Transportation Engineering, Planning & Policy Consultants

Final Draft Report

FAF^4 FREIGHT TRAFFIC ASSIGNMENT

Submitted to

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Submitted by

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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 went 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), and many others.

Given its importance to national and state freight flow analysis, the FAF version 4 (FAF^4) commodity flow data updated and enhanced by the Oak Ridge National Laboratory (ORNL) for FHWA to estimate the dollar value and tons of shipments between 132 regions used in the 2012 Commodity Flow Survey (CFS) and eight international trade regions. These flows are broken down by type of commodity and mode of transport. The FAF^4 commodity flow data are benchmarked to calendar year 2012, with a forecast for the year 2045. In the earlier version of FAF, the freight network assignments were carried out using a low accuracy network and needed an updated version of freight analysis network that can be developed using the State's geospatial road network submittal. Therefore, the FAF version 3 highway network database and its inclusive traffic assignments were updated and accommodated as part of the FAF^4 network data products and approach.

1.2 Objectives of the FAF^4 Project

To update and improve the FAF^3 database, FHWA recently developed the next generation FAF^4 freight origin-destination (O-D) database using the 2012 CFS and other public data sources. Intended in part to address issues and lessons learned from the earlier FAF products, some of the primary objectives of the development of the FAF^4 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 network flow database
- Make FAF^4 data more transparent to all public and private users outside the U.S. DOT.

1.3 Objectives of FAF^4 Freight Traffic Assignment

This study is directed at conducting a national highway freight analysis designed to estimate the base year 2012 and the 2045 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:

- Developed new FAF network using Highway Performance Monitoring System (HPMS) 2012 Geospatial data submittal
- Integrate bridge underpass, overpass and truck restriction information as part of the network
- Accommodate new FAF zones as part of the network assignment
- Updated FAF highway network coverage data with HPMS) 2010 data elements essential for freight network assignment
- Conflate FAF^3 assignments related attributes to the new FAF network
- Update FAF O-D share allocation matrix using the Warehouse distribution database developed in 2008 by FHWA
- Use demand responsive dynamic allocation for FAF^4 truck O-D for subsequent freight network assignment using the HPMS combination truck traffic as a base reference
- Develop a database of freight truck flows (freight assignment) on the highway network for the base year 2012 and forecasted year 2045
- Produce FAF^4 maps depicting national freight flows and congestion for the years 2012 and 2045.

1.4 Overview of the Methodology

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

1. FAF^4 network development and integration of 2012 HPMS database
2. Conflation of FAF^3 assignment related attributes to new FAF^4 network
3. Pre-assign non-FAF^4 traffic counts to the FAF^4 highway network
4. Update if necessary, truck trips, payload, trip length distribution
5. Apply virtual FAF O-D allocation for macro level assignment using the HPMS combination trucks counts as a reference.
6. Assign FAF^4 O-Ds (2012 and 2045) to the FAF highway network
7. Prepare variation and reliability for each of the data sources and assignment results
8. Documentation.

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 132 FAF^4 freight analysis zones to the required number of virtual loading/unloading points. Chapter 4 describes the freight assignment models and associated calibration procedures utilized for the development of base year 2012 and year 2045 network flows. Chapter 5 discuss the assignment reliability checks. Chapter 6 presents conclusions.

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CHAPTER 2: FAF^4 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 446,000 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^4 network include:

- Updates to NHS designation and intermodal revisions current to version 2015.4 releases
- Additions or updates to urban bypass or other state specific highway alignment including interstate
- Integration and updating of NN and long combination vehicle (LCV) designations, state link specific truck restrictions, clearances, and hazmat route restrictions

2.2 FAF^4 Network and HPMS 2012 Data Integration Process

The 2012 HPMS database was selected for the network update. Since HPMS is a state specific database, the FAF national network data 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 2045 values for average traffic volume and truck traffic were estimated using the state growth factor reported in the HPMS 2012 database and projected to 2045 using a linear growth algorithm. The following sections describe the work process performed to update the FAF^4 network with the 2012 HPMS database.

2.2.1 Route Matching

The HPMS provide LRS information. Maks Inc. utilizes a Multifaceted Analysis Tools (MFAT), an in-house proprietary software tool that employs algorithms to relate the HPMS and FAF 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. For section with missing LRS, Sign1 was used as reference system.

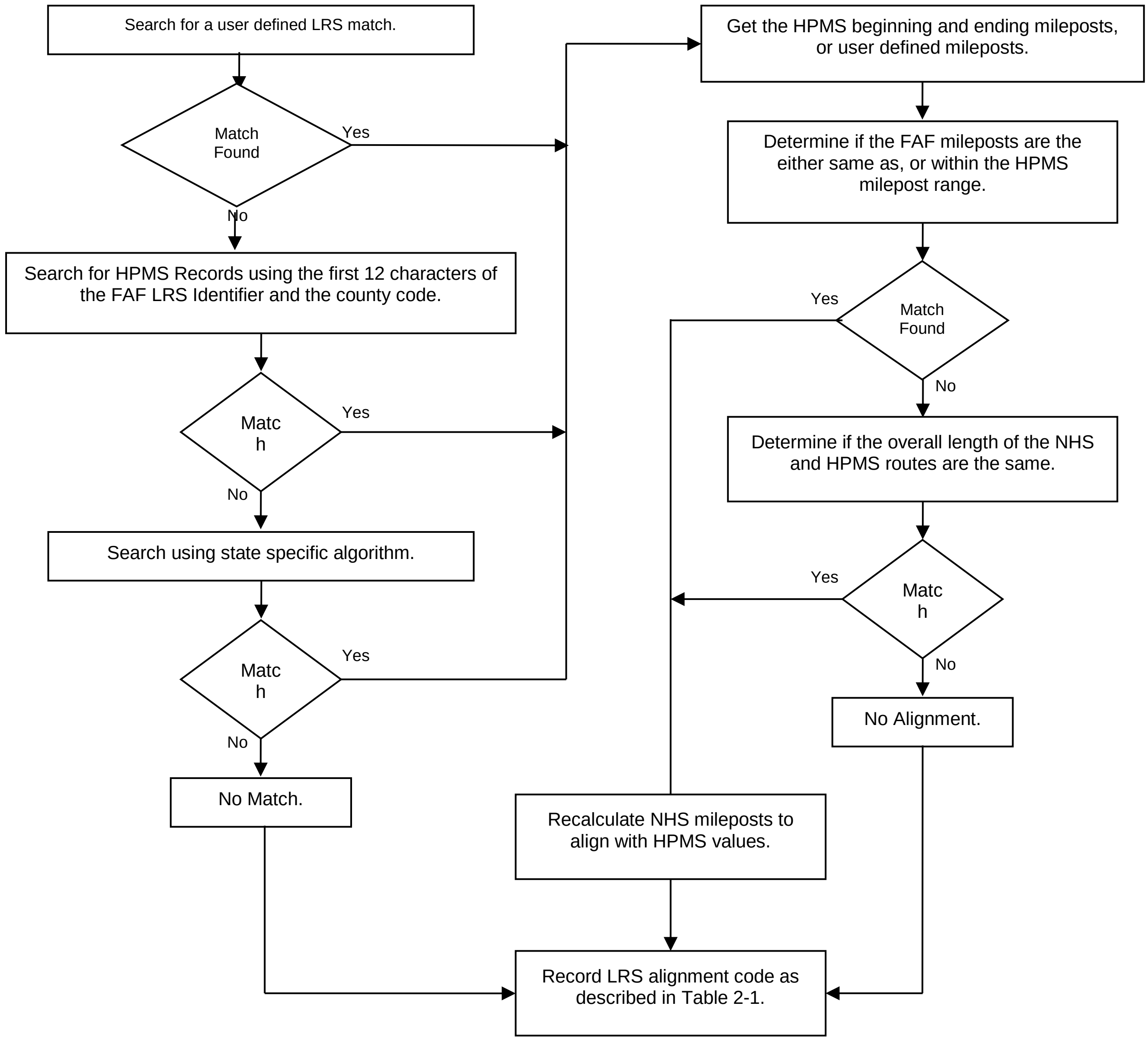


Figure 2-1. Route Matching Diagram

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

2.2.2 Reassigning Mileposts

When a matching LRS route is found between the HPMS and FAF datasets, and the route has the same overall length in both datasets but different beginning and ending mileposts, then MFAT 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 MFAT analysis tool will reassign the beginning and ending mileposts of the FAF route to match with the HPMS milepost values.

