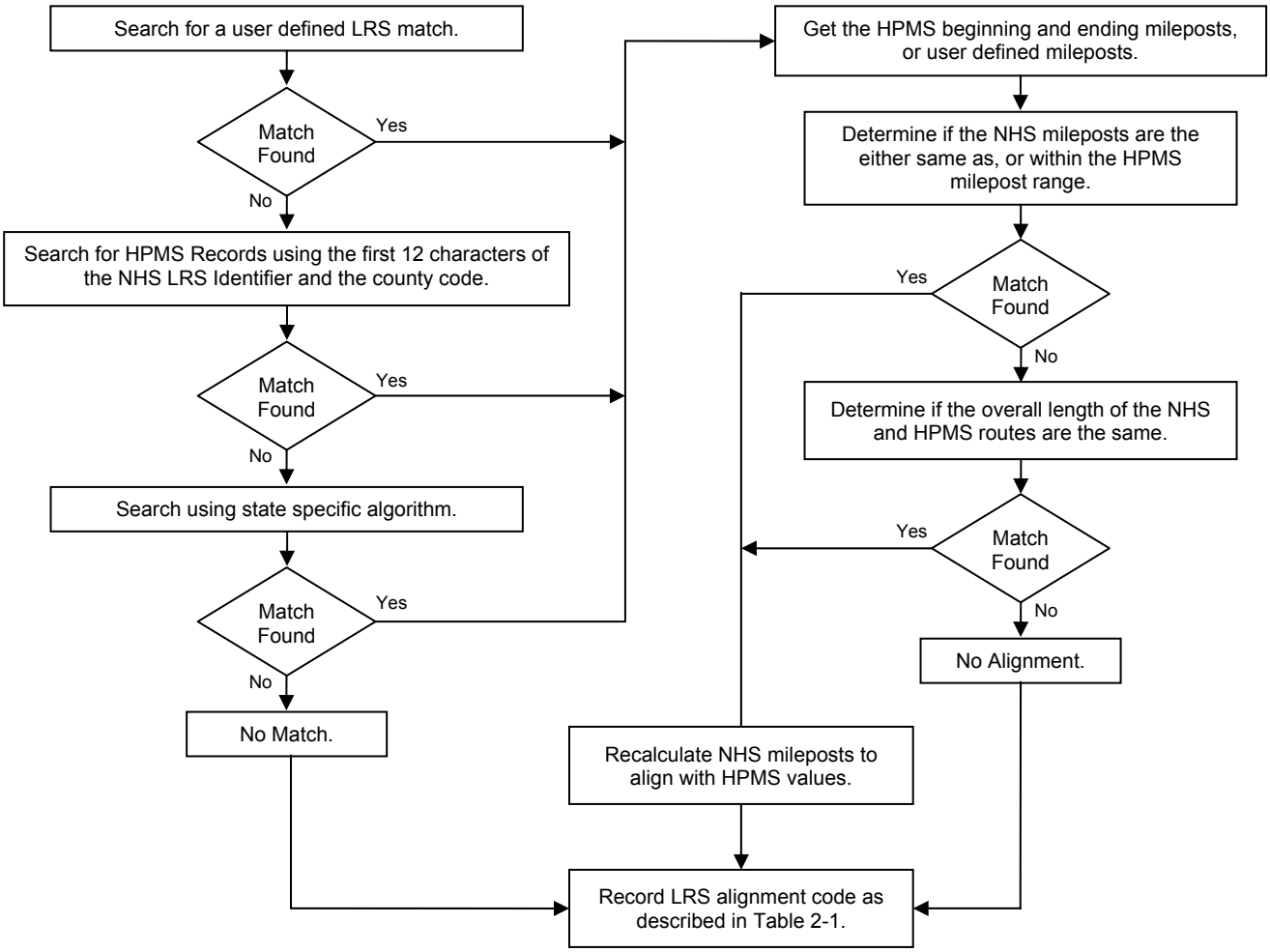


Figure 2-1. Route Matching Flow Diagram

Table 2-1. LRS Alignment Codes

Code	Description
0	LRS match was found; mileposts are aligned.
1	LRS match was found, overall route-length matches but the beginning and ending mileposts are different; NHS mileposts were recalculated to align with the HPMS values.
3	No LRS match was found.
22	The HPMS route-length is shorter than the NHS; the beginning mileposts are the same, but HPMS ending milepost is less than the NHS ending milepost.
86	The HPMS route-length is shorter than the NHS; both the beginning and ending HPMS mileposts are less than the NHS mileposts.
90	The HPMS route-length is longer than the NHS; both the beginning and ending HPMS mileposts are less than the NHS mileposts.
106	The HPMS route-length is longer than the NHS; the beginning HPMS milepost is less than the beginning NHS milepost and the ending HPMS milepost is greater than the ending NHS milepost.
134	The HPMS route-length is shorter than the NHS; the ending mileposts are the same, but HPMS beginning milepost is greater than the NHS beginning milepost.
150	The HPMS route-length is shorter than the NHS; the beginning HPMS milepost is greater than the beginning NHS milepost, and the ending HPMS milepost is less than the ending NHS milepost.
166	The HPMS route-length is shorter than the NHS; both the beginning and ending HPMS mileposts are greater than the NHS mileposts.
170	The HPMS route-length is longer than the NHS; both the beginning and ending HPMS mileposts are greater than the NHS mileposts.

Note: By default, a tolerance of 0.5 mile is used when determining if two mileposts match, and a tolerance of 1 mile is used when determining if two routes are of the same length.

Only alignment codes 0 and 1 should be considered as a valid match between the HPMS and NHS datasets. The other codes indicate that either no matching LRS route was found, or that the algorithm was unable to align the mileposts between the two datasets.

2.2.2 User Specified Associations

When automatic matching algorithms fail, the BMFAT analysis tool provides a means to manually associate the HPMS and NHS routes. Manual associations have the highest priority and will supersede any of the automated algorithms used to identify matches. When necessary, the manual associations may also specify a beginning and ending milepost; when doing so, the mileposts must be within the range of the existing HPMS mileposts and produce a length equivalent to the NHS route length.

2.2.3 Reassigning Mileposts

When a matching LRS route is found between the HPMS and NHS datasets, and the route has the same overall length in both datasets but different beginning and ending mileposts, then BMFAT analysis tool will assume that these represent the same route but are using different points of reference for their mileposts (i.e., State or County based). In these instances, the

BMFAT analysis tool will reassign the beginning and ending mileposts of the NHS route to match with the HPMS milepost values.

2.2.4 Recalculating Mileposts

When the beginning or ending mileposts for an NHS route are reassigned to match the milepost values of the HPMS dataset, the value of all the intermediate milepost breaks that may exist in the route are recalculated as well. When being recalculated, the ratio between the intermediate mileposts is maintained.

2.3 Quality Assurance Analysis

After completion of database loading, visual inspection was conducted by developing scale-based theme maps using the TransCAD GIS software. This approach is very effective at identifying the major discrepancies between adjacent links (,e.g. a significant drop of average annual daily traffic, or AADT, between two adjacent highway links) or among various functional classes. The approach also helps to identify any inherent anomalies with the HPMS database. The purpose of the quality assurance subtask was to manually check the accuracy of merged data. For example, if the difference in traffic volume from one link to the next was greater than 20 percent, the original state traffic data collected in the FAF^2 project were consulted to verify if the accurate value had been merged to the network. If the values compared well with the state data, then the more common value for that link was used to ensure continuity in the traffic volume. These abrupt changes could also result from the merging process where aggregation was used. This is a smoothing process that served as a reasonableness check of the traffic data merged with the network.

Freight demand modeling requires that there be a value for each link segment. Therefore, a default lookup table data schema was developed to address the missing data. Table 2-2 shows the type and number of lookup tables developed and the intended purpose of each. These default lookup tables were used to fill the missing data elements where required for assignment. The total number of missing links used to populate the relevant information using the lookup table was less than 5 percent of total network coverage.

Table 2-2. FAF^3 Network Missing Data Lookup Tables

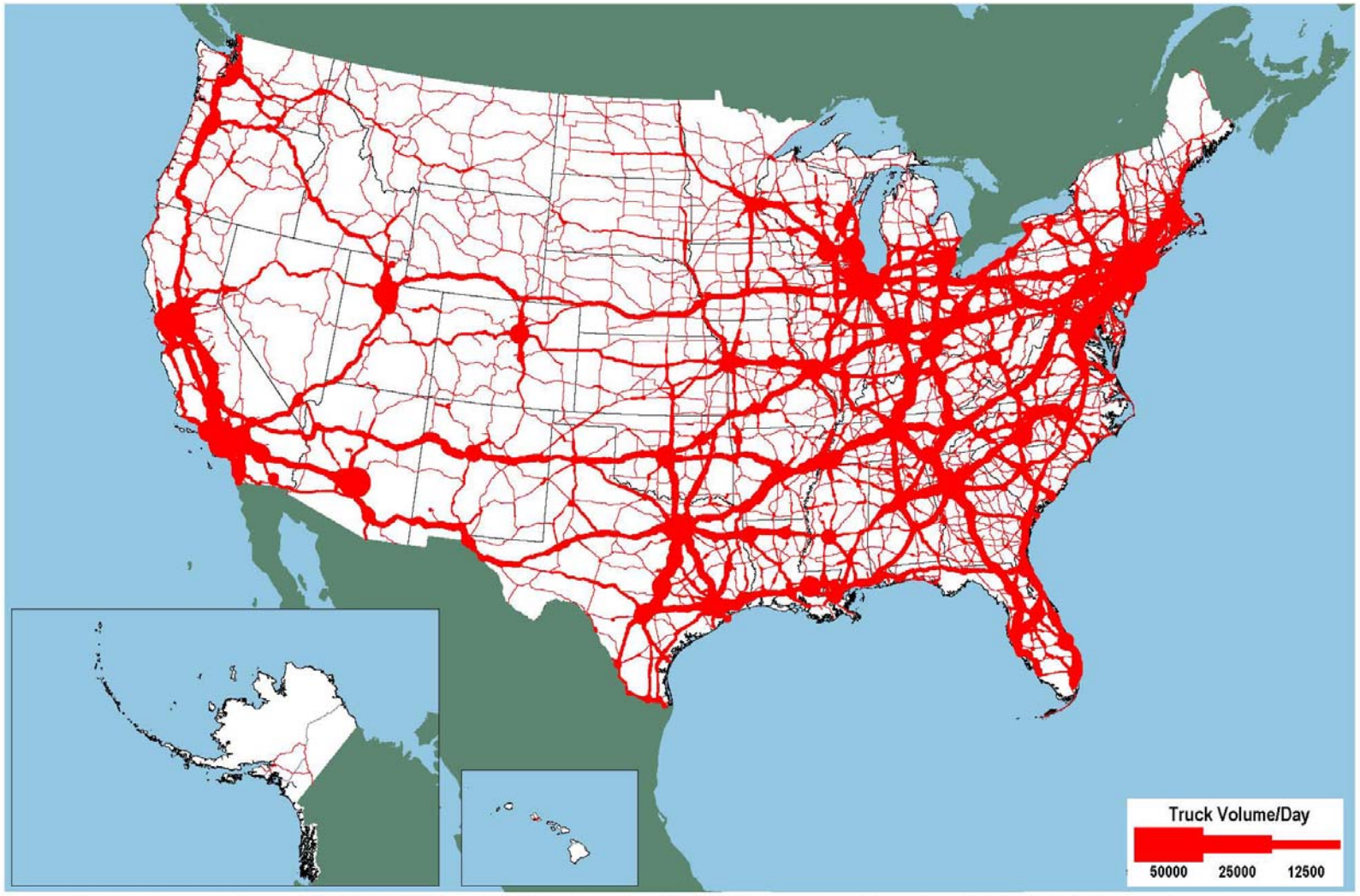
Lookup Table Name	Purpose
AADTLookup	National average AADT grouped by state and county codes and functional classification. This table is used to populate missing AADT of the network table.
AADTLookUpPerState	National average AADT grouped by state codes and functional classification. This table is used to populate missing AADT of the network table where the previous lookup table failed to do.
DFactorLookUp	For missing network D-factor values.
FixFClassLookUp	For missing functional classifications.
FreeWayFidLookUp	Adjustment factor for freeway interchange density.
FreeWayFlcLookUp	Adjustment factor for right shoulder lateral clearance; applies to freeway.
FreeWayFlwLookUp	Adjustment factor for freeway lane width.
FreeWayFnLookUp	Adjustment factor for number of lanes.
FreeWayRuralEtLookUp	Rural equivalence table for SU, Comb, ST, DT, and TT.
FreeWayTempEtLookUp	Equivalence table truck. This table is used only for peak hr factor (PHF) calculation.
FreeWayUrbanEtLookUp	Urban equivalence table for SU, Comb, ST, DT, and TT.
KFactorLookUp	For missing network K-factor values.
MultiLaneFaLookUp	For multi-lane adjustment factor for access points.
SpeedLookUp	For missing network speed values.
TruckLookUP	For missing non-network truck, SU and Comb.

Note: Single unit (SU); Combination (Comb); Semi-trailer (ST); Double trailer (DT); Triple trailer (TT)

2.4 Summary of Freight Network Development

The outcome of this task was a routable FAF^3 highway network loaded with 2007 traffic volume and other HPMS-attributable information required for the development of subsequent link parameters that are themselves required for freight assignment. Figure 2-2 illustrates the truck volume on the FAF^3 network developed using the HPMS 2007 database.

Average Daily HPMS Truck Traffic on the National Highway System: 2007



Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2011.

Figure 2-2. HPMS 2007 Truck Volume on FAF^3 Network

CHAPTER 3: DEVELOPMENT OF TRUCK PAYLOAD EQUIVALENCY FACTOR

3.1 Introduction

For freight transportation planning and highway deficiency analysis, it is important to know the number of truck trips passing through a particular highway section between freight origins and destinations. While States collect and maintain data on the number of trucks passing sections of the highway network, there is currently no direct source of information on the number of truck trips between origins and destinations. The CFS, which is a comprehensive nationwide freight movement data source, provides information in terms of the tonnage and value of commodities between destination pairs. Consequently, it is necessary to convert commodity volume into truck trips for the purposes of assignment onto the highway network as part of the freight planning process. This chapter describes procedures to convert the commodity flows measured in tons into the equivalent number of trucks for the development of the FAF^2 truck O-D matrix.

