Research, Development, and Application of Methods to Update Freight Analysis Framework Out-of-Scope Commodity Flow Data and Truck Payload Factors

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Foreword

The Federal Highway Administration (FHWA) Office of Operations (HOP) is pleased to present this report on the research, development, and application of methods to update Freight Analysis Framework (FAF) Out-of-Scope Commodity (OOS) flow data and Truck Payload Factors (TPF).

An improved method to estimate Commodity Flow Survey (CFS) Out of Scope (OOS) data along with an updated Truck Payload Factors (TPF) will further national freight transportation data and analysis capability and will allow for a more accurate analysis of transportation network performance for various freight flow scenarios. This report provides improved and detailed information regarding freight flow patterns to better support FHWA's current and future freight analysis needs through the Freight Analysis Framework (FAF). The report provides an improved method to integrate CFS OOS data with FAF and an updated and transparent TPF within FAF to convert Origin-Destination (O-D) flow of commodity weight to O-D flow of number of trucks. This report also serves as a reference for transportation planners, departments of transportation, metropolitan planning organizations (MPOs) and other transportation agencies tasked with the development of freight forecasts especially when considering truck payload factors for conversion of annual tons to daily trucks.

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16. Abstract

Methods for modeling freight demand and goods movement in the United States (U.S.) are evolving from aggregated methods to disaggregated methods. Emerging technologies are providing opportunities for more efficient data collection and new data collection that support more advanced freight modeling, analysis and data development environments. An improved method to estimate Commodity Flow Survey (CFS) Out of Scope (OOS) data along with an updated Truck Payload Factors (TPF) will further national freight transportation data and analysis capability and will allow for a more accurate analysis of transportation network performance for various freight flow scenarios. This report provides improved and detailed information regarding freight flow patterns to better support FHWA's current and future freight analysis needs through the Freight Analysis Framework (FAF). The report provides an improved method to integrate CFS OOS data with FAF and an updated and transparent TPF within FAF to convert Origin-Destination (O-D) flow of commodity weight to O-D flow of number of trucks.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
ACS	American Community Survey
AMSA	American Moving and Storage Association
BEA	U.S. Bureau of Economic Analysis
BTS	Bureau of Transportation Statistics
C&D	Construction and Demolition
CAFO	Concentrated Animal Feeding Operation
CBP	County Business Patterns
CDRA	Construction and Demolition Recycling Association
CFIRE	National Center for Freight and Infrastructure Research and Education
CFS	Commodity Flow Survey
CG	Commodity Group
COE	U.S. Department of Energy
CSFFM	California Statewide Freight Forecasting Model
CTR	Center for Transportation Research
CU	Combination Unit
DOT	Department of Transportation
EIA	Energy Information Administration
ELD	Electronic Logging Device
EPA	U.S. Environmental Protection Agency
FAF	Freight Analysis Framework
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FIA	Forest Inventory and Analysis
FIDO	Forestry Inventory Data Online
FIPS	Federal Information Processing Standards
GIS	Geographic Information System
GISPA	USDA Grain Inspection, Packers, and Stockyards Administration
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HH&B	Household and Business
HS	Harmonized System codes
IPF	Iterative Proportional Fitting
IRP	International Registration Plan
LNG	Liquefied Natural Gas
MPO	Metropolitan Planning Organization

MSW	Municipal Solid Waste
NAICS	North American Industry Classification System
NASS	USDA National Agricultural Statistics Service
NCFRP	National Cooperative Freight Research Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NYMTC	New York Metropolitan Transportation Council
NYSDEC	New York State Department of Environmental Conservation
O-D	Origin-Destination
ODCM	Origin-Destination Commodity Mode
OOS	Out-of-Scope
ORNL	Oak Ridge National Laboratory
PADD	Petroleum Administration for Defense Districts
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIERS	Port Import/Export Reporting Service
PUM	Public Use Microdata
RIC&P	Reinventing Conditions & Performance
SCTG	Standard Classification of Transported Goods
SU	Single Unit
TAHC	Texas Animal Health Commission
TCEQ	Texas Commission on Environmental Quality
TLMA	Texas Livestock Marketing Association
TPF	Truck Payload Factor
TPO	Timber Product Output
TSW	Truck Size and Weight
TWC	Texas Workforce Commission
USDA	United States Department of Agriculture
USDOT	U.S. Department of Transportation
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Miles Traveled
VTRIS	Vehicle Travel Information System
WIM	Weigh in Motion