2.2.3 Recalibrating Mileposts

When the beginning or ending mileposts for an FAF 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 HPMS database loading to FAF network, visual inspection was conducted by developing scale-based theme maps using the TransCAD GIS software. This approach is very effective to identify the major discrepancies between adjacent links (i.e., significant drop of average annual daily traffic, or AADT, between two adjacent highway links) or among various functional classes. This 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 were greater than 20 percent, the original state traffic data available through the state website is 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. FAF4 Network Missing Data Lookup Tables

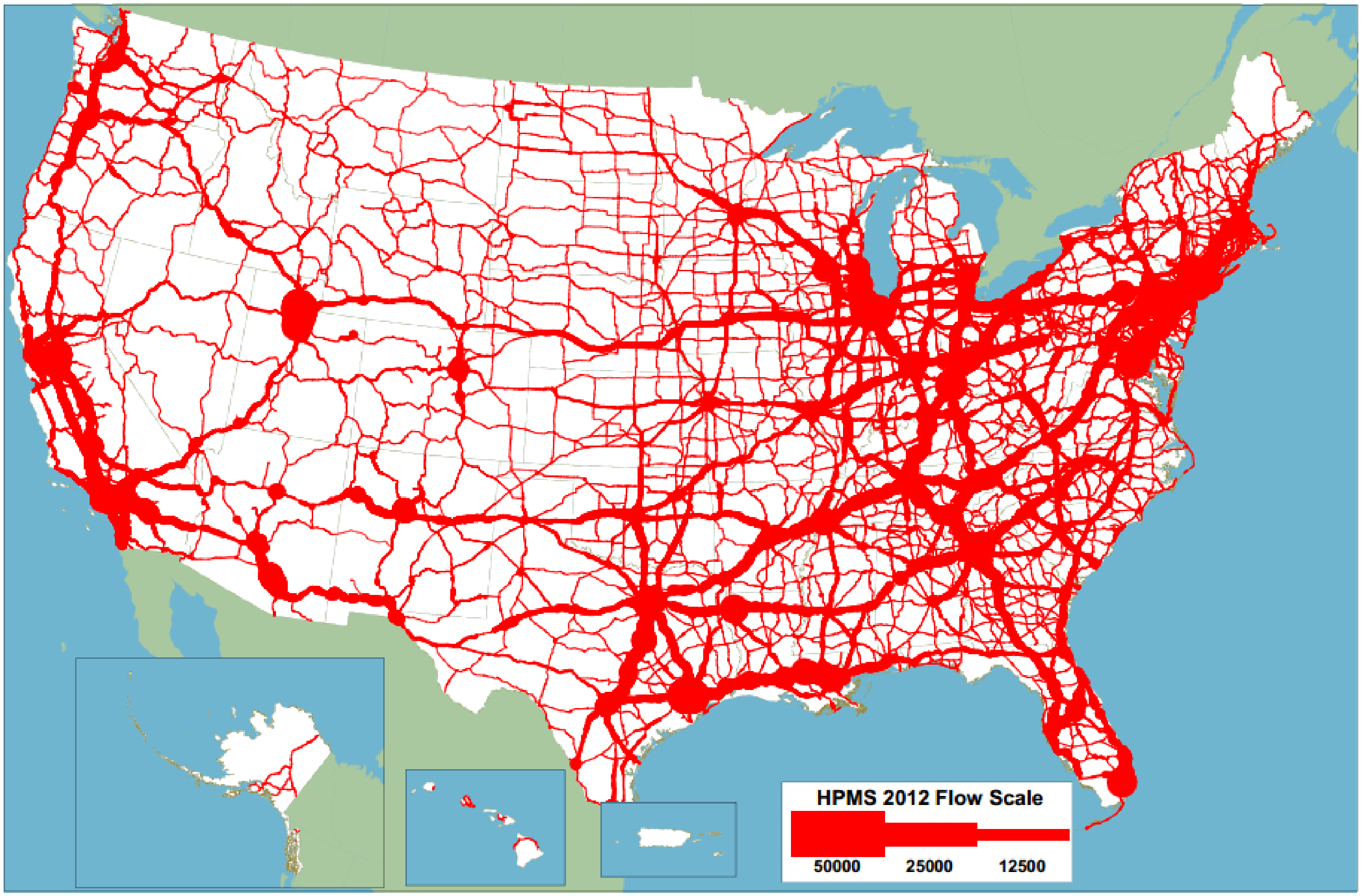
Lookup Table Name	Purpose
AADTLookup	National average AADT grouped by state and county codes and functional classification. This table is used to populate missing AADT of the network table.
AADTLookUpPerState	National average AADT grouped by state codes and functional classification. This table is used 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 FAF4 highway network loaded with 2012 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 combination truck volume on the FAF4 network developed using the HPMS 2012 database.

2012 HPMS Truck Flows on the NHS Portion of the FAF4 Network



Freight OD Data Source: Office of Freight Management and Operation, US Department of Transportation, FHWA
Source: HPMS 2012, Office of Policy

Figure 2-2. HPMS 2012 Combination Truck Volume on FAF^4 Network

CHAPTER 3: 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 truck O-D matrix, developed during earlier version of FAF^3 product.

3.2 Tonnage to Truck Payload Conversion Process

The FAF 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.