3.2 Tonnage to Truck Payload Conversion Process

The FAF^3 data do not provide an estimation of the Average Daily Truck Traffic (ADTT) used to move freight between the shipping zones. The work flow diagram shown in Figure 3-1 illustrates a general overview of the process of estimating the AADT. The primary source of information for developing the procedures for converting commodity flows in tons to truck trips was the 2002 Vehicle Inventory and Use Survey (VIUS) database. The VIUS provides national and state-level estimates of the total number of trucks by truck type. These data are gathered through surveys of a sample of the motor carrier industry, and the survey is conducted every five years as part of the U.S. Economic Census.

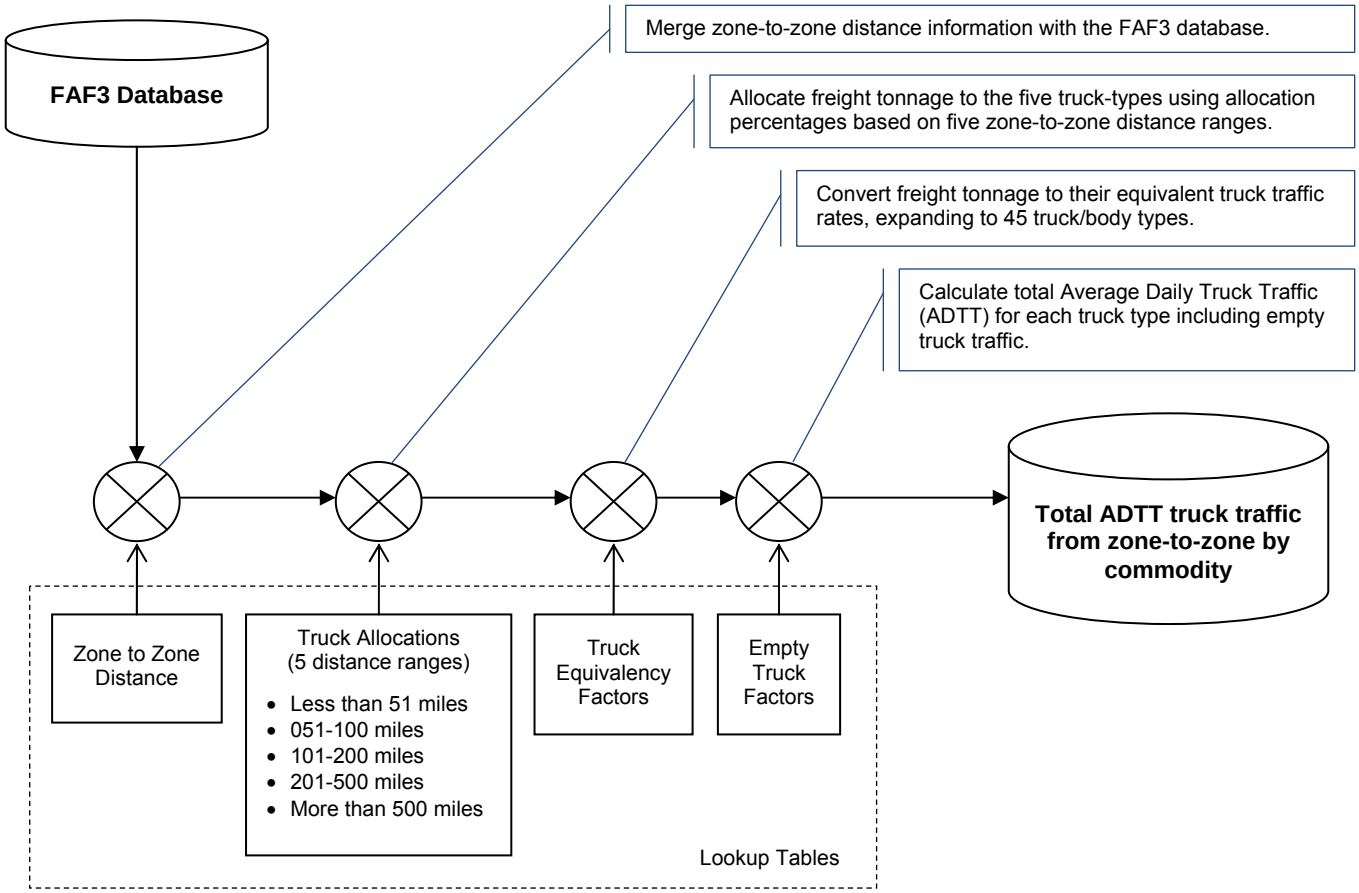


Figure 3-1. Truck Conversion Flow Diagram

The conversion of commodity flows from tons to truck trips involved five steps:

- Identifying the primary truck configurations and major truck body types (Table 3-1 and Table 3-2).
- Allocating commodities to truck configurations used to transport these commodities (Table 3-3). See Appendix B for commodity definitions.
- Estimating average payloads by vehicle group and body type.
- Converting the commodity tons into the equivalent number of trucks.
- Estimating the percent of empty truck trips.

<u>Identifying Truck Configurations and Body Types</u>

There are five primary truck configuration categories, as shown in Table 3-1.

Table 3-1. Truck Configurations

Group	Abbreviation	Description
1	SU	Single Unit Trucks
2	TT	Truck plus Trailer Combinations
3	CS	Tractor plus Semitrailer Combinations
4	DBL	Tractor plus Double Trailer Combinations
5	TPT	Tractor plus Triple Trailer Combinations

There are nine major truck-body types selected in order of decreasing percentage in the truck fleet as shown in Table 3-2.

Table 3-2. Truck-Body Types

Body	Truck Fleet	Description
1	37.72%	Dry Van
2	24.37%	Flat Bed
3	14.73%	Bulk
4	8.15%	Reefer
5	7.97%	Tank
6	2.12%	Logging
7	1.7%	Livestock
8	0.91%	Automobile
9	2.33%	Other

Allocating Commodities to Truck Configurations

The allocation of the FAF^3 O-D tonnages to each truck configuration and body type was done for each type of commodity that these trucks carry. Separate allocations were done for each of five distance ranges. This process ensured that tonnage was not assigned to a wrong truck configuration and body type when the trip length was out of the typical operating range for such trucks. The five distance ranges and allocation factors for each truck type are shown in Table 3-3.

Table 3-3. Truck Allocation Factors

Minimum Range (miles)	Maximum Range (miles)	Single Unit	Truck Trailer	Combination Semitrailer	Combination Double	Combination Triple
0	50	0.793201	0.070139	0.130465	0.006179	0.0000167
51	100	0.577445	0.058172	0.344653	0.019608	0
101	200	0.313468	0.045762	0.565269	0.074434	0.000452
201	500	0.142467	0.027288	0.751628	0.075218	0.002031
501	10000	0.06466	0.0149	0.879727	0.034143	0.004225

Estimating Average Payloads

Development of truck equivalent factors was carried out in a two-step process. First, the mean payloads by truck type, body type, and commodity type were established using VIUS 2002 database and a study prepared by Battelle for FHWA titled:

Development of Truck Payload Equivalent (TEP) Factor, June 15, 2007.

Second, the mean payloads were applied to the percent allocations by body type to convert the commodity volume in tons to an equivalent number of trucks. The formulation of the conversion from commodity tons to equivalent number of trucks is outlined in Table 3-4.

Table 3-4. Definition of the Conversion Factor Equations

i	Commodity index (1, 2, … 43)
j	Truck configuration group index (1, 2, … 5)
k	Truck body-type index (1, 2, … 9)
X_i	Tonnage of commodity (i)
Y_j	Number of trucks in truck configuration group (j)
β_{ijk}	Fraction of commodity (i) moved by truck type (j) with body type (k)
ω_{ijk}	Mean payload of truck type j with body type k transporting commodity i
$X_i\ \beta_{ijk}$	The tonnage of commodity (X_i) carried by truck type (j) and body type (k)
$X_i\ \beta_{ijk} / \omega_{ijk}$	Number of trucks of type (j) and body type (k) required to move ($X_i\ \beta_{ijk}$) tons

The number of trucks of type ($Y_{j=1}$) used to move ($X_i\ \beta_{ijk}$) tons of commodity (X_i) by all body types is given by Equation 3-1.

$$Y_{j=1} = \frac{X_i \beta_{i11}}{\omega_{i11}} + \frac{X_i \beta_{i12}}{\omega_{i12}} + \frac{X_i \beta_{13}}{\omega_{i13}} + \ldots\ldots\ldots + \frac{X_i \beta_{i19}}{\omega_{i19}} = \sum_{k=1}^{k=9} \frac{X_i \beta_{i1k}}{\omega_{i1k}} \qquad (3\text{-}1)$$

Similarly, the number of trucks of type ($Y_{j=2}$) used to move ($X_i\ \beta_{ijk}$) tons of commodity (X_i) by all body types is given by Equation 3-2.

$$Y_{j=2} = \frac{X_i \beta_{i21}}{\omega_{i21}} + \frac{X_i \beta_{i22}}{\omega_{i22}} + \frac{X_i \beta_{i23}}{\omega_{i23}} + \ldots\ldots\ldots + \frac{X_i \beta_{i29}}{\omega_{i29}} = \sum_{k=1}^{k=9} \frac{X_i \beta_{i29}}{\omega_{i2k}} \tag{3-2}$$

Thus, the number of trucks of type (Y_j) needed to move ($X_i\ \beta_{ijk}$) tons of commodity (X_i) by all body types can be expressed in Equation 3-3.

$$Y_j = \sum_{k=1}^{k=9} \frac{X_i \beta_{ijk}}{\omega_{ijk}} = X_i \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3-3}$$

Finally, the total number of trucks assigned to move commodity (X_i) and the total number of trucks assigned to move all commodities are given by Equations 3-4 and 3-5.

$$\sum_{j=1}^{j=5} Y_j = X_i \sum_{j=1}^{j=5} \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3-4}$$

$$Total_Trucks = \sum_{i=1}^{i=50} X_i \sum_{j=1}^{j=5} \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3-5}$$

The truck equivalency factor is therefore given by Equation 3-6.

$$TEF_{ijk} = \frac{\beta_{ijk}}{\omega_{ijk}} \tag{3-6}$$

The truck equivalency factor converts tons of a commodity shipped to its equivalent number of trucks. This is a three-dimensional factor that is a function of truck configuration, body type, and commodity. A complete listing of the truck equivalency factors for all truck configurations, body types, and commodities is provided in Appendix A.

Converting Tonnage to Equivalent Trucks

The truck equivalency factors were applied to the commodity flows allocated for each truck configuration to create a disaggregated data set describing the total number of loaded trucks required to move the freight between the FAF zones. The loaded truck traffic estimates were disaggregated by commodity type, truck configuration, and body type.

Estimating Empty Trucks

The empty truck percentage for a given truck and body type configuration must be added to estimate the total long distance truck population. The number of empty trucks was estimated by analyzing the percent of miles that a truck is empty in VIUS, to determine the percent of trucks operated in empty conditions. However, it was also found that more than 50 percent of trucks in each vehicle group operate more than half capacity, but less than full. Therefore, for analysis

purposes, the contribution of empty trucks is further reduced by an additional 50 percent, as reported in the VIUS data. The empty truck factors are shown in Table 3-5.

Table 3-5. Empty Truck Factors

Body Type	Single Unit	Truck Trailer	Combination Semitrailer	Combination Double	Combination Triple
Domestic and Sea-Port Shipping					
Dry Van	0	0	0.14	0	0
Flat Bed	0	0	0.2	0.16	0
Bulk	0.21	0.14	0.2	0.2	0.06
Reefer	0.14	0.16	0.16	0.2	0.03
Tank	0.17	0.18	0.2	0.2	0
Logging	0.12	0.07	0.1	0.04	0.07
Livestock	0.1	0.08	0.09	0.13	0
Automobile	0.24	0.21	0.2	0.13	0
Other	0.1	0.06	0.25	0	0
Land Border Shipping					
Dry Van	0	0	0.28	0	0
Flat Bed	0	0	0.4	0.32	0
Bulk	0.42	0.28	0.4	0.4	0.12
Reefer	0.28	0.32	0.32	0.4	0.06
Tank	0.34	0.36	0.4	0.4	0
Logging	0.24	0.14	0.2	0.08	0.14
Livestock	0.2	0.16	0.18	0.26	0
Automobile	0.48	0.42	0.4	0.26	0
Other	0.2	0.12	0.5	0	0

3.2.1 Truck Conversion – Example

The following paragraphs describe an example of the process used to determine the annual truck traffic between FAF border zones for agricultural commodities. In the first step of the analysis, zone distance information is merged with the raw FAF^3 database as shown in Table 3-6. The zone-zone distance information is provided by a lookup table.

Table 3-6. FAF^3 Data with Zone-Distance

Data Item	Value	Unit
Origin FAF Zone	49	
Destination FAF Zone	41	
Commodity	3 – Agricultural	
Tonnage	1519.15	Kilotons
Value	1373.96	Millions
Annual Truck Traffic		Trucks
Distance	171.6	Miles

The next step allocates the tonnage information between the FAF zones to the five truck types shown in Table 3-7. The tonnage for each truck type is determined using the allocation factors for the appropriate zone-distance range provided by Table 3-3.

Table 3-7. Tonnage Allocated to the Five Truck Types

Truck Type	Allocation Factors[1]	Value	Unit
Single Unit	0.313468	476.20	Kilotons
Truck Trailer	0.045762	69.52	Kilotons
Combination Semitrailer	0.565269	858.73	Kilotons
Combination Double	0.074434	113.08	Kilotons
Combination Triple	0.000452	0.69	Kilotons

Next, the freight tonnage assigned to each truck type is converted into their equivalent annual truck traffic values as shown in Table 3-8. The annual traffic values for each truck type are expanded to nine body styles. The annual traffic values are determined using the truck equivalency factors for each commodity provided by Appendix A.

[1] Allocation factors are from Table 3-3 for distance range from 101 to 200 miles.