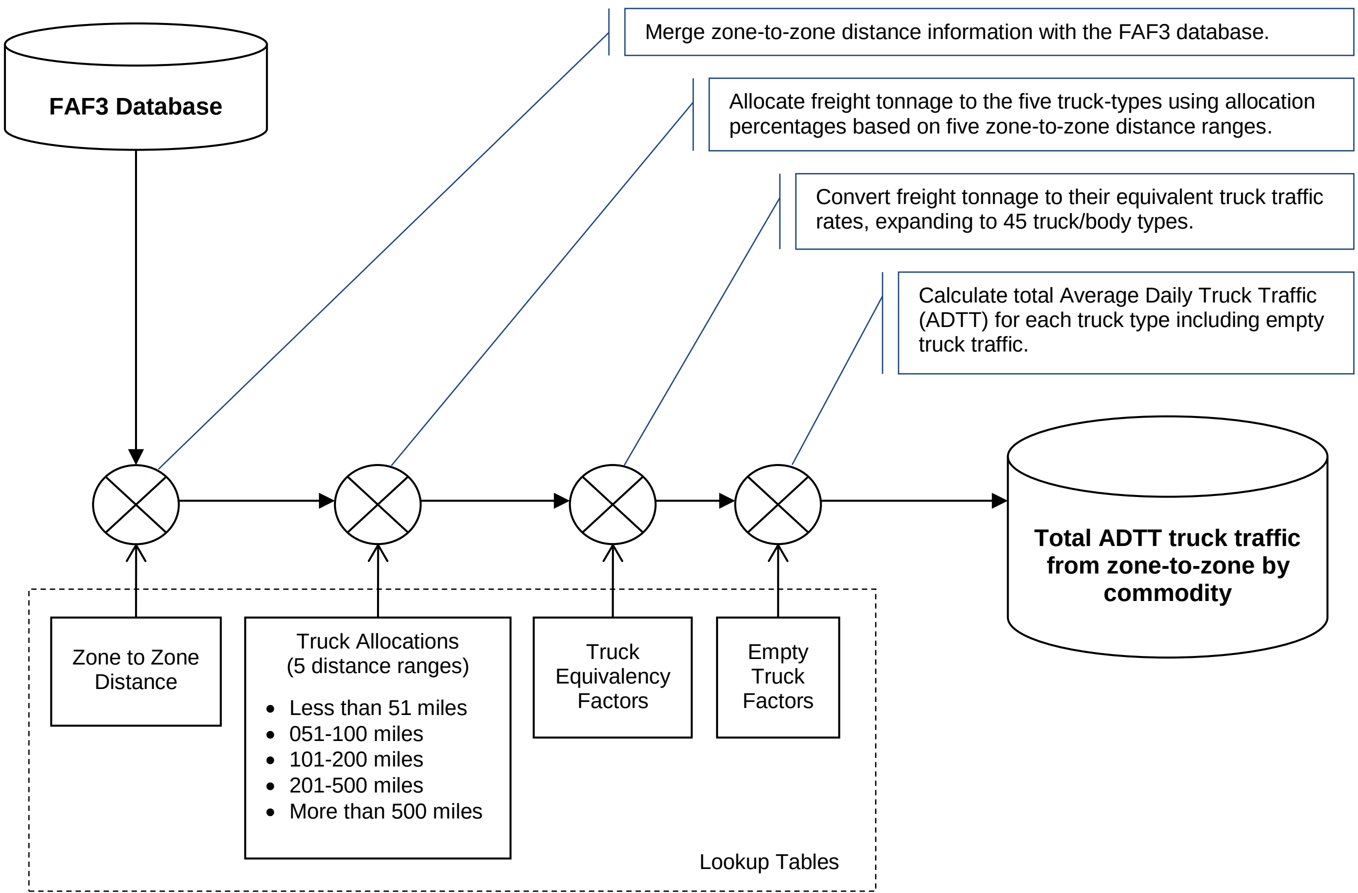


Figure 3-1. Truck Conversion Flow Diagram

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.

Identifying Truck Configurations and Body Types

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

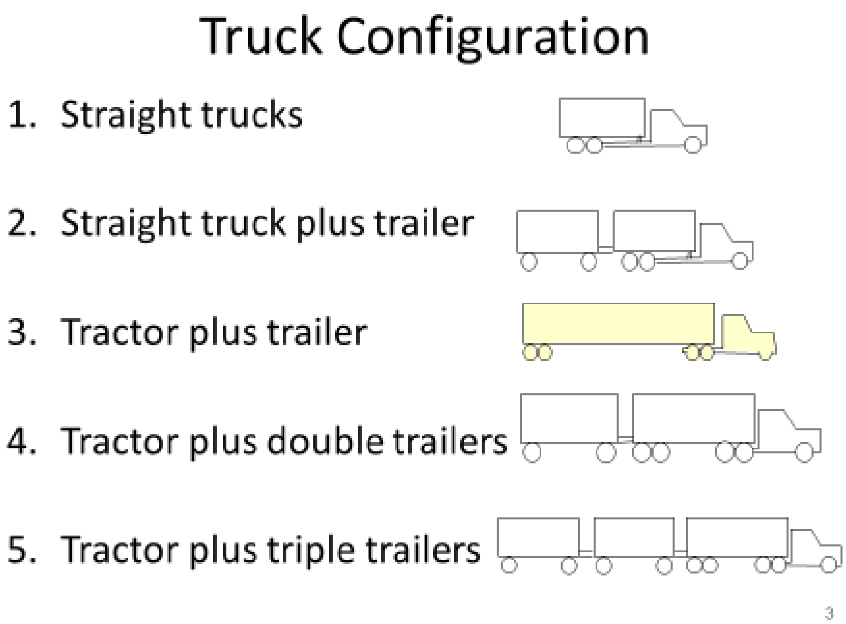


Figure 3-2: Illustrative Example of Truck Configuration used in FAF

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

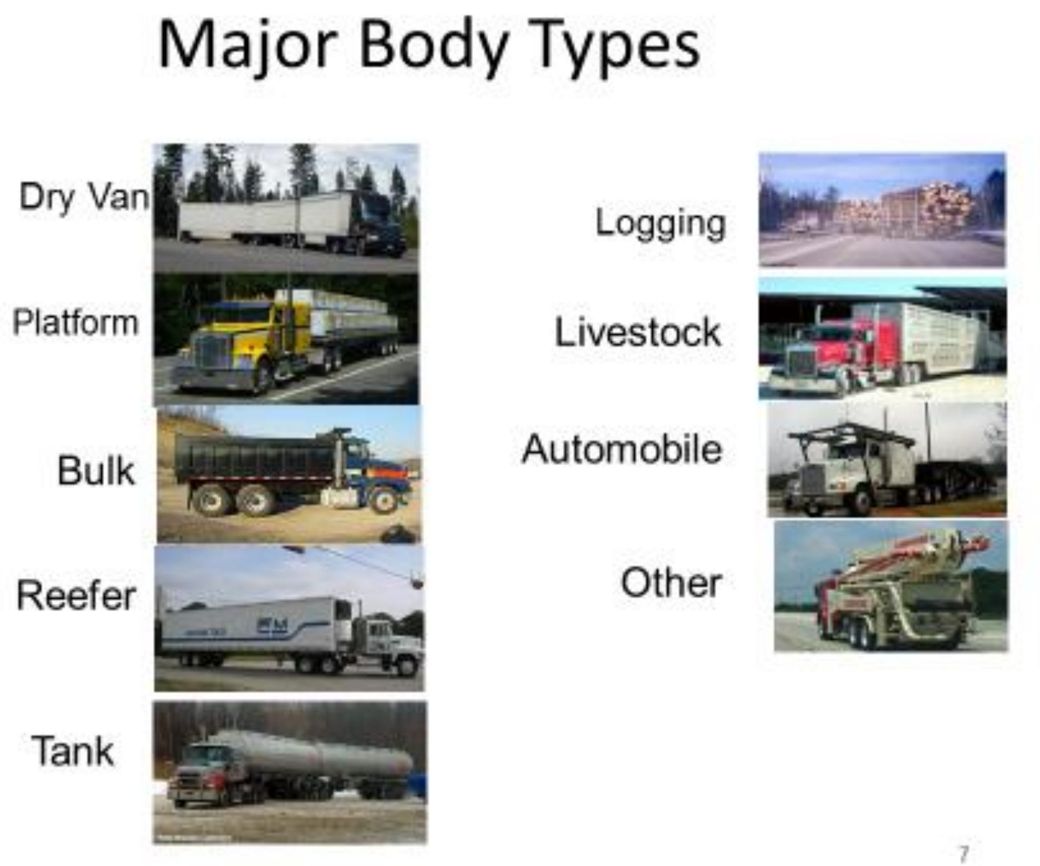


Figure 3-3: Illustrative Example of Major Body Type

Allocating Commodities to Truck Configurations

The allocation of the FAF 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 β_{ijk}) tons of commodity (X_i) by all body types is given by Equation 3-1.