Table 3-8. Annual Truck Traffic, Loaded Trucks

	Single Unit	Truck Trailer	Tractor Semitrailer	Tractor Double	Tractor Triple
Dry Van	0	0	0	0	0
Flat Bed	0	0	429.36	0	0
Bulk	5090.62	1142.21	5461.51	410.46	0
Reefer	9433.60	3765.88	9789.49	3023.65	0
Tank	485.73	29.89	532.41	64.45	0
Logging	4742.99	670.86	3804.16	241.98	0
Livestock	4485.85	0	12185.35	0	0
Automobile	0	0	0	0	0
Other	700.02	387.22	0	0	0

The total annual truck traffic only accounts for loaded trucks; as noted above, however, some portion of the actual truck traffic consists of empty trucks traveling between loads. To account for these empty trucks, the annual truck traffic must be adjusted using the empty truck factors provided in Table 3-5. The final total annual truck traffic is shown in Table 3-9.

Table 3-9. Annual Truck Traffic, Loaded and Empty Trucks

	Single Unit	Truck Trailer	Tractor Semitrailer	Tractor Double	Tractor Triple
Dry Van	0	0	0	0	0
Flat Bed	0	0	601.11	0	0
Bulk	7228.68	1462.03	7646.11	574.65	0
Reefer	12075.02	4970.97	12922.13	4233.12	0
Tank	650.88	40.66	745.37	90.23	0
Logging	5881.32	764.79	4564.99	261.34	0
Livestock	5383.02	0	14378.71	0	0
Automobile	0	0	0	0	0
Other	840.02	433.69	0	0	0

The next step is to consolidate the total annual truck traffic for all the body styles together for each truck type, as shown in Table 3-10.

Table 3-10. Annual Truck Traffic by Truck Type

Truck Type	Annual Traffic	Unit
Single Unit	32059	Trucks
Truck Trailer	7672	Trucks
Combination Semitrailer	40858	Trucks
Combination Double	5159	Trucks
Combination Triple	0	Trucks

The final step is to sum the annual truck traffic for all the truck types to determine the overall annual truck traffic between the FAF zones. The value is then inserted back into the original table, as shown in Table 3-11.

Table 3-11. FAF^3 Data with Annual Truck Traffic

Data Item	Value	Unit
Origin FAF Zone	49	
Destination FAF Zone	41	
Commodity	3 – Agricultural	
Tonnage	1519.15	Kilotons
Value	1373.96	Millions
Annual Truck Traffic	**85748**	Trucks
Distance	171.6	Miles

The example illustrated above has determined the average number of loaded and empty trucks used to move agricultural freight between FAF zones 49 and 41. A summary of the estimated number of trucks and average load weight is provided in Table 3-12.

Table 3-12. Annual Truck Traffic Summary

Total Freight (tons)	Total Trucks	Loaded Trucks	Empty Trucks	Tons per Truck
1519150	85748	66877	18872	22.7

3.3 Dynamic Virtual Disaggregation

The disaggregation of FAF Origin/Destination (O-D) data from 131 FAF traffic analysis zones to demand responsive virtual analysis zones was carried out for domestic and international trips separately. The work flow diagram in Figure 3-2 illustrates O-D disaggregation process.

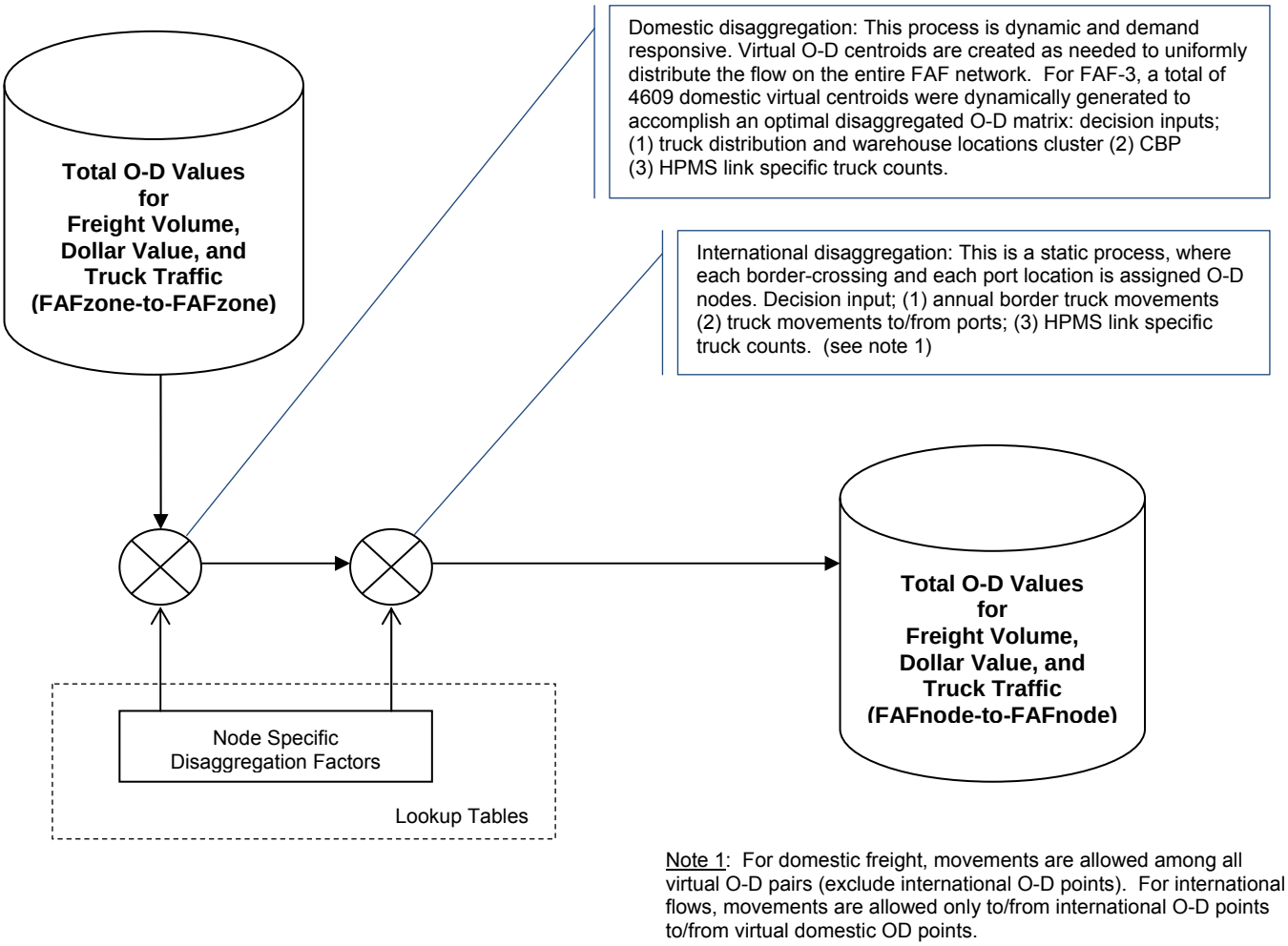


Figure 3-2. Virtual Disaggregation Flow Diagram

For domestic trips, a demand responsive virtual O-D disaggregation technique and associated software was developed using the Battelle internal research and development (IR&D)-funded BMFAT interface. The process is interactive and defines nodes in a network that are used as virtual zones that have no relationship to the FAF zone, count, or zip code centroids. The nodes allow the FAF O-D matrix to distribute flows on the U.S. highway network using off-the-shelf traffic assignment software, so that assigned flows are comparable with the link specific ground truth truck flows established from HPMS and state truck databases. The computer model developed under the BMFAT interface dynamically adjusted the location of each node as well as its share of freight flow associated, using a set of constraints that are a function of:

- Geographical location of truck related warehouse and distribution centers (18,000)
- County business patterns
- Adjacent link traffic volumes for candidate virtual nodes
- Highway functional classes connected to the virtual node
- Freight intermodal geo-locations.

For international O-D pairs, the process was static where an adjacent network node of each border crossing or port geo-location was a virtual O-D zone. The virtual O-D zone for international movement was further divided into cross-border movements (Canada and Mexico) and port movements. Cross-border movements were defined as O-D pairs originating from a FAF zone adjacent to Canada or Mexico and destined to another FAF zone, and vice versa. Similarly, for ports, the O-D pairs originated from, or were headed toward, a FAF zone containing one or more ports or gateways. Prior to assignment, domestic and international FAF O-Ds were disaggregated to virtual loading and unloading points by distributing the freight proportionately to virtual nodes using Equation 3-7.

$$(T)_{c(s)} = (T)_s \times (E_{c(s)} / E_s) \tag{3-7}$$

Where:

$(T)_{c(s)}$	Freight trucks/tons produced or attracted in virtual node c(s)
$(T)_s$	Freight truck/tons produced or attracted in FAF zone (s), which comprises a set of virtual nodes
$E_{c(s)}$	The percent share of freight activity by virtual node c(s) for FAF zone (s)
E_s	The total freight activity within the FAF zone (s)

3.3.1 Virtual Disaggregation – Example

The following paragraphs describe an example of the process used to spread the granularity of the FAF O-D zone matrix to the virtual node matrix. The truck conversion process illustrated in the previous example produced the Annual Truck Traffic (ATT) per commodity values for commodity 3 (Agricultural). Completing the same process for each commodity produces the ATT values shown in Table 3-13.

Table 3-13. ATT between FAF Zones 49 and 41

Index	ATT	Index	ATT	Index	ATT
1	1941	16	0	31	1530
2	235	17	0	32	3826
3	85748	18	0	33	528
4	122	19	0	34	5889
5	28	20	16	35	4925
6	382	21	9	36	116
7	1319	22	20	37	12
8	187	23	147	38	1596
9	0	24	2604	39	240
10	0	25	0	40	105
11	0	26	1247	41	0
12	0	27	38	42	0
13	600	28	230	43	1507
14	6	29	15		
15	0	30	2973		

The first step of the disaggregation process is to determine the overall total ADTT between the O-D zones using the formula given in Equation 3-8. For this example, this process produces the values shown in Table 3-14.

$$ADTT = \left(\sum_{i=1}^{i=43} ATT \right) \div 365 \tag{3-8}$$

Where:

ADTT	Average Daily Truck Traffic
ATT	Annual Truck Traffic per Commodity
i	Commodity index (1, 2, … 43)

Table 3-14. FAF^3 Data with ATT and ADTT

Data Item	Value	Unit
Origin FAF Zone	49	
Destination FAF Zone	41	
Commodity	All Commodities	
Annual Truck Traffic	118141	Trucks
Average Daily Truck Traffic	323	Trucks

Next, the ADTT is spread among the virtual shipping nodes that exist for the origin zone to produce a node-to-zone disaggregation table shown in Table 3-15. Share factors for each virtual node are provided by an extensive lookup table that defines what portion of the total freight flow for the zone is handled by each node. For domestic freight, the lookup table is a virtual one and is adjusted as the number of dynamic node varies one too many.

Table 3-15. Node-to-Zone Disaggregation

Origin Zone	Zone AADT	Node Index	Node Share	Node-to-Zone AADT
49	323	135463	0.115658	37.35
		135466	0.072342	23.36
		135468	0.799469	258.23
		135643	0.012531	4.05

The final step is to further spread the ADTT for each origin node among the virtual shipping nodes that exist for the destination zone to produce a node-to-node disaggregation table, as shown for example in Table 3-16. As before, a lookup table provides the share factors for each virtual node.

Table 3-16. Node-to-Node Disaggregation

Origin Node Index	Node AADT	Destination Node Index	Node Share	Node-to-Node AADT
135463	37.35	134702	0.016667	0.6225
		134703	0.025	0.9338
		134729	0.208333	7.7812
		134857	0.033333	1.245
		134974	0.033333	1.245
		135000	0.008333	0.3112
		135060	0.016667	0.6225
		135091	0.041667	1.5563
		135107	0.041667	1.5563
		135248	0.15	5.6025
		135257	0.016667	0.6225
		135284	0.008333	0.3112
		135725	0.133333	4.98
		135926	0.033333	1.245
		135958	0.166667	6.225
		136044	0.016667	0.6225
		136078	0.05	1.8675
135466	23.36	134702	0.016667	0.3893
		134703	0.025	0.584
		134729	0.208333	4.8667
		134857	0.033333	0.7787
		134974	0.033333	0.7787
		135000	0.008333	0.1947
		135060	0.016667	0.3893
		135091	0.041667	0.9733
		135107	0.041667	0.9733
		135248	0.15	3.504
		135257	0.016667	0.3893
		135284	0.008333	0.1947
		135725	0.133333	3.1147
		135926	0.033333	0.7787
		135958	0.166667	3.8933
		136044	0.016667	0.3893
		136078	0.05	1.168

Table 3-16. Node-to-Node Disaggregation (Continued)

Origin Node Index	Node AADT	Destination Node Index	Node Share	Node-to-Node AADT
135468	258.23	134702	0.016667	4.3039
		134703	0.025	6.4558
		134729	0.208333	53.7978
		134857	0.033333	8.6076
		134974	0.033333	8.6076
		135000	0.008333	2.1518
		135060	0.016667	4.3039
		135091	0.041667	10.7597
		135107	0.041667	10.7597
		135248	0.15	38.7345
		135257	0.016667	4.3039
		135284	0.008333	2.1518
		135725	0.133333	34.4306
		135926	0.033333	8.6076
		135958	0.166667	43.0384
		136044	0.016667	4.3039
		136078	0.05	12.9115
135643	4.05	134702	0.016667	0.0675
		134703	0.025	0.1013
		134729	0.208333	0.8437
		134857	0.033333	0.135
		134974	0.033333	0.135
		135000	0.008333	0.0337
		135060	0.016667	0.0675
		135091	0.041667	0.1688
		135107	0.041667	0.1688
		135248	0.15	0.6075
		135257	0.016667	0.0675
		135284	0.008333	0.0337
		135725	0.133333	0.54
		135926	0.033333	0.135
		135958	0.166667	0.675
		136044	0.016667	0.0675
		136078	0.05	0.2025

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CHAPTER 4: FREIGHT TRUCK ASSIGNMENT AND CALIBRATION

4.1 Introduction

This chapter describes the processes of network preparation for freight demand modeling and associated freight assignment procedures and calibration.

4.2 Network Preparation

Network preparation is required to define and populate the attributes of the highway links that are necessary for freight assignment. These include travel impedance functions, free flow speeds, and link capacities. These attributes determine the capacity-related performance characteristics of each link.