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

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

$$Y_{j=2} = \frac{X_i \beta_{i21}}{\omega_{i21}} + \frac{X_i \beta_{i22}}{\omega_{i22}} + \frac{X_i \beta_{i23}}{\omega_{i23}} + ... + \frac{X_i \beta_{i29}}{\omega_{i29}} = \sum_{k=1}^{k=9} \frac{X_i \beta_{i29}}{\omega_{i2k}} \quad (3\text{-}2)$$

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

$$Y_j = \sum_{k=1}^{k=9} \frac{X_i \beta_{ijk}}{\omega_{ijk}} = X_i \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \quad (3\text{-}3)$$

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.

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

$$Total\_Trucks = \sum_{i=1}^{i=50} X_i \sum_{j=1}^{j=5} \sum_{k=1}^{k=9} \frac{\beta_{ijk}}{\omega_{ijk}} \quad (3\text{-}5)$$

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

$$TEF_{ijk} = \frac{\beta_{ijk}}{\omega_{ijk}} \quad (3\text{-}6)$$

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.

<u>Converting Tonnage to Equivalent Trucks</u>

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					
Auto	0	0	0.14	0	0
Livestock	0	0	0.2	0.16	0
Bulk	0.21	0.14	0.2	0.2	0.06
Flatbed	0.14	0.16	0.16	0.2	0.03
Tank	0.17	0.18	0.2	0.2	0
Day Van	0.12	0.07	0.1	0.04	0.07
Reefer	0.1	0.08	0.09	0.13	0
Logging	0.24	0.21	0.2	0.13	0
Other	0.1	0.06	0.25	0	0
Land Border Shipping					
Auto	0	0	0.28	0	0
Livestock	0	0	0.4	0.32	0
Bulk	0.42	0.28	0.4	0.4	0.12
Flatbed	0.28	0.32	0.32	0.4	0.06
Tank	0.34	0.36	0.4	0.4	0
Dry Van	0.24	0.14	0.2	0.08	0.14
Reefer	0.2	0.16	0.18	0.26	0
Logging	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 database as shown in Table 3-6. The zone-zone distance information is provided by a lookup table.

Table 3-6. FAF 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

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

expanded to nine body styles. The annual traffic values are determined using the truck equivalency factors for each commodity provided by Appendix A.

Table 3-8. Annual Truck Traffic, Loaded Trucks

	Single Unit	Truck Trailer	Tractor Semitrailer	Tractor Double	Tractor Triple
Auto	0	0	0	0	0
Livestock	0	0	429.36	0	0
Bulk	5090.62	1142.21	5461.51	410.46	0
Flatbed	9433.60	3765.88	9789.49	3023.65	0
Tank	485.73	29.89	532.41	64.45	0
Dry Van	4742.99	670.86	3804.16	241.98	0
Reefer	4485.85	0	12185.35	0	0
Logging	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
Auto	0	0	0	0	0
Livestock	0	0	601.11	0	0
Bulk	7228.68	1462.03	7646.11	574.65	0
Flatbed	12075.02	4970.97	12922.13	4233.12	0
Tank	650.88	40.66	745.37	90.23	0
Dry Van	5881.32	764.79	4564.99	261.34	0
Reefer	5383.02	0	14378.71	0	0
Logging	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 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. The daily traffic is estimated by dividing the annual value by 365.

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 OD Allocation

The allocation of FAF Origin/Destination (O-D) data from 132 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 3-4 illustrates O-D disaggregation process.

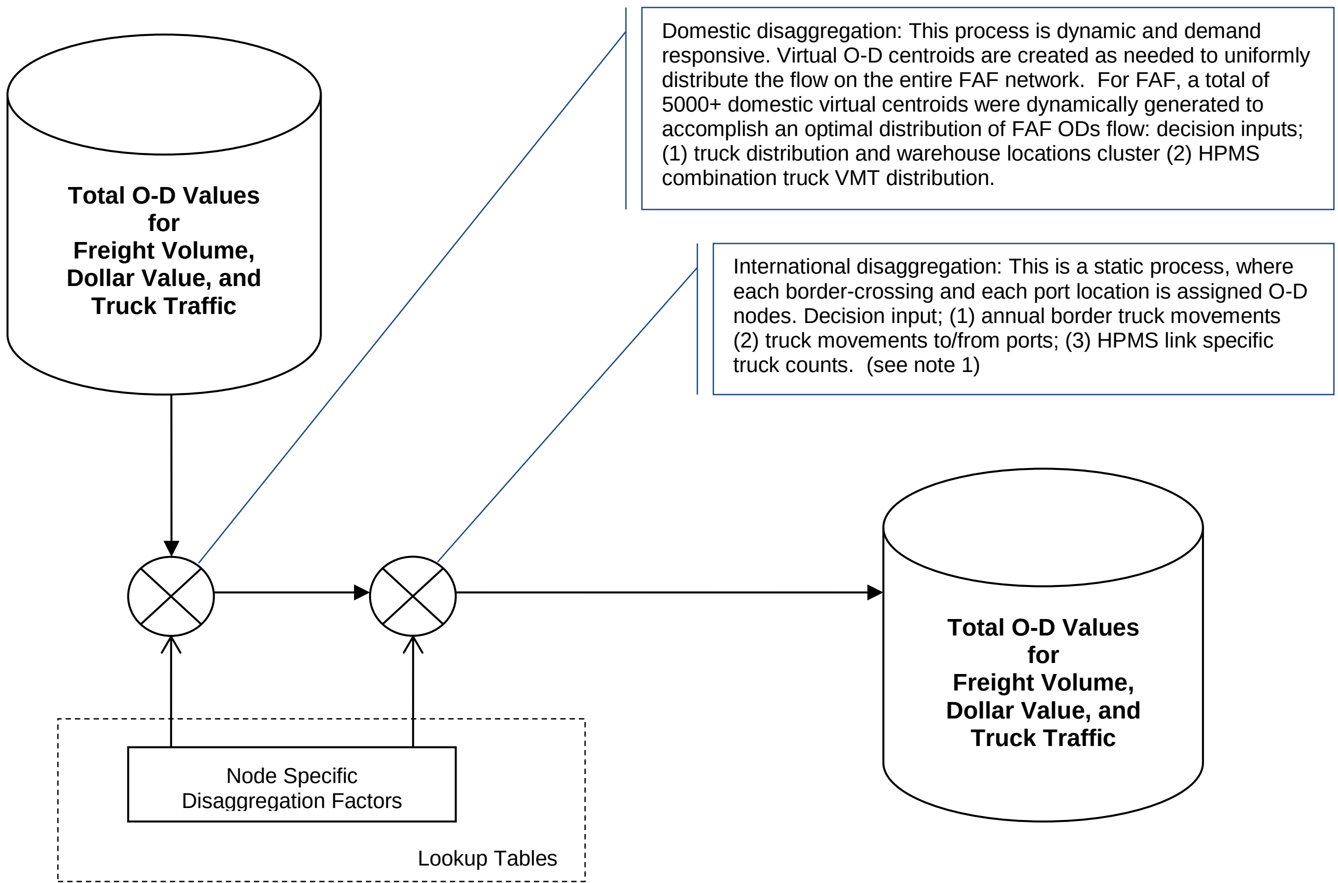


Figure 3-4. Virtual Disaggregation Flow Diagram

For domestic trips, a demand responsive virtual O-D disaggregation technique and associated software was developed using the Maks Inc. internal research and development (IR&D). 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 truck flows established from HPMS and state truck databases. The computer model developed under the MFAT 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)
- 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.

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

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)

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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:

$$T = \sum_{j=1}^{n} T_j \qquad (4\text{-}4)$$

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). It is assumed that a trucker most likely prefer a 4-lane highway vs a 2-lane highway if he has the choice to take either route.

Urban bypass: When the given link is on an urban bypass, its travel time is increased by 4 percent (r = 1.04). It is assumed that a trucker most likely will take a shorter route through the urban area unless it is forced to do so or to avoid congestion.

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). This was done to allow a trucker to deliver the products when it has no alternate route to drop-off the goods.

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:

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

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

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 the major route.

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 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 base capacity of the FAF network is estimated using the HCM 2000 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[4] 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 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[4] 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 constraint assignment. The primary objective of the model capacity to calibrate the assignment flows in conjunction with the alpha and beta calibration factors.

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[4] freight demand modeling are described in the following sections.

4.3.1 Assignment Algorithm

The Stochastic User Equilibrium (SUE) traffic assignment procedure in TransCAD 7.0 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[4] 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.

The analysis starts with a default calibration constant as a function of road class and then adjusted to divert or induced the truck flow that is more consistent with the ground count flow.

For earlier version of FAF, Maks Inc. has successfully used this procedure. This approach reasonably forecast 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 of these two methods of freight assignment.

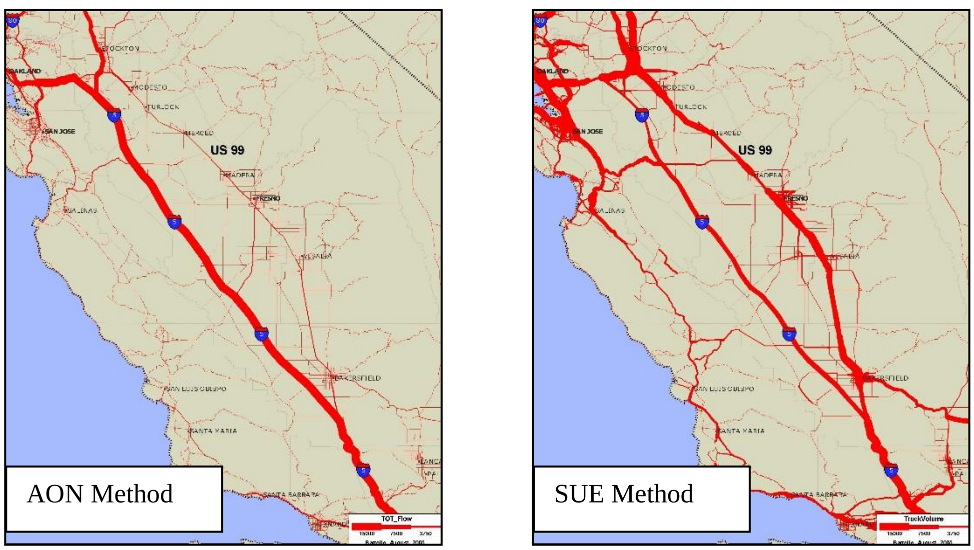


Figure 4-1. Comparison of AON and SUE Truck Traffic Assignment

4.3.2 Freight Assignment Calibration

The purpose of this step was to calibrate the 2012 base year demand flow so that the assigned truck VMT closely match the HPMS truck VMT 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.

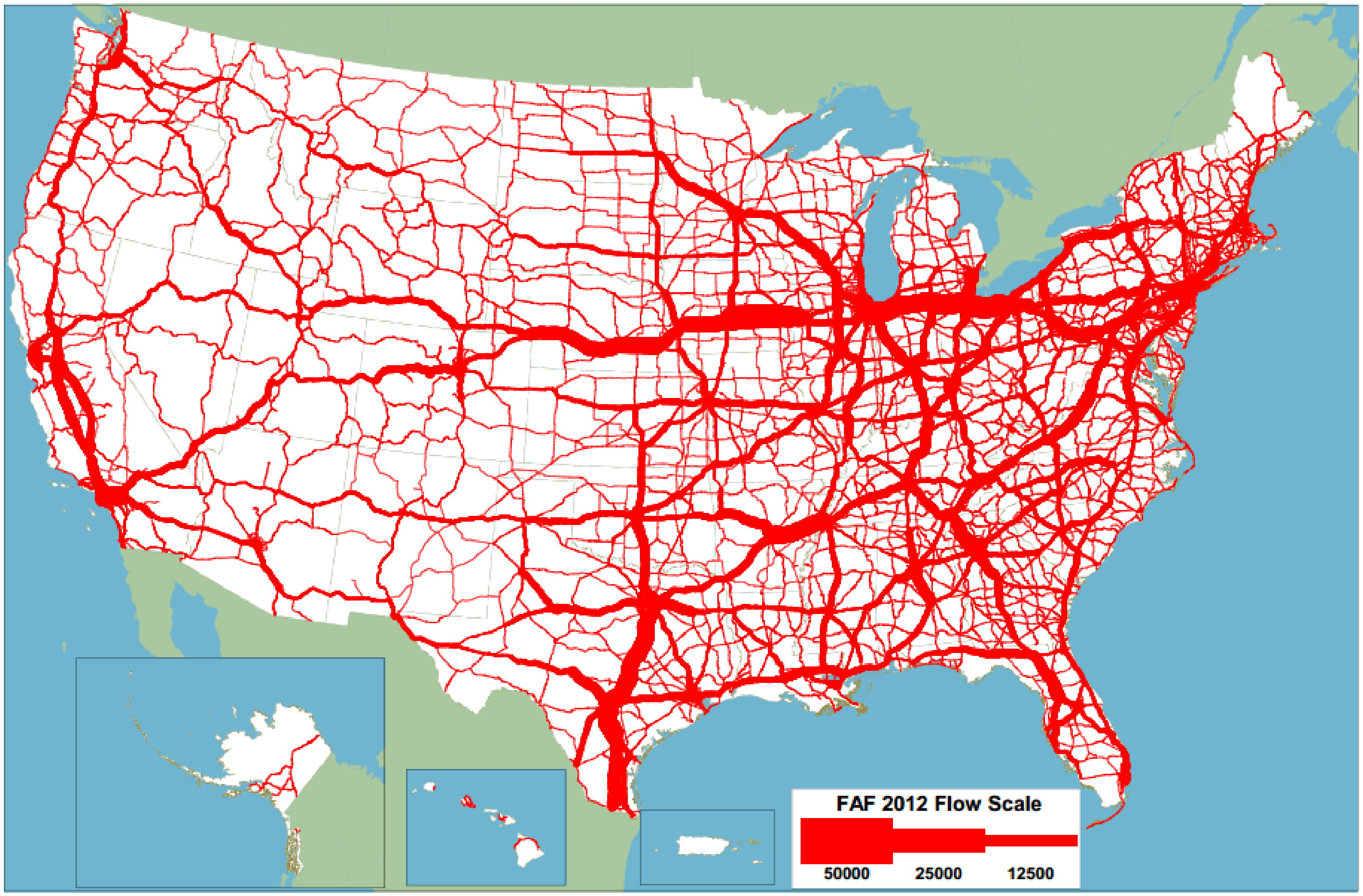
The challenge in calibrating network assignments is that the tonnage to truck freight data and the HPMS truck data, which form the baseline traffic, were derived from different sources. The baseline HPMS truck data were derived from states with varying data quality and data collection methods, and freight flow data were derived by converting the FAF^4 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 the major route (mostly interstate and principal arterials). Once the network was calibrated, the forecast truck trip matrices for 2045 were assigned to the network using base case the 2012 calibrated network. This was done to ensure the consistency with the base year (2012), with an assumption that route choice behavior will remain the same between 2012 and 2045 scenario, and with constant network (no improvement) during the analysis period.