4.2.1 Impedance Function

Travel time on a given link was estimated by dividing its length by the travel speed on that link. Therefore, travel time for a given link changes as the travel speed fluctuates. The speed of a given link can also be affected by roadway type or other conditions, as indicated earlier. Consequently, this reduced speed would introduce a penalty to the initial link travel time. Thus the impedance function of a link can be mathematically expressed as:

$$T_j = \frac{L_j}{S_j} r_j + f_j \tag{4-1}$$

where T_j = the link free flow travel time

L_j = the length of link *j* in miles

S_j = the free flow speed on link *j* in miles-per-hour

r_j = travel time adjustment factors, which is a function of the number of lanes, urban bypass, traffic restriction, truck route designation, tolls, and the link reliability

f_j = the penalty.

4.2.2 Free Flow Travel Speed

The free flow speed (FFS) of a link can be defined as the average speed of a vehicle on that link, measured under low-volume conditions when drivers tend to drive at their desired speed and are not constrained by control delay. The FFS for the FAF network link was determined by the following equations from the NCHRP Report 387, "*Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications*":

$$\text{FFS} = (0.88 * \text{Link Speed Limit} + 14);\ \text{for speed limits} > 50\ \text{mph} \tag{4-2}$$

$$\text{FFS} = (0.79 * \text{Link Speed Limit} + 12);\ \text{for speed limits} <= 50\ \text{mph} \tag{4-3}$$

The link speed limit was obtained from HPMS data. The FAF network link with missing speed limit values was assumed based on the following four physical characteristics of highway segments:

1. Access control for the given highway segment
2. Median type
3. Quality of the roadway pavement (paved vs. unpaved)
4. Classification of the highway segment within or outside of an urban boundary.

Assumed speed limits for the combinations of these four characteristics are given in Table 4-1.

Table 4-1. Speed Limits (mph) for Missing HPMS Speed Data

Functional Class	Pavement Type	Fully Controlled		Partially Controlled		Uncontrolled	
		With Median	Without Median	With Median	Without Median	With Median	Without Median
Rural	Paved	65	60	65	55	65	55
	Unpaved	25	15	20	15	15	10
Urban	Paved	55	45	45	35	35	25
	Unpaved	15	10	10	10	10	10

4.2.3 Travel Impedance

The total impedance of a selected highway path (i.e., truck route), denoted as *T*, can be expressed mathematically as the sum of all link impedances (i.e., T_j 's). Assuming there are n links on the selected path, the impedance of the selected path is then equal to:

$$T = \sum_{j=1}^{n} T_j \tag{4-4}$$

The adjustment factors as denoted by r_j in Equation 4-1 were estimated based on several road characteristics or criteria. The total adjustment factor, *r*, is a mathematical product of all adjustment factors that meet the following criteria:

Number of lanes: When there are 4 or more lanes of traffic in both directions, the link travel time is reduced by 2 percent (r = 0.98).

Urban bypass: When the given link is on an urban bypass, its travel time is increased by 4 percent (r = 1.04).

Truck restrictions: When the link has known truck restrictions, the link travel time is increased by 60 percent (r = 1.6). For highway segments that prohibit trucks carrying hazardous materials, the travel time of the link is increased by 5 percent (r = 1.05).

Truck route designation: If a link is on a federal or state designated truck route, the given link's travel time is reduced by 1.5 percent (r = 0.985).

Tolls: When the given link is a toll road or bridge, its travel time is increased by 2.5 percent (r =1.025).

Reliability: This factor is based on the assumption that travel time on links with interstate designations are more predictable to the drivers than the other links. If the given link is on the rural interstate, then the travel time is reduced by 10 percent (r = 0.9). For an urban interstate, travel time is reduced by 5 percent (r = 0.95).

For example, assume that a FAF link is a multi-lane (4 or more) urban bypass with an urban interstate designation. The link is also part of a toll road and part of a federally designated truck route. The resultant adjustment factor of *r* for free flow travel time for this particular link can be estimated as:

$$\text{Adjusted } r = r_{number\ of\ lanes} \times r_{urban\ bypass} \times r_{truck\ route} \times r_{tolls} \times r_{urban\ interstate} \quad (4\text{-}5)$$

$$\text{Adjusted } r = 0.98 \times 1.04 \times 0.985 \times 1.025 \times 0.95 = 0.978 \quad (4\text{-}6)$$

The final adjustment of the travel impedance cost was done during the network calibration process under the FAF assignment. The network calibration was done by adjusting the link impedance cost, capacity, or both, so that the link flow was as close as possible to the baseline traffic. The baseline is the truck traffic data on the links that are derived from the state's actual truck classification counts. The size of the network does not allow baseline truck flow to be balanced with assigned truck trip (using the FAF O-D freight matrix) for each link. However, efforts were made to adjust the nation's truck flow pattern for major routes.

Travel impedance cost is not a simple function of travel time only, and therefore caution must be taken to convert the travel cost to equivalent speed.

4.2.4 Link Capacity

The capacity of a given link can be defined as the a maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a specified time period under given roadway, geometric, traffic, environmental, and control conditions; this capacity is usually expressed as vehicles per hour, passenger cars per hour, or persons per hour.

The link capacity of the FAF network is populated from 2008 HPMS data or estimated using the HPMS capacity estimation procedures. The general procedures for estimating highway capacity for 2-lane facilities, multilane facilities—divided and undivided and freeways by design are included in Appendix N of the HPMS Manual [11].

The capacity value reported in an HPMS sample section is for one direction on multilane facilities and for both directions on 2- or 3-lane facilities. Capacity is expressed as maximum service flow rate at Level of Service (LOS) E in passenger cars per hour direction (one direction for multilane and both directions for 2 or 3 lane). The HPMS capacity is also called "practical capacity," because the reported capacity has been reduced to account for the presence of heavy vehicles.

Since the FAF^3 truck assignment is based on average annual daily truck traffic (AADTT) virtual O-D matrices, adjustments to capacity values were required to simulate the 24-hour equivalent capacity for a given link. This was done by expanding the capacity using the links D (directional) and K (traffic factor). This capacity is referred to as model capacity, to be used as a

freight assignment input. Typically an assignment model is carried out for an hourly trip that is estimated by multiplying the AADT by the D and K factors. To simulate the similar capacity constraint scenario, the FAF^3 AADTT virtual O-D matrix was kept in terms of a daily average trip, and the capacity was expanded by dividing the capacity (volume/hour/lane) by the D and K factors and the applicable numbers of lanes. The result (daily average capacity, expressed as volume/day/link) was then used as the model capacity for subsequent capacity constrained assignment.

4.3 Assignment Algorithm and Calibration

Traffic assignment models are used to estimate the flow of traffic on a network to establish the traffic flow patterns and analyze congestion points. Intra-zonal truck movements (local traffic) are not included in the assignment process. Even though the highway capacity analysis is focused on a detailed assessment of freight flows and impacts on the highway system, highway bottlenecks are highly dependent on the interaction of total truck and passenger car traffic. Therefore passenger traffic was a key consideration in the assignment process. In this regard, freight flows were assigned with passenger traffic and non-freight (local) trucks pre-loaded on the freight analysis network. Detailed demand analysis of passenger traffic was not performed as part of the study. Rather, current passenger traffic counts and future growth rates as included in the HPMS database were used. The assignment model and procedure applied to the FAF^3 freight demand modeling are described in the following sections.

4.3.1 Assignment Algorithm

The Stochastic User Equilibrium (SUE) traffic assignment procedure in TransCAD 5.0 with user defined volume delay function (VDF) was used. This assignment is constrained by the highway network's current capacity. The SUE is a generalization of user equilibrium (a modified capacity constraint approach) that assumes travelers may not have perfect information concerning network congestion and delay and/or perceive travel costs in different ways; therefore, they may change the travel pattern by taking alternate routes as the network (or a specific link of a network) gets congested. The selected VDF for FAF^3 assignment is the Bureau of Public Roads (BPR) function. A detailed description of this function can be found in Chapter 9 of TransCAD user guide for Travel Demand Modeling with TransCAD. The general form of the BPR function is shown in Equation 4-7.

$$t = t_i \bullet \left[1 + \alpha_i \left(\frac{x_i}{C_i} \right)^{\beta_i} \right] \tag{4-7}$$

Where

t = Congested travel time
t_i = Free flow travel time on link i
C_i = Capacity of link i
x_i = Flow on link i
α_i = Calibration constant
β_i = Calibration constant.

Battelle has successfully used this procedure on FAF[1] and ongoing FHWA Strategic Multimodal Analysis (SMA) projects. This approach reasonably forecasts the link traffic volumes on two parallel highways with the same route distance but different degrees of congestion. An example is US-99 in and I-5 in Los Angeles County, California. The all or nothing (AON) or non-capacity traffic assignment without a passenger traffic pre-load will assign most of the truck traffic to I-5, but in reality, a large portion of truck traffic also uses US-99. Figure 4-1 illustrates the significant difference between these two methods of freight assignment.

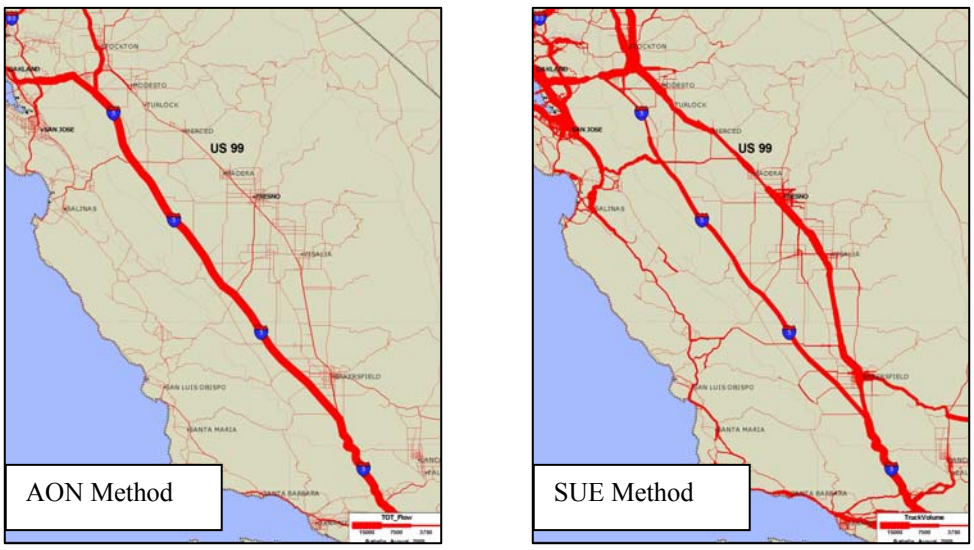


Figure 4-1. Comparison of AON and SUE Truck Traffic Assignment

4.3.2 Freight Assignment Calibration

The purpose of this step was to calibrate the 2007 base year demand flow so that the assigned truck trips match the HPMS truck volumes in the network as closely as possible. The calibration ensured that differences or discrepancies between the actual traffic flows and those estimated from freight O-D data were minimized. This was an iterative process that involved comparing assigned demand truck traffic flow with baseline flows. The output of this task was a calibrated baseline AADTT O-D matrix for the entire freight analysis network.

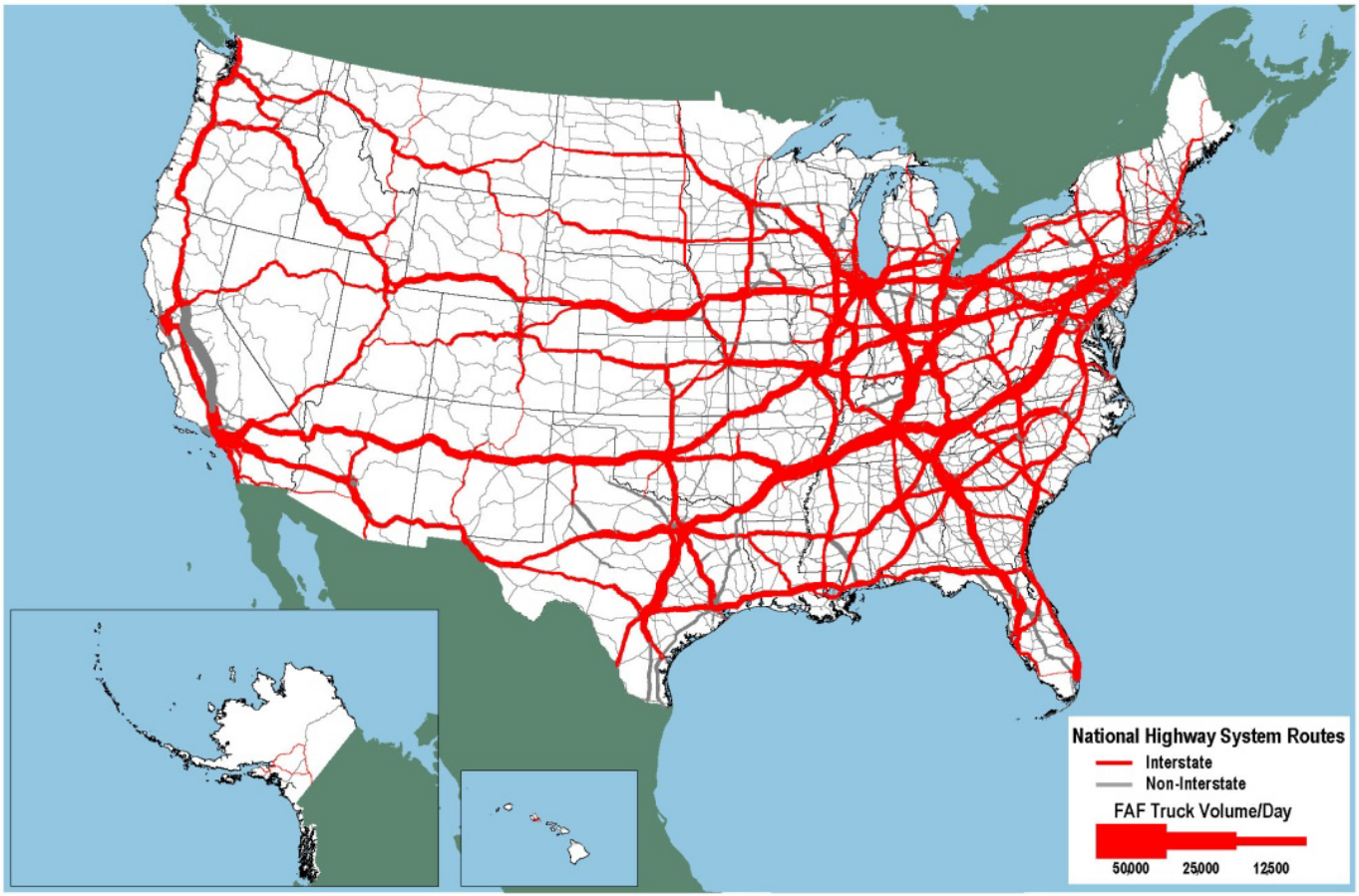
The challenge in calibrating network assignments is that the tonnage to truck freight data and the HPMS truck data, which form the baseline traffic, were derived from different sources. The baseline HPMS truck data were derived from states with varying data quality and data collection methods, and freight flow data were derived by converting the FAF[3] tonnage data using a set of

tons to truck equivalent factors based on several assumptions and expert knowledge. Assumptions were made about the truck capacity and types of commodities carried. Reconciling these flows or minimizing the differences is a major challenge.