Figure 4-2 and Figure 4-3 illustrate the FAF^4 base year 2012 flow, and FAF^4 2045 flow respectively.

The next major step was to assess reliability of the assignments using a set of statistical measures. The outputs of the assignment process and the HPMS truck volumes were used in the assignment reliability checks presented in Chapter 6.

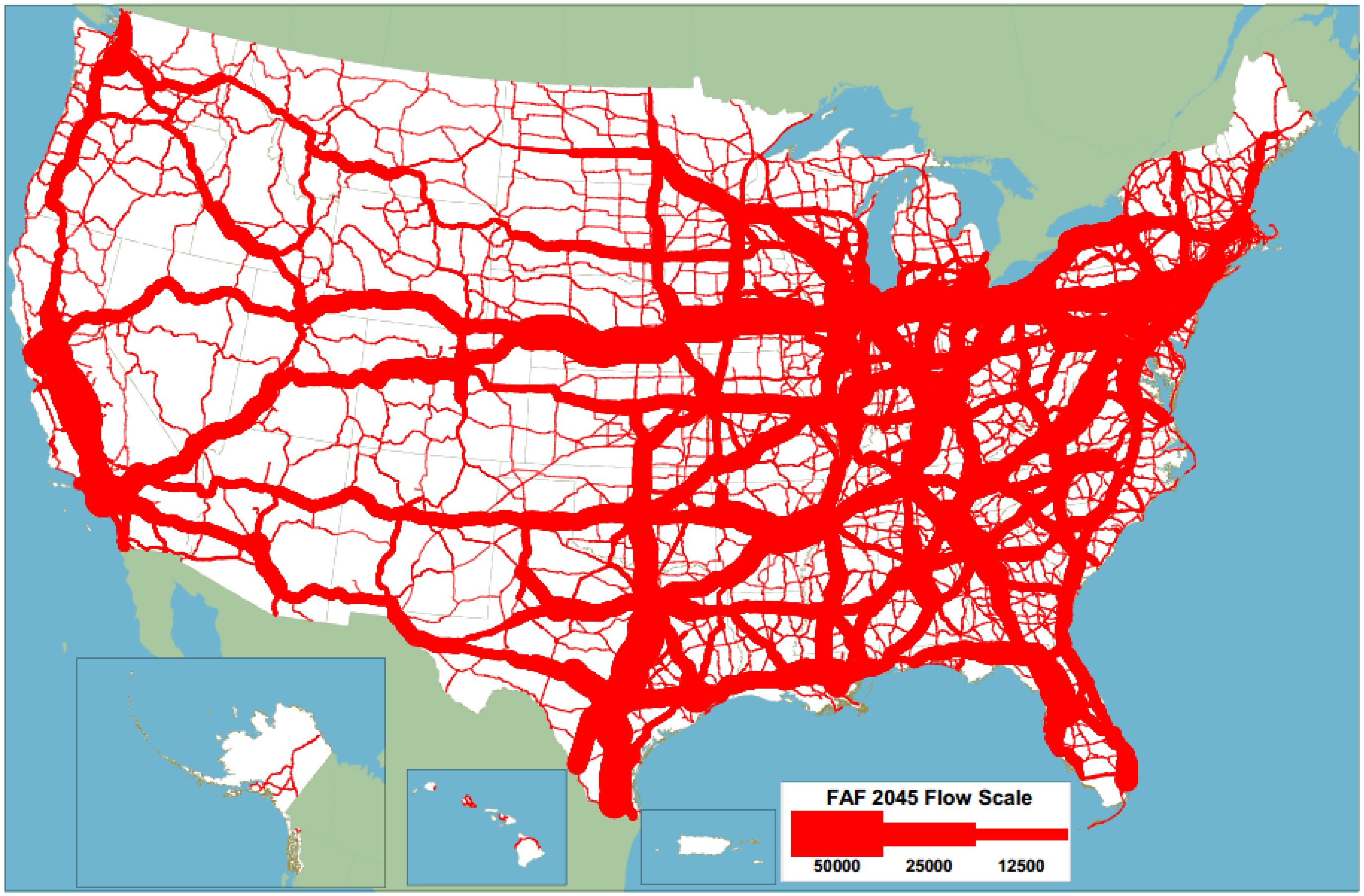
2012 FAF Truck Flows on the NHS Portion of the FAF4 Network



Freight OD Data Source: Office of Freight Management and Operation, US Department of Transportation, FHWA

Figure 4-2. Base Year 2012 FAF[4] Truck Flow on FAF[4] Highway Network

2045 FAF Truck Flows on the NHS Portion of the FAF4 Network



Freight OD Data Source: Office of Freight Management and Operation, US Department of Transportation, FHWA

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

CHAPTER 5: ASSIGNMENT RELIABILITY CHECK

5.1 Introduction

The purpose of the assignment reliability analysis is to address the reliability of those data components that have a direct impact on FAF assignment output as well as their sensitivity on predicted FAF truck volumes on the highway network. Though O-D is the most integral part of the assignment process, the reliability did not make any attempt to quantify the errors that may exist in the source's O-D database. It should be acknowledged that any underlying fatal data errors on the O-D can significantly influence the assignment outcomes. The analysis assumes FAF O-D may have some inherent errors independent of the 3-step freight demand modeling. The general analytical approach adopted for this analysis followed the guidelines as outlined the FHWA Manual Titled "Travel **Model Validation and Reasonableness Checking Manual Second Edition",** September 24, 2010 as appropriate for the freight demand modeling and complemented with other statistical criteria that best fit the assignment reliability objective. A brief review of the guideline applicable to national level freight assignment is summarized in the following paragraphs.

In travel model validation, assignment is the last step of any modeling process of the four-step process, which consists of production, distribution, model choice, and assignment. One important part of the modeling process is assignment validation, which validates both the assignment process and the entire modeling process. This validation is obtained by data procured from independent validation data such as traffic counts, independent traffic speed, and travel time studies. However, because there is a plethora of independent validation data, trip assignments are used as the main mode of validation for replicating observed travel using a travel model. For FAF assignment, the validation process only deals with the assignment as constrained by the FAF OD. Given the limitations, the reliability analysis mostly focused on Vehicle-Miles of Travel (VMT) by functional classification.

Table 2: Assignment Reliability Test Criteria

CHECKS	TEST	QUANTITATIVE/QUALITATIVE
VMT	• Regional- indicates how reasonable the overall level of travel is • facility- indicate issues with the operation of assignment procedures • geographic- uncover geographic bias in modeling group	Quantitative
Traffic volume-related	Comparison between modeled and observed traffic volumes on link-by-link basis	Qualitative
Range	Finding and correcting network/assignment errors	Qualitative
Route choice	Comparison between modeled and observed paths for selected trips based on the traffic flow pattern as described by the ground truth traffic	Qualitative
Localized sensitivity	Key network elements are modified and assignment results for changes and reaction to network elements	Qualitative

5.1.1 VMT Checks

The VMT comparison as shown in the following table by functional class, highway administrative class (NHS Vs Non-NHS) as well as by major corridors. Based on the VMT estimates following observations can be made:

- On average the FAF estimated VMT is less than the HPMS 2012 Total truck traffic reported VMT
- I80, I65and I35 have reported higher VMT than average of all top 14 corridor VMT as reported by HPMS data