The calibration effort involved adjusting the link travel time or capacity or the calibration constant (α_i and β_i) of the network or both so that the assigned link flows were as close as possible to the baseline flows. The size of the network made it impossible to balance the flows link by link. However, efforts were made to balance the assigned flows to the baseline link flows as closely as possible for major routes (mostly interstate and principal arterials). Once the network was calibrated, the forecast truck trip matrices for 2040 were assigned to the network using base case congestion travel time as the impedance value using AON assignment procedure. This was done to ensure the consistency with the base year (2007), with an assumption that route choice behavior will remain the same between 2007 and 2040 scenario, and with constant network (no improvement) during the analysis period. Figure 4-2 and Figure 4-3 illustrate the FAF^3 base year 2007 flow, and FAF^3 2040 flow respectively.

The next major step was to determine the highway capacity-related performance measures resulting from the assigned freight traffic for 2007 and 2040. The outputs of the assignment process were used in the capacity analysis presented in Chapter 6.

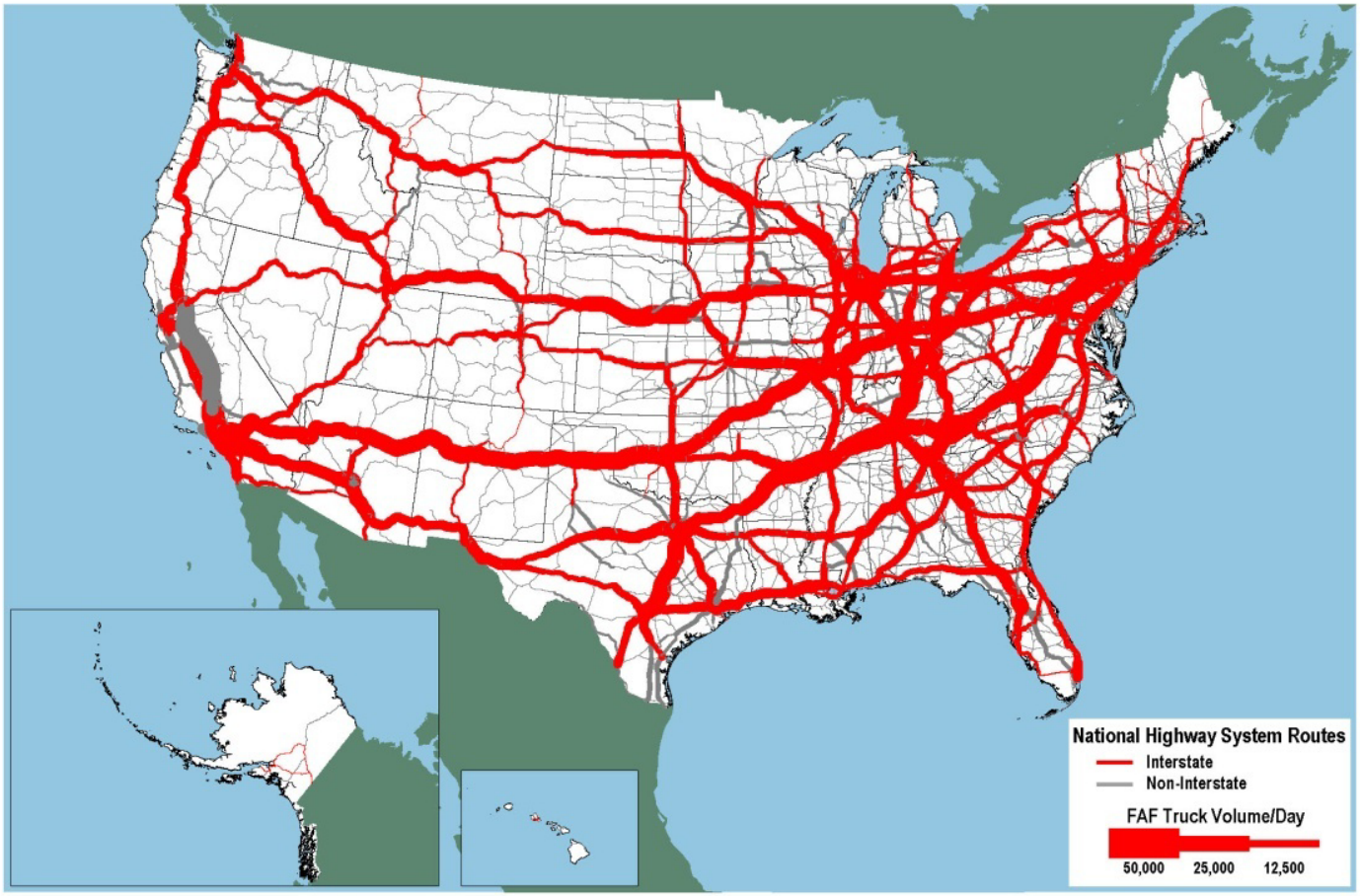
Average Daily Long-Haul Freight Truck Traffic on the National Highway System: 2007



Note: Long-haul freight trucks typically serve locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010.

Figure 4-2. Base Year 2007 FAF^3 Truck Flow on FAF^3 Highway Network

Average Daily Long-Haul Freight Truck Traffic on the National Highway System: 2040



Note: Long-haul freight trucks typically serve locations at least 50 miles apart, excluding trucks that are used in movements by multiple modes and mail.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010.

Figure 4-3. Year 2040 FAF^3 Truck Flow on FAF^2 Highway Network

CHAPTER 5: CAPACITY AND PERFORMANCE ANALYSIS

5.1 Introduction

The next step of this project was to determine the capacity deficiencies of the freight transportation highway network based on the supply and demand of freight (truck traffic) flows. Given that truck travel patterns are different from commuter travel patterns, it is necessary to determine the effects of truck traffic on capacity requirements of the network for truck peak hour design flows.

5.2 Capacity Analysis

The highway capacity analysis was intended to provide information on a set of performance measures for each highway link. Highway capacity-related performance measures include traffic volume, travel time, link delay, congested speed, and service to flow ratio. These performance measures were estimated for the 2007 base year as well as the forecast year 2040. Differences in these performance measures between the base year and the forecast year are indications of changes in congestion and the ability of the highway system capacity to support freight transportation system demand in the future.

The capacity and performance results can be used to generate thematic maps that show highway links with capacity problems. The performance measures can also be aggregated to identify those congested highway links connecting border crossings, seaports, airports, and other gateways including intermodal transfer points. The performance measures resulting from the analysis can also be organized and aggregated to serve as inputs to other policy-related analyses.

This section explains the calculation of the performance measures for capacity analysis including

- Traffic Volume
- Design Hour Volume
- Capacity
- *v/c* (volume:capacity) ratios
- Travel times, Speed, and Delay.

5.2.1 Traffic Volume

The traffic volume on any link on the network, for a particular forecast year *x*, is the sum of passenger vehicles, freight trucks, and non-freight trucks as expressed in Equation 5-1.

$$V_x = N_x + FAF_x + P_x \tag{5-1}$$

where

$\boldsymbol{V_x}$ = The total AADT volume in a segment of the network

$\boldsymbol{N_x}$ = The total non-FAF trucks on the segment

$\boldsymbol{FAF_x}$ = The total freight trucks on the segment

$\boldsymbol{P_x}$ = The passenger cars on the segment.

The freight truck volumes on each highway link for 2007 and 2040 are outputs of the assignment process. This relationship holds true for both years. However, the calculation of non-freight and passenger volumes varies from 2007 to 2040. The non-FAF truck volume in 2007 was calculated as follows:

$$N_{2007} = \begin{cases} AADTT - FAF_{2007} & if AADTT >= FAF_{2007} \\ 0 & otherwise \end{cases} \tag{5-2}$$

where ***AADTT*** = baseline HPMS truck volume for 2007.

The passenger car volume is the difference between the AADT and the AADTTs available for each segment.

$$P_{2007} = AADT_{2007} - AADTT_{2007} \tag{5-3}$$

where ***AADT*** = baseline total traffic volumes for 2007.

In order to obtain the corresponding passenger and non-FAF truck traffic volumes for 2040, growth factors were applied. The growth factors were derived using the county-specific HPMS growth factor using HPMS vehicle miles traveled (VMT, for sample sections only) over the next 20 years from the base year 2007. A straight-line projection was used to estimate the 2040 growth rate. The volumes of passenger cars and non-freight trucks for 2040 is given by equations 6.4 and 6.5 as follows.

$$P_{2040} = P_{2007}(1 + G_p)^{33} \tag{5-4}$$

$$N_{2040} = N_{2007}(1 + G_t)^{33} \tag{5-5}$$

Where

G_p = HPMS growth rate for passenger cars per year
G_t = HPMS growth rate for trucks per year
P_{2007} = passenger car traffic volume for 2007
P_{2040} = passenger car traffic volume for 2040
N_{2007} = non-FAF truck traffic volume for 2007
N_{2040} = non-FAF truck traffic volume for 2040.

5.2.2 Design Hour Volume

While daily volumes are useful for planning purposes, they cannot be used alone for design or operational analysis. Volume varies considerably during the course of the day and by direction. The peak hour volumes are often used as the basis for highway design and for many types of operational analysis. One way of estimating peak hourly volumes is to use the daily volume projections and the K factor, using the following relationship.

$$DHVx = V_x \times K\text{-Factor} \tag{5-6}$$

where

DHV_x	=	Design hour volume on the link for forecast year *x (vph)*
V_x	=	Daily volume on the link for forecast year *x (vpd)*
K-Factor	=	Proportion of daily traffic occurring during the peak hour, expressed as a decimal. For design purposes, this represents the proportion of AADT occurring during the 30th highest peak hour of the year.

The AADT volumes for 2007 and 2040 were converted using the above relationships to obtain design hour volumes.

5.2.3 Capacity

The capacity of a segment is assumed as the service volume at LOS E. The general procedures for estimating highway capacity for 2-lane facilities, multilane facilities—divided and undivided, freeways by design are included in Appendix N of the HPMS Manual and utilize Highway Capacity Manual (HCM) 2000 procedures.

5.2.4 V/C Ratios

A critical factor in any capacity analysis is the proportion of the facility's capacity being utilized by current or projected traffic. This ratio is often used as a measure of sufficiency of existing or proposed capacity. In forecasting situations, a volume to capacity (v/c) ratio above 1.00 predicts that the facility will fail, i.e., be unable to discharge the demand arriving at the section, leading to excessive delays and queues. The v/c ratios for each segment are calculated by dividing the design hour volume by the capacity calculated in the previous section. These ratios are then classified into three groups: <0.75, 0.75 to 95.0, and >0.95 for different groupings like functional classes, rural/urban, etc. The v/c ratios can also be combined with the network and plotted thematically, allowing visual inspection of congested segments of the roadway.

5.2.5 Travel Time, Speed, and Delay

The congested travel time and link speed for the FAF network was estimated using the HCM 2000 area wide planning level procedure listed in Chapter 30 of the HCM 2000. The vehicle speed for the FAF link was computed using Equation 5-7:

$$S = \frac{L}{R + \frac{D}{3600}} \tag{5-7}$$

Where

S= link speed
L=link length
R=link transversal time (h)
D = Node delay and assumed zero for this exercise.

The link traversal time was calculated using Equation 5-8:

$$R = R_0 + D_0 + 0.25T\left[(X-1) + \sqrt{(X-1)^2 + \frac{16J * X * L^2}{T^2}}\right] \tag{5-8}$$

Where

R = link transversal time (h)
R_0 = link transversal time at link FFS (h)
D_0 = zero-flow control delay at signalized intersection (h)
T = expected duration of demand (typically 1h) (h)
X = link demand to capacity ratio
J = calibration parameter
L = link length (mi).

The link transversal time for free-flow condition (R_0) was computed from the FFS, using Equation 5-9:

$$R_0 = \frac{L}{S_0} \tag{5-9}$$

Where

R_0 = link transversal time at link FFS (h)
L = link length (mi)
S_0 = link FFS (mi/h).

The calibration parameter J was selected so that the transversal time equation will predict the mean speed of the traffic when demand is equal to capacity. Substituting x = 1.00 in the transversal time equation and solving for J yields the equation:

$$J = \frac{(R_C - R_0)^2}{L^2} \tag{5-10}$$

Where

J = calibration parameter
R_0 = link transversal time at link FFS (h)
R_0 = link transversal time when demand equals capacity (h)
L = link length (mi).

The assumed values of parameter J for freeway, multilane, and urban links are listed in Table 5-1 and are derived from HCM Exhibit 30-4. Table 5-2 lists the J values for urban links. Since FAF used the BPR vehicle delay function for freight assignment, these values are more appropriate for estimating link transversal times.

Table 5-1. J Values for Multilane, Freeway, and Rural FAF Highway Links

RoadType	MinSpeed	MaxSpeed	J
1	0	55	3.31E-06
1	56	60	8.65E-06
1	61	65	0.0000148
1	66	70	0.000021
1	71	85	0.0000269
2	0	45	2.52E-06
2	46	50	1.63E-06
2	51	55	2.03E-06
2	56	80	0.0000023
3	0	44	0.000929
3	45	50	0.0004
3	51	56	0.000202
3	57	63	0.000114
3	64	80	0.0000691

Table 5-2. J Values for Urban FAF Highway Links

RoadType	FClass	J
4	14	0.000468
4	16	0.000502
4	17	0.00455
4	19	0.0137

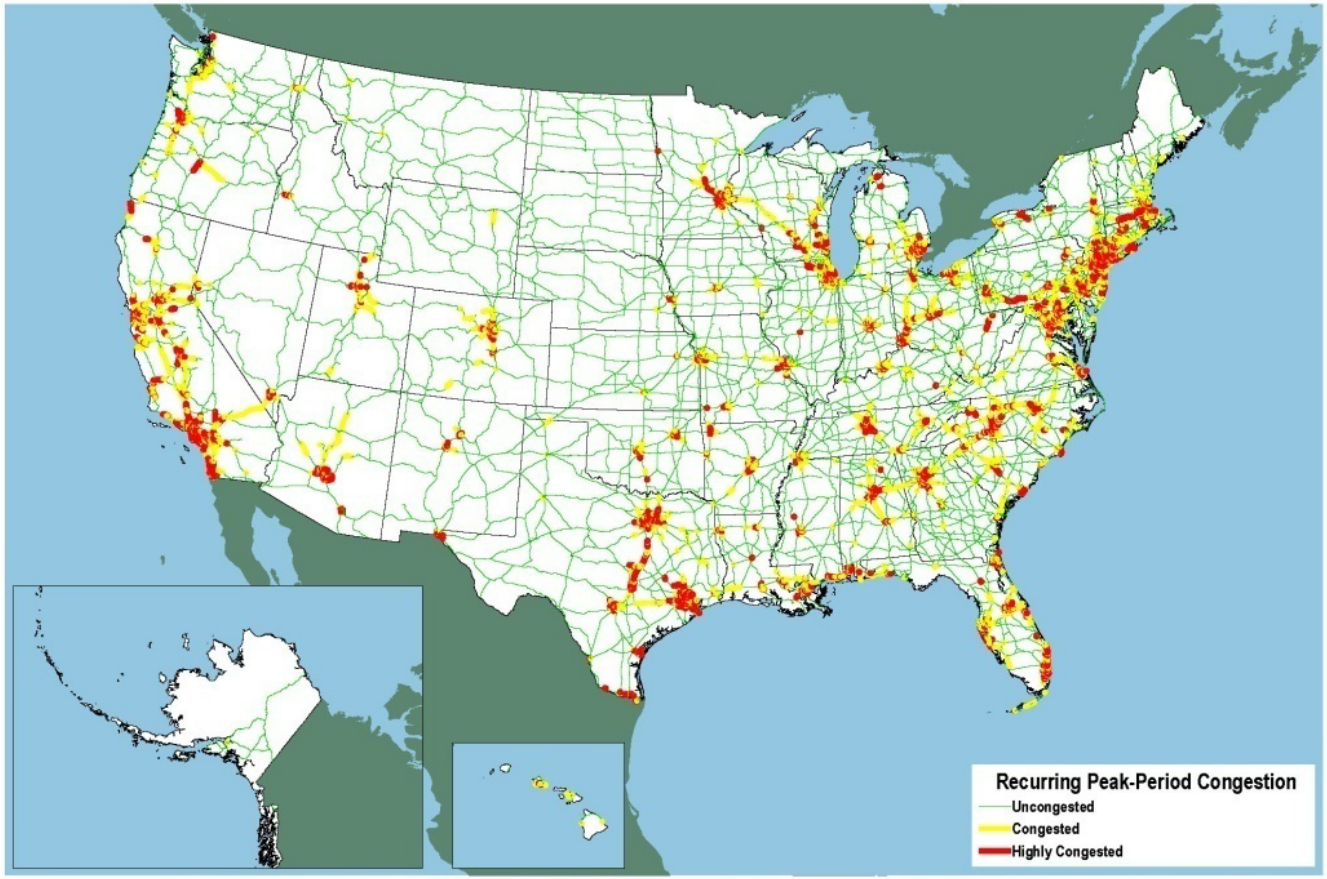
5.3 Highway Capacity Impacts

A summary of highway capacity impacts due to 2007 and 2040 freight truck traffic volumes was also estimated, using the service v/c ratio value. The impact on highway capacity is expressed as the miles of highway that fall into one of three categories based on the following v/c ratios:

1. Below capacity – v/c less than 0.75
2. Approaching capacity – v/c ratio 0.75 to 0.95
3. Exceeding capacity – v/c ratio greater than 0.95.

Figure 5-1 and Figure 5-2 illustrate highway congestion for 2007 and 2040.

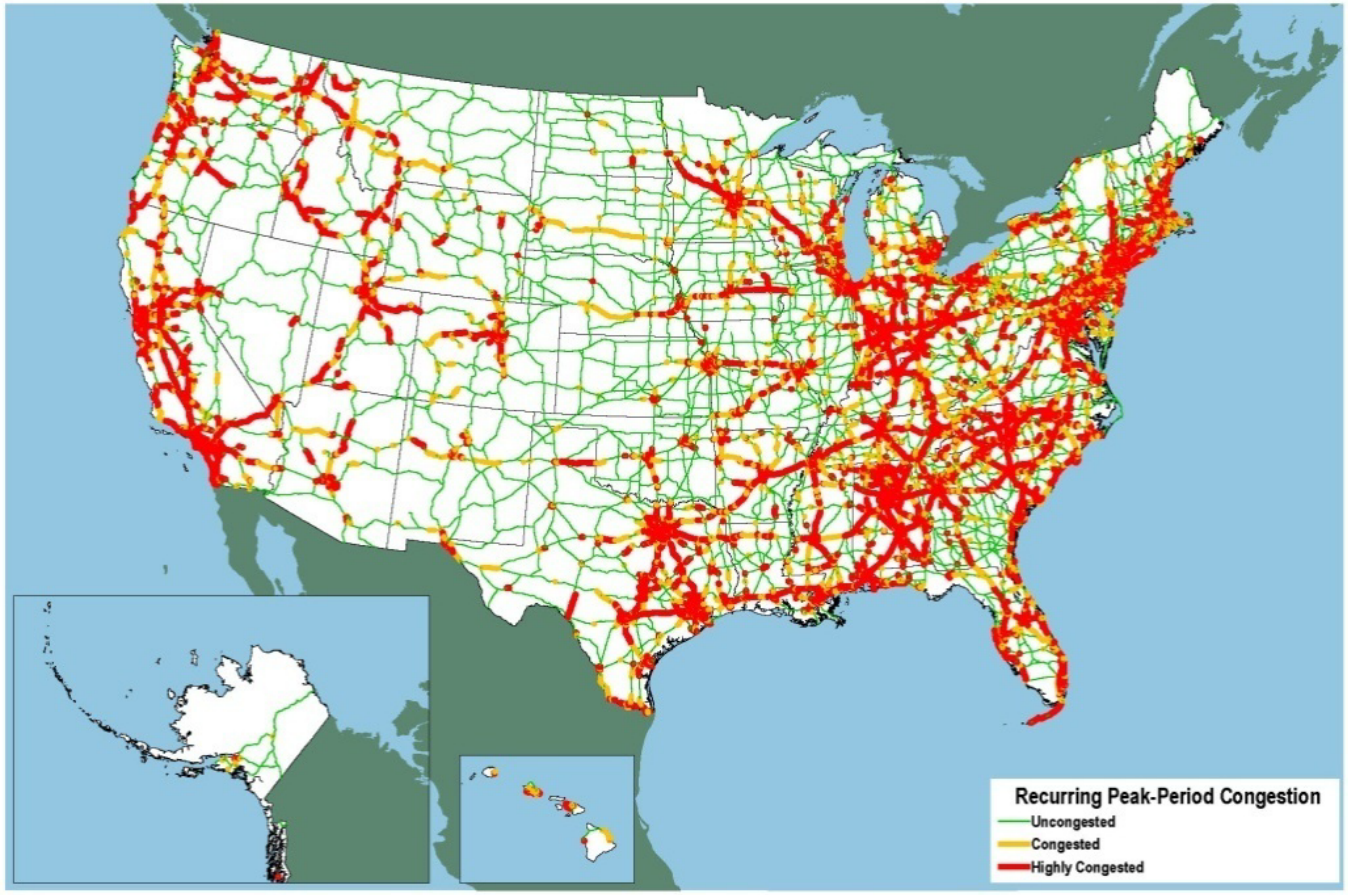
Peak-Period Congestion on the National Highway System: 2007



Note: Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95.
Source: U. S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, Highway Performance Monitoring System, and Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010

Figure 5-1. NHS Highway Network Congestion for Year 2007

Peak-Period Congestion on the National Highway System: 2040



Note: Highly congested segments are stop-and-go conditions with volume/service flow ratios greater than 0.95. Congested segments have reduced traffic speeds with volume/service flow ratios between 0.75 and 0.95. The volume/service flow ratio is estimated using the procedures outlined in the HPMS Field Manual, Appendix N
Source: U. S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.1, 2010

Figure 5-2. NHS Highway Network Congestion for Year 2035

The capacity analysis results for the scenario analysis are summarized in Table 5-3, which shows the highway miles in the three categories of capacity as defined by the v/c ratios by functional highway class. Highway miles in each v/c category are also expressed as percentages of the total highway miles in that functional class and state.

Table 5-3. Summary Statistics of Capacity Analysis

Miles of Highway by V/C Ratio Category			2007		2040	
NHS,IS (miles)	Urban	<= 0.75	8,565	51.96%	2,785	16.90%
		0.75 - < 0.95	4,558	27.65%	2,299	13.95%
		> 0.95	3,361	20.39%	11,399	69.16%
	Rural	<= 0.75	27,361	90.65%	15,640	51.82%
		0.75 - < 0.95	2,239	7.42%	5,279	17.49%
		> 0.95	583	1.93%	9,265	30.70%
NHS, Non-IS (miles)	Urban	<= 0.75	27,495	82.57%	16,283	48.90%
		0.75 - < 0.95	3,406	10.23%	6,095	18.30%
		> 0.95	2,397	7.20%	10,920	32.79%
	Rural	<= 0.75	82,207	97.74%	70,053	83.29%
		0.75 - < 0.95	1,416	1.68%	6,486	7.71%
		> 0.95	483	0.57%	7,568	9.00%
All NHS (miles)		<= 0.75	145,628	88.76%	104,761	63.85%
		0.75 - < 0.95	11,619	7.08%	20,159	12.29%
		> 0.95	6,824	4.16%	39,152	23.86%
Non-NHS (miles)	Urban	<= 0.75	55,795	93.14%	37,747	63.01%
		0.75 - < 0.95	2,463	4.11%	9,595	16.02%
		. 0.95	1,647	2.75%	12,562	20.97%
	Rural	<= 0.75	217,698	99.09%	200,035	91.05%
		0.75 - < 0.95	1,283	0.58%	9,550	4.35%
		> 0.95	714	0.32%	10,110	4.60%
All FAF network (miles)		<= 0.75	419,121	94.47%	342,543	77.21%
		0.75 - < 0.95	15,365	3.46%	39,304	8.86%
		> 0.95	9,185	2.07%	61,824	13.93%

NOTE: The analysis excludes ferry and roadway through Canada.

Figure 5-3 shows the number of interstate and non-interstate highway miles that exceed capacity in the years 2007 and 2040. Figure 5-4 shows the percentage of miles exceeding the capacity in the year 2007 and 2040.

- In all, 4.16 percent of NHS miles exceeded the capacity in 2007, and this will increase to 23.86 percent in 2040.
- In 2007, 483 miles of rural interstate exceeded the capacity, and the miles with heavy congestion will increase to 9,265 miles in 2040, which represents 30.70 percent of the total rural interstate miles.
- About 3,361 miles of urban interstate were heavily congested in 2007, accounting for 20.39 percent of the total NHS urban interstate miles. This percentage increases

considerably to 69.16 percent in 2040, corresponding to 11,399 miles of urban interstate that will exceed the capacity.

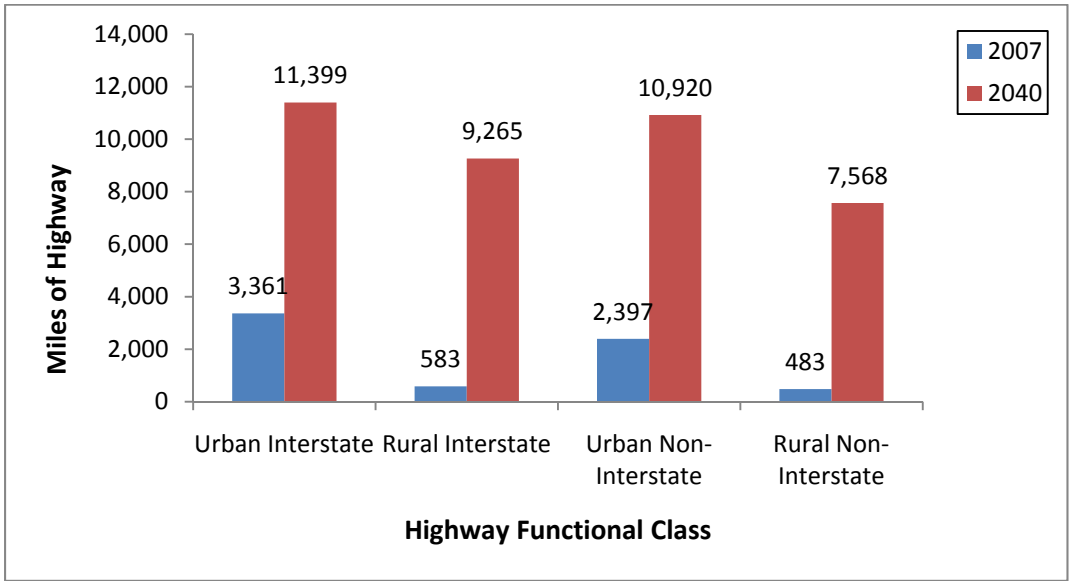


Figure 5-3. NHS Highway Miles Exceeding Capacity

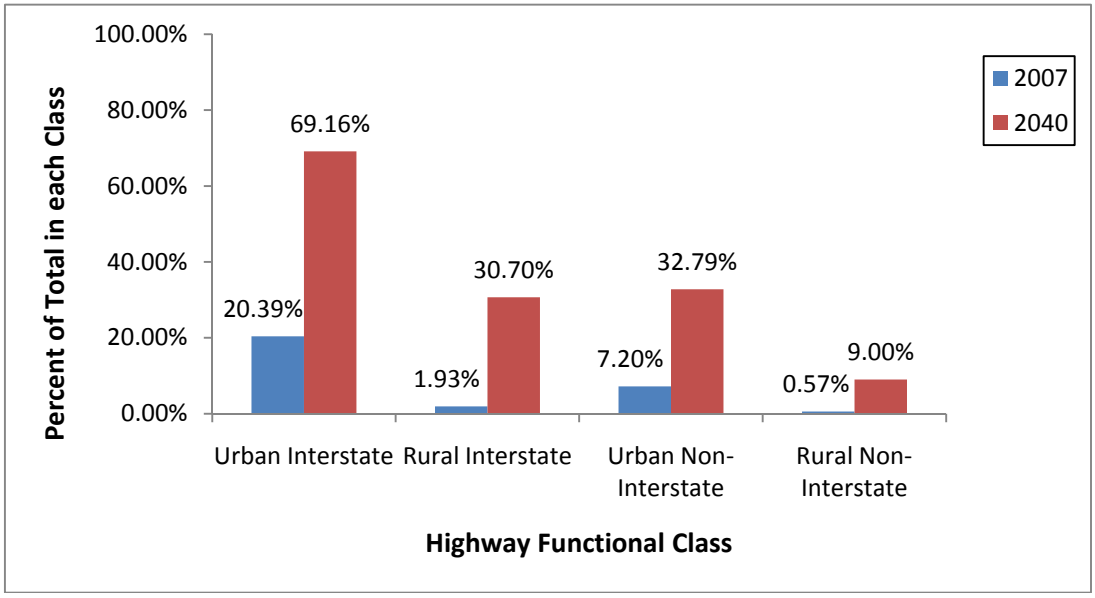


Figure 5-4. Percentage of NHS Highway Miles Exceeding Capacity

Figure 5-5 shows miles of NHS interstate for the year 2007 and 2040 by volume to capacity ratio.