		Daily VMT		
Item	Road Type	HPMS AADTT	HPMS Combination Trucks	FAF Trucks
Urban	Interstate	175,088,024	140,175,041	174,885,633
	Freeway/Expressway	36,295,536	16,976,058	4,384,156
	Principal Arterial	62,908,167	23,943,642	5,421,921
	Minor Arterial	9,096,422	3,305,615	370,576
	Other	1,026,470	324,786	57,672
Rural	Interstate	123,707,723	81,722,194	73,661,243
	Principal Arterial	10,548,087	6,594,601	4,576,524
	Minor Arterial	95,043,148	58,488,372	22,518,896
	Major Colletor	45,938,833	23,255,436	5,995,804
	Other	15,239,485	6,217,193	1,584,276
NHS Post MAP-21	NHS	451,709,396	307,579,503	281,556,745
	Non-NHS	124,677,707	53,614,666	12,017,899
NHS-Map 21	NHS	503,016,118	327,376,743	285,753,224
	Non-NHS	73,370,985	33,817,426	7,821,418
Restricted Truck Route	Link with Truck Restriction	2,468,193	822,475	0
Corridor	I-80	21,137,972	17,370,441	30,552,563
	I-5	13,546,294	9,595,687	8,758,200
	I-70	11,961,674	9,928,935	12,009,691
	I-95	14,340,986	9,925,333	9,694,899
	I-10	21,387,367	15,202,058	15,533,823
	I-40	19,861,556	15,594,825	15,741,038
	I-65	6,405,421	5,345,201	7,736,066
	I-94	8,087,075	6,148,139	6,598,457
	I-45	2,995,065	2,322,254	1,413,355
	I-75	15,886,306	12,571,459	11,285,030
	I-81	7,331,968	5,908,157	6,538,756
	I-77	4,133,302	3,400,815	3,049,074
	I-20	11,708,007	9,249,158	8,790,105
	I-35	9,632,790	7,711,532	11,567,063

5.1.2 Co-efficient of Variation

Higher the functional class lower the co-efficient of variation. This is true across the HPMS as well as the FAF assignment.

		CV		
Item	Road Type	HPMS AADTT	HPMS Combination Trucks	FAF Trucks
Urban	Interstate	1.00	0.73	0.75
	Freeway/Expressway	1.03	1.21	2.80
	Principal Arterial	1.11	1.45	4.07
	Minor Arterial	1.26	1.67	7.19
	Other	1.54	1.94	6.14
Rural	Interstate	0.66	0.75	0.82
	Principal Arterial	1.07	1.19	2.22
	Minor Arterial	1.15	1.37	3.50
	Major Colletor	1.15	1.33	4.11
	Other	1.73	2.06	5.60
NHS Post MAP-21	NHS	1.22	1.35	1.70
	Non-NHS	1.39	1.62	5.28
NHS-Map 21	NHS	1.43	1.65	2.19
	Non-NHS	1.45	1.73	5.92
Restricted Truck Route	Link with Truck Restriction	1.19	1.25	0.00
Corridor	I-80	0.67	0.73	0.70
	I-5	0.50	0.58	0.56
	I-70	0.64	0.65	0.39
	I-95	0.61	0.59	0.61
	I-10	0.64	0.58	0.59
	I-40	0.45	0.56	0.55
	I-65	0.81	0.85	0.35
	I-94	0.76	0.75	0.68
	I-45	0.38	0.42	0.57
	I-75	0.50	0.55	0.57
	I-81	0.40	0.45	0.38
	I-77	0.38	0.41	0.35
	I-20	0.51	0.52	0.42
	I-35	0.68	0.70	0.62

5.1.3 Evaluation of the Network Assignment Results with Traffic Counts Data

	VMT (2012)				
	Urban Interstate	Rural Interstate	NHS-Pre MAP21	NHS-Post MAP21	All System
HPMS Total Trucks	173,422,681	123,523,337	449,275,781	500,147,712	572,172,420
HPMS Combo Trucks	140,175,041	81,722,194	307,579,503	327,376,743	361,214,985
FAF	174,885,633	73,661,243	281,556,743	285,753,224	293,575,534

Change Of Ground Count	Total Links	Total Length	IS Count	IS Length	Count	Length		
Total Length	670,427	446,142	100,003	47,436	44292	15527	442284	225787
	Total		Interstate		Primary		NHS	
AADTT range with FAF=0	Link Count	Length	Link Count	Length	Link Count	Length	Link Count	Length
1-500	148937	11207	100	324	2167	561	55875	23287
501-1000	63925	29614	183	23	1419	432	40008	14622
1001-1500	31502	11802	119	24	1519	387	24084	8053
1501-2000	16612	5684	28	5	1701	466	13277	4274
2001-2500	8867	3093	33	15	1373	407	7524	2407
2501-3000	5168	1687	46	4.5	1071	265	4332	1357
>3000	1487	4259	507	68	6157	1560	13424	3745

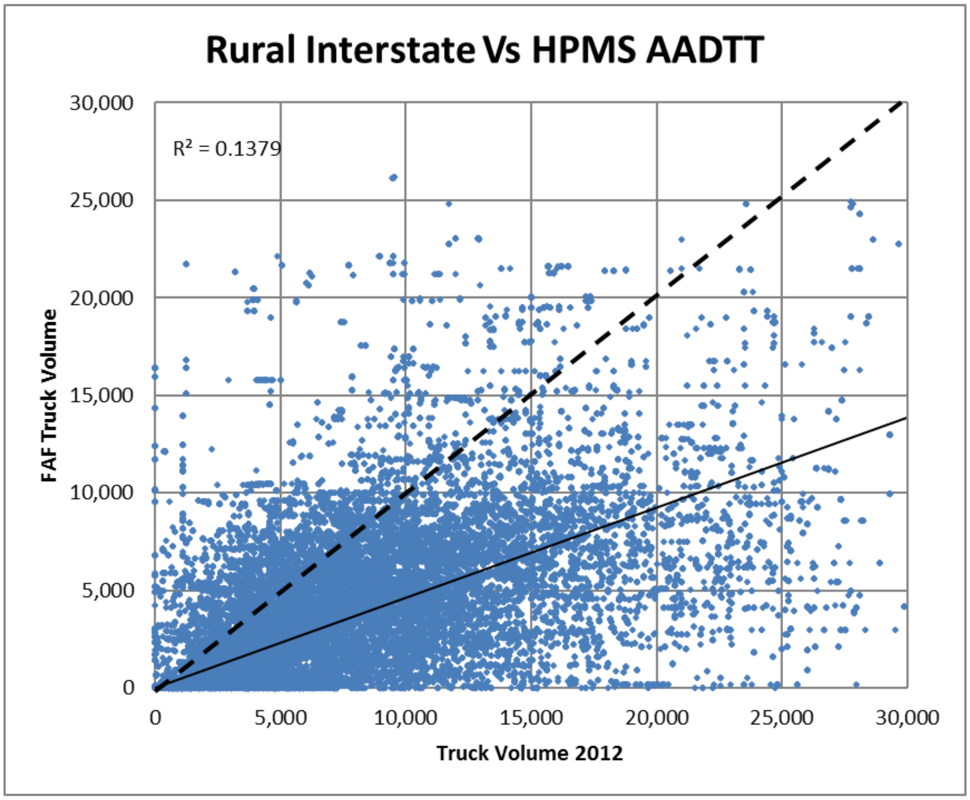
	Total		Interstate		Primary		NHS	
AADTT range with FAF=0	% Total Links	% Total Length	% Link Count	% Length	%Link Count	%Length	Link Count	Length
1-500	22.22	2.51	0.10	0.68	4.89	3.61	12.63	10.31
501-1000	9.53	6.64	0.18	0.05	3.20	2.78	9.05	6.48
1001-1500	4.70	2.65	0.12	0.05	3.43	2.49	5.45	3.57
1501-2000	2.48	1.27	0.03	0.01	3.84	3.00	3.00	1.89
2001-2500	1.32	0.69	0.03	0.03	3.10	2.62	1.70	1.07
2501-3000	0.77	0.38	0.05	0.01	2.42	1.71	0.98	0.60
>3000	0.22	0.95	0.51	0.14	13.90	10.05	3.04	1.66

5.1.4 Model RMSE Checks

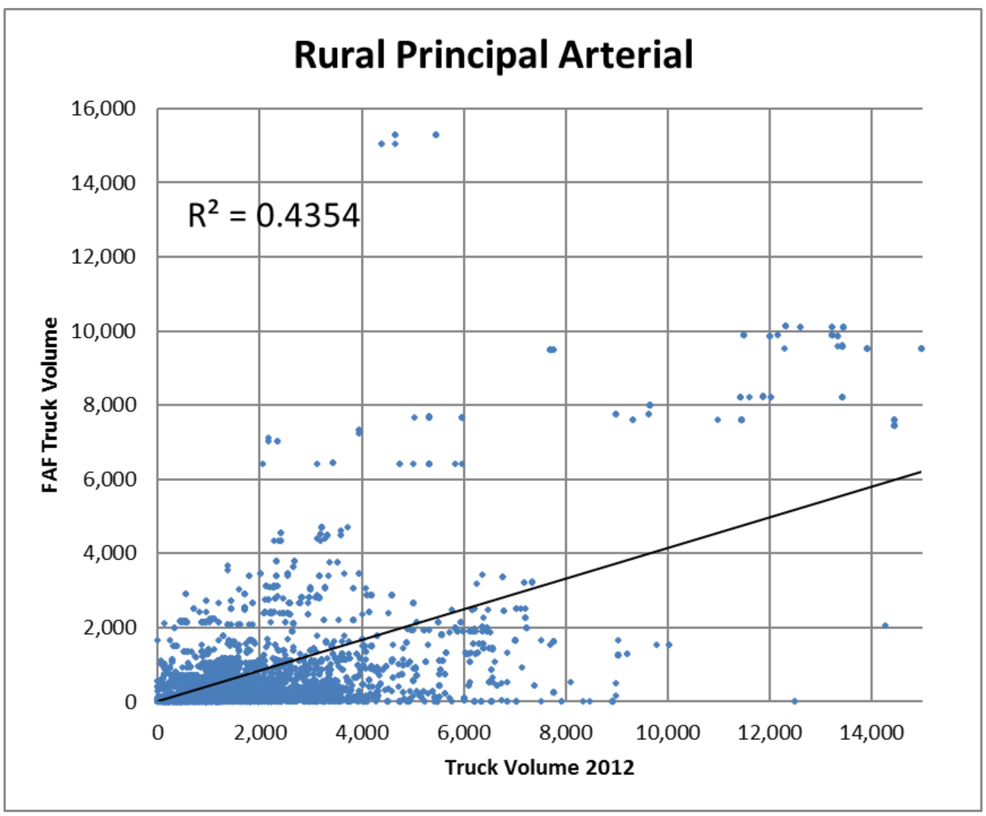
Assignment	Maximum Flow change	Relative Gap	RMSE	%RSME
FAF 2012	35	0.00008156	0.60197228	0.14415599
FAF 2045	93	0.00009950	2.26527201	0.20743006

5.1.5 Scatter Plot Checks

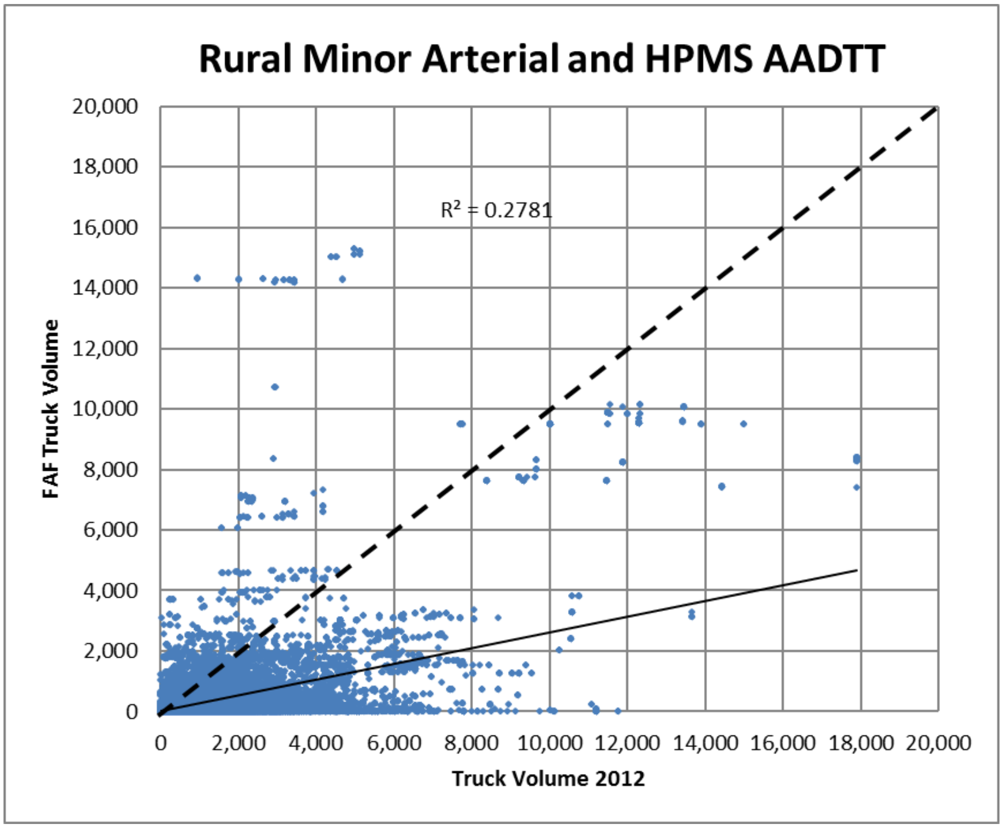
Please see attached



Rural Interstate Vs HPMS AADTT
R^2 = 0.1379
FAF Truck Volume
Truck Volume 2012
0
5,000
10,000
15,000
20,000
25,000
30,000



Rural Principal Arterial
R^2 = 0.4354
FAF Truck Volume
Truck Volume 2012
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000


Rural Minor Arterial and HPMS AADTT
R² = 0.2781
FAF Truck Volume
Truck Volume 2012
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000

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CHAPTER 6: CONCLUSIONS

The primary objective of the highway freight modeling 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.

The network assignment results are evaluated for the purpose of assessing any issues with the results in comparison with other sources. A comparison of pre and post-improvement assignment scenario shows encouraging improvement when measured against the traffic counts and VMT distribution, as well as RMSE test.

The macro level freight allocation also contributes to assignment issues that may affect certain segments more than others, such as rural and urban areas. The FAF freight traffic assignment is the last step of a typical four-step freight demand modeling: freight generation within a set of defined geographic areas, freight distribution, mode choices, and freight network assignment. CV analysis and scattered plot of estimated verses observed trucks were developed by rural interstate, rural principle arterial, urban interstate, urban freeway/expressway, and urban principle arterial. In addition to this, statistical measures such as R-squared and RMSE were also estimated for the final assignment result. The FAF database is composed of mostly long distance freight and consequently, does not take into consideration the local truck traffic found in urban areas. Therefore, there is more relationship in rural areas and less relationship in urban areas, regardless of disaggregation. The more disaggregation that exists in a particular area, the more improvement occurs. This is evident in the CV and scatterplots comparison.

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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^4 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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