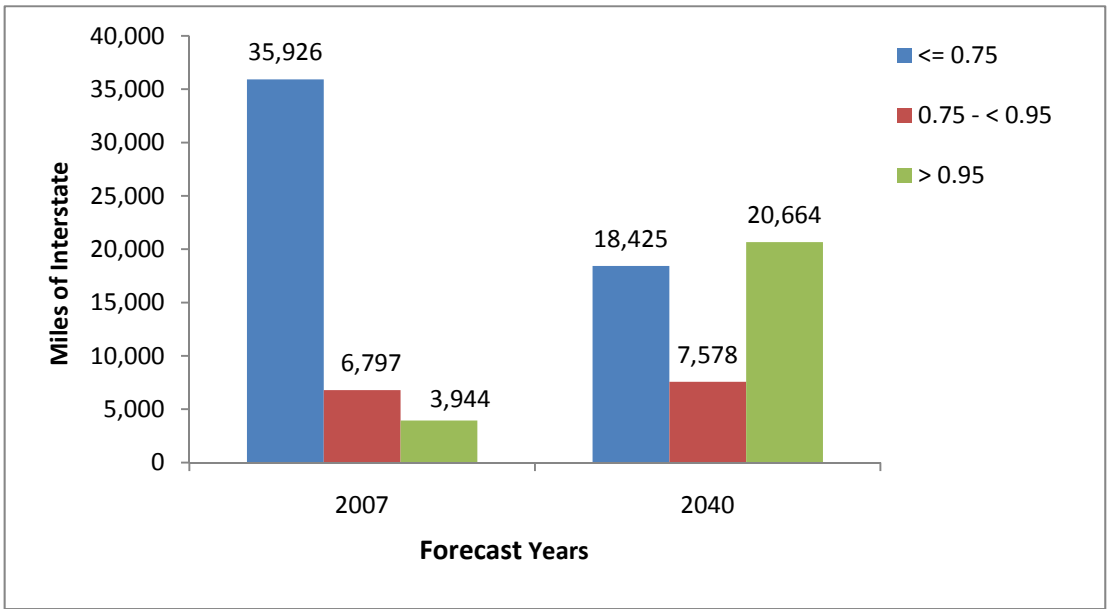


Figure 5-5. NHS Interstate Highway Miles by Capacity Categories

5.4 Highway Impact on Truck Traffic

The summary statistics for the years 2007 and 2040 are shown in Table 5-4 based on the truck traffic for various highway functional classes. The table represents the highway miles based on the functional class and AADTT volume groups. The three truck volume groups used are:

1. Light Truck Traffic – 0 – 5,000 AADTT
2. Moderate Truck Traffic – 5,000 to 10,000 AADTT
3. Heavy Truck Traffic – greater than 10,000 AADTT.

Figures 5-6 to 5-8 show the interstate, NHS non-interstate, and non-NHS miles by truck volume groups.

- In all, 80.38 percent and 65.10 percent of the NHS miles in the years 2007 and 2040 respectively carry less than 5,000 AADTT.
- In 2007, 6,360 (38.63 percent) miles of urban NHS interstate and 3,479 miles (11.53 percent) of rural NHS interstate carry more than 10,000 trucks per day. The miles with heavy truck traffic will increase more than twofold in 2040 to 12,615 miles (76.52 percent) of urban NHS interstate and 19,261 miles (63.81 percent) of rural NHS interstate.
- Out of the total 163,852 NHS miles, only 10,879 miles (6.64 percent) in 2007 and 36,045 miles (21.97 percent) in 2040 experience heavy truck traffic.
- The table shows that 0 percent to 2 percent of non-NHS miles carry daily truck traffic of more than 10,000 AADTT in 2007 and 2040. The percentage of non-NHS miles with heavy truck traffic is comparatively lower than rest of the highways in the NHS network.

Table 5-4. Miles of Highway by Truck Volume Groups

Miles of Highway AADTT Volume Groups			2007		2040	
NHS,IS (miles)	Urban	0-5,000	3,536	21.48%	1,145	6.94%
		5,000-10,000	6,568	39.90%	2,726	16.53%
		>10,000	6,360	38.63%	12,615	76.52%
	Rural	0-5,000	15,571	51.59%	4,320	14.31%
		5,000-10,000	11,135	36.89%	6,604	21.88%
		>10,000	3,479	11.53%	19,261	63.81%
NHS, Non-IS (miles)	Urban	0-5,000	29,589	89.18%	24,535	73.64%
		5,000-10,000	2,688	8.10%	5,850	17.56%
		>10,000	902	2.72%	2,932	8.80%
	Rural	0-5,000	83,014	98.80%	76,827	91.34%
		5,000-10,000	872	1.04%	6,044	7.19%
		>10,000	138	0.16%	1,237	1.47%
All NHS (miles)		0-5,000	131,710	80.38%	106,826	65.10%
		5,000-10,000	21,263	12.98%	21,224	12.93%
		>10,000	10,879	6.64%	36,045	21.97%
Non-NHS (miles)	Urban	0-5,000	59,255	99.08%	56,425	94.19%
		5,000-10,000	519	0.87%	2,865	4.78%
		>10,000	30	0.05%	617	1.03%
	Rural	0-5,000	219,508	99.98%	218,262	99.35%
		5,000-10,000	32	0.01%	1,357	0.62%
		>10,000	2	0.00%	77	0.04%
All FAF network (miles)		0-5,000	410,474	92.62%	381,513	85.98%
		5,000-10,000	21,814	4.92%	25,446	5.74%
		>10,000	10,911	2.46%	36,740	8.28%

NOTE: The analysis excludes ferry and roadway through Canada.

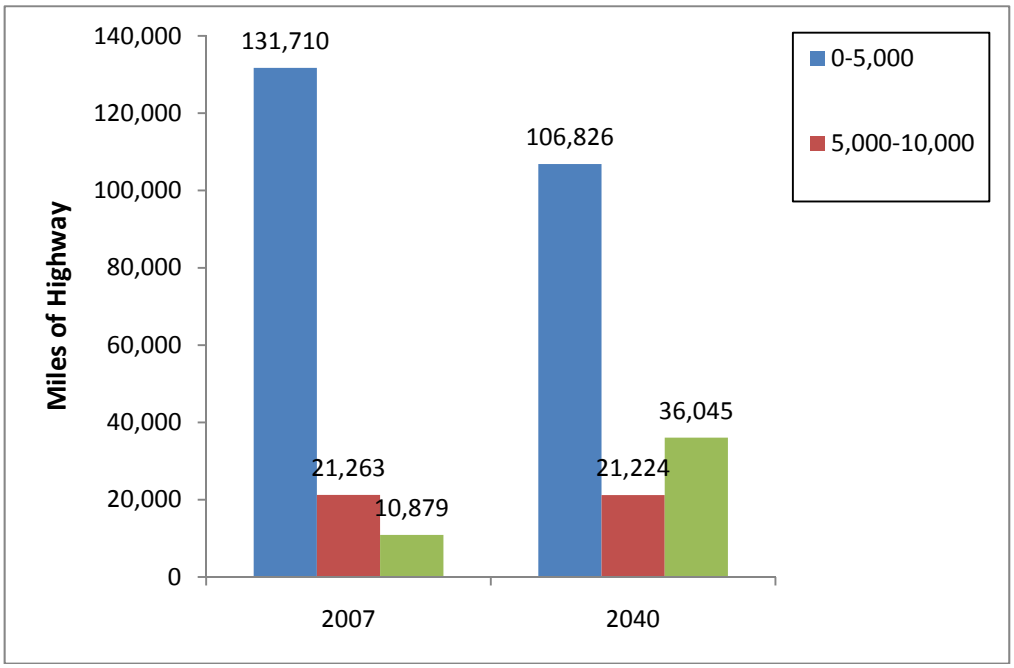


Figure 5-6. NHS Miles of Roadway by Truck Traffic (AADTT) Groups

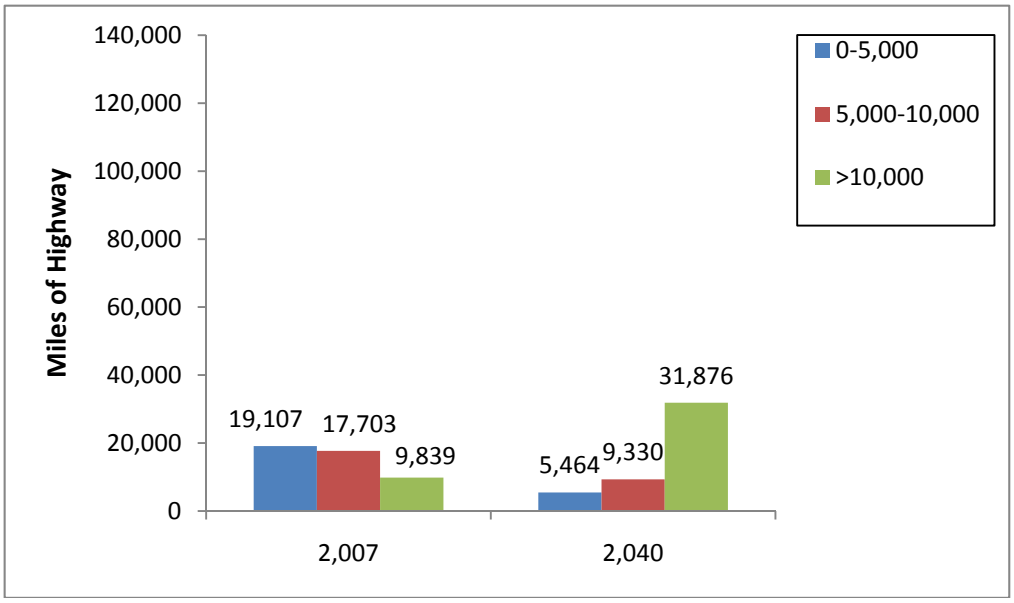


Figure 5-7. Interstate Miles of Roadway by Truck Traffic (AADTT) Groups

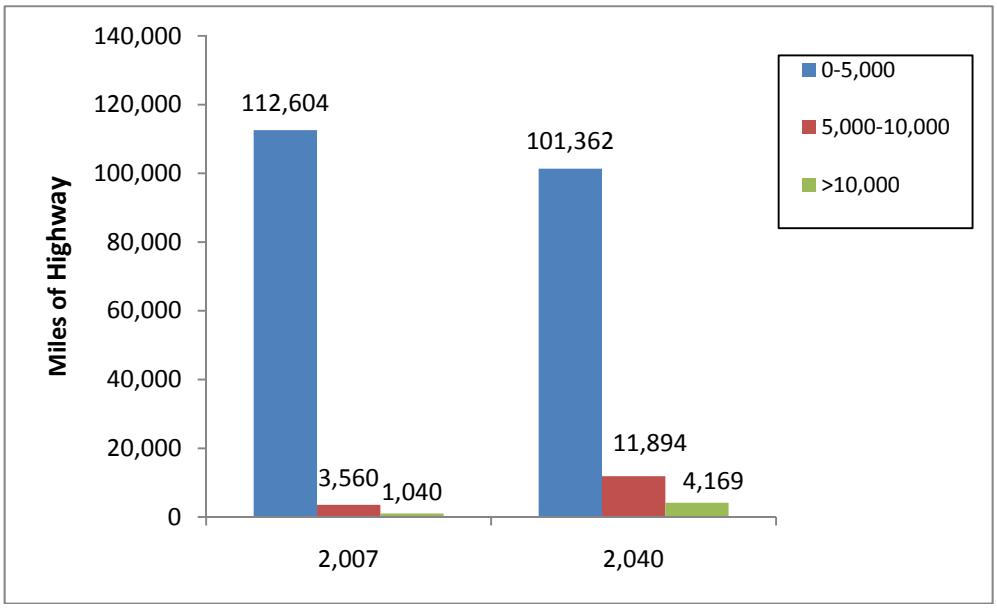


Figure 5-8. NHS Non-Interstate Miles of Roadway by Truck Traffic (AADTT) Groups

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CHAPTER 6: CONCLUSIONS

The primary objective of the highway freight capacity analysis is to develop a policy tool for analyzing potential freight-related policy and examining the sufficiency of capacity of the transportation system in meeting forecast freight demand. Developing a framework for policy analysis relating to the highway capacity for freight transportation is multi-dimensional and challenging. The U.S. freight system is complex and diverse in terms of the spatial and temporal distribution of freight generation activities and movement.

The critical elements of the national-level freight transportation modeling process include the establishment of the network and freight data preparation. Procedures for converting commodity flows into truck trips are not well developed. Inconsistencies in traffic data collection and reporting formats among states pose challenges in developing a comprehensive baseline truck traffic data base for national-level freight analysis.

It is important to take into account the specific characteristics of truck traffic in adapting and applying existing transport demand modeling techniques. The use of TransCAD based GIS-Transportation application software for the analyses is not only efficient but also facilitates communication of outputs of the analysis to policy makers. The truck flow maps and other thematic maps, for example, provide visual presentations of the volume and spatial variation of freight traffic. The outputs of the analyses can be expected to assist policy makers in evaluating improvement and policy options that affect freight transportation.

The link-specific freight flow data and the performance measures developed under this project should help FHWA freight policymakers to identify freight-related network problems and forecast the improvement or preservation needs of the national highway system to maintain the efficiency of freight movement. The database is available through the FHWA website: http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm

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Appendix A

Truck Equivalency Factors

Truck Equivalency Factors – Single Unit (SU)

Commodity	Auto	Livestock	Bulk	Flatbed	Tank	Day Van	Reefer	Logging	Other
1	0	0	0.0066	0.04922	0.00111	0.00419	0.00173	0	0
2	0	0	0.02675	0.0086	0.00103	0.00032	0.00003	0	0.00003
3	0	0	0.01069	0.01981	0.00102	0.00996	0.00942	0	0.00147
4	0	0	0.01463	0.02657	0.00562	0.00334	0.00137	0	0.00034
5	0	0	0.00004	0.00089	0	0.03835	0.04837	0	0.00033
6	0	0	0	0.00025	0	0.15767	0.00216	0	0.00011
7	0	0	0.00001	0.00032	0.00073	0.02096	0.02048	0	0.02192
8	0	0	0	0.00002	0	0.02133	0.00286	0	0.02956
9	0	0	0	0	0	0.06785	0.04242	0	0.01498
10	0	0	0.01399	0.01865	0.00029	0.00115	0	0	0.00185
11	0	0	0.02362	0.00638	0	0.00107	0	0	0.00058
12	0	0	0.02337	0.00292	0	0	0	0.00002	0.00034
13	0	0	0.02393	0.00255	0.00119	0.0008	0.00002	0	0.00048
14	0	0	0.01773	0.01261	0	0	0	0	0
15	0	0	0.01973	0.00307	0	0	0	0	0.001
16	0	0	0.00685	0.02455	0.01041	0.00086	0	0	0.01333
17	0	0	0	0.00186	0.02298	0.02755	0	0	0.00225
18	0	0	0.00026	0.00328	0.03386	0.00038	0	0	0.00261
19	0	0	0.00116	0.01074	0.0466	0.00273	0	0	0.00122
20	0	0	0.00171	0.02421	0.0146	0.01697	0	0	0.00266
21	0	0	0	0	0	0.10537	0.0122	0	0
22	0	0	0.01074	0.00974	0.01882	0.00302	0	0	0.00063
23	0	0	0.00145	0.01277	0.00987	0.03153	0	0	0.00539
24	0	0	0.00109	0.04904	0.00199	0.04913	0.00147	0	0.00863
25	0	0	0.0177	0.0167	0	0.00013	0	0.00831	0.00291
26	0	0	0.01437	0.03091	0.00002	0.01721	0	0.00017	0.00205
27	0	0	0	0.00142	0	0.07422	0	0	0
28	0	0	0.00262	0.00222	0	0.06609	0.00109	0	0.00223
29	0	0	0	0.00909	0	0.0857	0	0	0.00038
30	0	0	0.00154	0.0146	0	0.09299	0.00181	0	0.00251
31	0	0	0.00404	0.00588	0.00034	0.00436	0	0	0.01456
32	0	0	0.00076	0.06023	0	0.01594	0	0	0.01038
33	0	0	0.004	0.03186	0.00005	0.02246	0	0.00005	0.02908
34	0	0	0.00271	0.03187	0	0.03959	0	0.00002	0.00814
35	0	0	0.00033	0.01488	0	0.08017	0.00164	0	0.01258
36	0	0	0.00041	0.0073	0	0.00756	0	0	0.0548
37	0	0	0.00649	0.0228	0	0.00782	0	0	0.0141
38	0	0	0.00064	0.04872	0	0.11375	0	0	0.0006
39	0	0	0.00007	0.00432	0	0.11805	0.00166	0	0.00382
40	0	0	0.00027	0.01702	0.00117	0.07196	0.00051	0	0.01452
41	0	0	0.01372	0.00869	0.00221	0.00069	0.00011	0	0.01908
42	0	0	0.00215	0.01208	0.02291	0.00117	0	0	0.00181
43	0	0	0	0.00415	0	0.09378	0	0	0

Truck Equivalency Factors – Truck Trailer (TT)

Commodity	Auto	Livestock	Bulk	Flatbed	Tank	Day Van	Reefer	Logging	Other
1	0	0	0.00236	0.09792	0	0.01831	0	0	0.00305
2	0	0	0.03312	0.00683	0.00121	0	0	0	0
3	0	0	0.01643	0.05417	0.00043	0.00965	0	0	0.00557
4	0	0	0.0024	0.0652	0.00229	0.01552	0	0	0.0026
5	0	0	0	0.01384	0	0	0.2178	0	0
6	0	0	0	0.06766	0	0.52158	0.02743	0	0
7	0	0	0	0.01609	0.00255	0.167	0	0	0.02212
8	0	0	0	0	0	0	0	0	0.09053
9	0	0	0	0	0	0	0	0	0
10	0	0	0.04803	0.00814	0.00047	0	0	0	0
11	0	0	0.03288	0.01714	0	0	0	0	0
12	0	0	0.03672	0.00355	0.00002	0	0	0	0.00136
13	0	0	0.04044	0.00133	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0.01956	0.02797	0	0	0	0	0
16	0	0	0.01529	0	0.01659	0	0	0	0
17	0	0	0	0.06287	0.0246	0	0	0	0
18	0	0	0.00047	0.02735	0.01863	0	0	0	0
19	0	0	0.00855	0	0.01411	0.03128	0	0	0
20	0	0	0	0	0.04058	0.0037	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0.00321	0.02528	0.03006	0.03581	0	0	0.0015
23	0	0	0.00466	0.01526	0.00955	0.15924	0	0	0
24	0	0	0	0.25704	0	0	0	0	0
25	0	0	0.0087	0.00147	0	0	0	0.02241	0.01327
26	0	0	0.09538	0.03896	0	0.00107	0	0.00071	0.01724
27	0	0	0	0	0	0.06453	0	0	0
28	0	0	0	0	0	1.03919	0	0	0
29	0	0	0	0	0	1	0	0	0
30	0	0	0	0	0	0.43478	0	0	0
31	0	0	0.0194	0.01707	0	0	0	0	0.01178
32	0	0	0.00386	0.0495	0	0.00575	0	0	0.09511
33	0	0	0.02786	0.04576	0	0.125	0	0	0.04695
34	0	0	0.03163	0.03692	0	0.00129	0	0.00044	0.00078
35	0	0	0	0.13673	0	0.3511	0	0	0
36	0	0	0.02531	0.07947	0	0.03572	0	0	0.00623
37	0	0	0.02199	0.05941	0	0	0	0	0.00491
38	0	0	0	0.5	0	0	0	0	0
39	0	0	0.04346	0.02042	0	0.07936	0	0	0
40	0	0	0	0.06769	0	0.02033	0	0	0.02866
41	0	0	0.06573	0.02041	0	0	0	0	0.00178
42	0	0	0	0.00708	0.05154	0.00145	0	0	0
43	0	0	0	0	0	0.15382	0	0	0

Truck Equivalency Factors – Combination Semitrailer (CS)

Commodity	Auto	Livestock	Bulk	Flatbed	Tank	Day Van	Reefer	Logging	Other
1	0	0.02634	0.00087	0.00628	0.00046	0.00116	0.00061	0	0
2	0	0.00006	0.03127	0.00162	0.00124	0.00056	0.00004	0	0
3	0	0.0005	0.00636	0.0114	0.00062	0.00443	0.01419	0	0
4	0	0.00028	0.00873	0.00598	0.01261	0.00691	0.00257	0	0
5	0	0	0	0.00071	0	0.00449	0.03397	0	0
6	0	0	0	0	0.00389	0.03253	0.00495	0	0
7	0	0	0	0.00023	0.00373	0.01631	0.01912	0	0
8	0	0	0	0.00045	0.00021	0.04709	0.00137	0	0
9	0	0	0	0	0	0.0333	0.00725	0	0
10	0	0	0.012	0.02245	0.00221	0.00072	0	0	0
11	0	0	0.03032	0.00064	0.00423	0.00016	0	0	0
12	0	0	0.03249	0.00175	0.00032	0.0001	0	0.00002	0
13	0	0	0.01708	0.00104	0.01462	0.00124	0	0	0
14	0	0	0.02508	0.00955	0	0.00143	0	0	0
15	0	0	0.03109	0	0	0.00053	0	0	0
16	0	0	0.00055	0	0.03505	0	0	0	0
17	0	0	0	0	0.02918	0.00044	0	0	0
18	0	0	0.00005	0.00033	0.02883	0.00059	0	0	0
19	0	0	0.0003	0.00153	0.03075	0.00344	0	0	0
20	0	0	0.00004	0.00467	0.0281	0.0054	0	0	0
21	0	0	0	0	0	0.02969	0.01779	0	0
22	0	0	0.01042	0.00925	0.01569	0.00166	0.00025	0	0
23	0	0	0	0.0013	0.0266	0.00896	0.0003	0	0
24	0	0	0.00033	0.00511	0.00599	0.03019	0.00065	0	0
25	0	0	0.00172	0.00586	0	0.00117	0	0.02563	0
26	0	0	0.00529	0.02031	0	0.00905	0.0001	0.00109	0
27	0	0	0	0.00495	0	0.02996	0.00046	0	0
28	0	0	0	0.00031	0	0.03765	0.0005	0	0
29	0	0	0	0.00071	0	0.03842	0.00187	0	0
30	0	0	0	0.00096	0	0.03345	0.00069	0	0
31	0	0	0.00288	0.01613	0.01163	0.00331	0.00005	0.00024	0
32	0	0.00027	0.00144	0.03045	0.00017	0.00344	0.00018	0.00036	0
33	0	0	0.00048	0.02839	0.0001	0.00839	0	0	0
34	0	0.00009	0.0001	0.03017	0	0.00621	0.00018	0	0
35	0	0	0	0.00344	0	0.03622	0	0	0
36	0.01607	0	0.00038	0.00722	0	0.01871	0	0	0
37	0.0003	0	0.00022	0.0187	0	0.0167	0	0.00102	0
38	0	0	0	0.00625	0	0.03851	0	0	0
39	0	0	0	0.00233	0	0.03413	0.00171	0	0
40	0	0	0.00006	0.00374	0	0.03022	0.00159	0	0.00478
41	0	0	0.02326	0.00207	0.00785	0.00289	0.00013	0	0
42	0	0	0	0.0015	0.03183	0.00323	0	0	0
43	0	0	0	0.0009	0	0.04007	0.00082	0	0

Truck Equivalency Factors – Combination Double (DBL)

Commodity	Auto	Livestock	Bulk	Flatbed	Tank	Day Van	Reefer	Logging	Other
1	0	0.02963	0	0	0	0	0	0	0
2	0	0	0.02166	0.00434	0.0003	0	0	0	0
3	0	0	0.00363	0.02674	0.00057	0.00214	0	0	0
4	0	0	0.0114	0.01572	0.00081	0.00436	0	0	0
5	0	0	0	0	0	0	0.0625	0	0
6	0	0	0	0	0	0.05882	0	0	0
7	0	0	0	0.01003	0.00116	0.00546	0.01426	0	0
8	0	0	0	0	0	0	0.06061	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0.01584	0	0.01808	0	0	0	0
11	0	0	0.02342	0	0	0	0	0	0
12	0	0	0.02123	0	0.00041	0	0	0	0
13	0	0	0.00567	0.00066	0.01929	0	0	0	0
14	0	0	0.00851	0	0.0177	0	0	0	0
15	0	0	0.01622	0	0.00158	0	0	0	0
16	0	0	0	0	0.03043	0	0	0	0
17	0	0	0	0	0.00862	0.03876	0	0	0
18	0	0	0	0	0.02204	0	0	0	0
19	0	0	0.01252	0	0.01619	0	0	0	0
20	0	0	0.00395	0.01861	0.00758	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0.00749	0.02477	0.00117	0	0	0	0
23	0	0	0	0	0	0	0.02186	0	0
24	0	0	0	0.01595	0	0.05582	0	0	0
25	0	0	0	0	0	0	0	0.02353	0
26	0	0	0.00151	0.02389	0	0.00368	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0.0413	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0.13793	0	0	0
31	0	0	0.00429	0.00411	0.01484	0	0	0	0
32	0	0	0.00232	0.01454	0	0	0	0.19078	0
33	0	0	0	0	0	0.0339	0	0	0
34	0	0	0	0.00878	0	0.03608	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0.06667	0	0	0
37	0	0	0	0.02857	0	0	0	0	0
38	0	0	0	0	0	0.11765	0	0	0
39	0	0	0	0	0	0.03463	0	0	0
40	0	0	0	0	0	0.05285	0	0	0
41	0	0	0.01953	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0.04439	0.00003	0	0

Truck Equivalency Factors – Combination Triple (TPT)

Commodity	Auto	Livestock	Bulk	Flatbed	Tank	Day Van	Reefer	Logging	Other
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0.02454	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	0.02181	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	0	0	0	0.01752	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0
37	0	0	0	0.01986	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0.02557	0	0	0

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Appendix B

FAF^3 Commodities

FAF Commodity Categories

Index	Description	Index	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	26	Wood products
5	Meat/seafood	27	Pulp, newsprint, paper, and paperboard
6	Milled grain products	28	Paper or paperboard articles
7	Other foodstuffs	29	Printed products
8	Alcoholic beverages	30	Textiles and leather
9	Tobacco products	31	Nonmetallic mineral products
10	Building stone	32	Base metal in primary or finished forms
11	Natural sands	33	Articles of base metal
12	Gravel and crushed stone	34	Machinery
13	Nonmetallic minerals	35	Electronic and electrical equipment
14	Metallic ores and concentrates	36	Motorized and other vehicles
15	Coal	37	Transportation equipment
16	Crude Petroleum	38	Precision instruments and apparatus
17	Gasoline and aviation turbine fuel	39	Furniture
18	Fuel oils	40	Miscellaneous manufactured products
19	Coal and petroleum products	41	Waste and scrap
20	Basic chemicals	42	Commodity unknown
21	Pharmaceutical products	43	Mixed freight
22	Fertilizers		

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