CHAPTER 1. INTRODUCTION

Methods for modeling freight demand and goods movement in the U.S. are evolving from aggregated methods to disaggregated methods. Emerging technologies are providing opportunities for more efficient data collection and new data collection that support more advanced freight modeling, analysis and data development environments. An improved method to estimate commodity flow data that are Out-of-Scope (OOS) to Commodity Flow Survey (CFS) along with an updated Truck Payload Factors (TPF) will further national freight transportation data and analysis capability and will allow for a more accurate analysis of transportation network performance for various freight flow scenarios.

In partnership with the Bureau of Transportation Statistics (BTS), Federal Highway Administration (FHWA) has developed and maintains the Freight Analysis Framework (FAF), a national, commodity-based, freight flow modeling tool. Originally designed by FHWA as a policy-support tool for the U.S. Department of Transportation (USDOT), the FAF is the only publicly available data source that provides a comprehensive resource of long distance national freight movement data across all modes of transportation. The FAF integrates data from a variety of sources to create a comprehensive national picture of freight movement. It estimates commodity flows and relates freight transportation activities among States, sub-State regions, and major international gateways. FAF then assigns those flows to the national highway network.

The FAF has been used in a variety of freight-related transportation and multimodal freight policy analyses. It has also become an important freight data source for transportation practitioners and researchers. State departments of transportation (DOT) and metropolitan planning organizations (MPO) regularly utilize FAF to understand regional and State freight transportation needs and initiatives. The latest version of FAF (Freight Analysis Framework Version 4 (FAF4)) is based on the 2012 Commodity Flow Survey (CFS) and provides future estimates to a horizon year of 2045 for freight flows, on a regional basis by Origin-Destination (O-D) pairs. It also provides estimates of long-haul truck flows along the nation's highway network.

Although FAF O-D commodity flow data is primarily based on the national CFS, the CFS sample frame excludes freight flows from specific industry sectors: farms, fisheries, transportation, construction and demolition, most retail and service industries, foreign establishments (imports), crude petroleum and natural gas shipments, municipal solid waste, logging, as well as household and business moves. These commodity flow data not captured through the CFS or CFS OOS data are available through various sources and differ in formats, reporting schedules and geographical representations. They are compiled and then modeled to supplement the FAF analysis framework to establish a comprehensive national FAF base year O-D matrix.

Finally, by pivoting off the base year FAF O-D matrix, FAF forecasts are prepared by applying mathematical models and macroeconomic data that are based on industry research knowledge. These forecasts are driven by the most up-to-date macroeconomic assumptions on short- and long-term U.S. economic trends at the time of FAF4 forecast development.

FAF also provides estimates of base year and future year long-haul truck traffic volume on the nation's highway network. This requires translation of commodity tonnage O-D moved by trucks into the O-D number of trucks needed to transport commodities. Once truck O-D are estimated, then network assignment modeling procedures are used to estimate freight truck traffic on the national highway system. In FAF, the truck payload factors (TPF) are used to convert O-D for truck tonnage flows to O-D for number of trucks.

The existing TPF is primarily based on the Vehicle Inventory and Use Survey (VIUS) 2002 database (see https://www.census.gov/econ/overview/se0501.html). VIUS provides data on the physical and operating characteristics of the nation's truck population such as: ownership, equipment type, truck configurations, dimensions, capacity, trip mileage, and commodities hauled. The first VIUS survey was conducted in 1963 and every five years thereafter beginning in 1967 and until 2002. TPF is also informed by the FHWA Vehicle Traveler Information System (VITRIS) Weigh-In-Motion (WIM) data.

This project is motivated by the need to provide an improved and detailed information regarding freight flow patterns to better support FHWA's current and future freight analysis needs through FAF. The objectives of this project are to provide:

- An improved method to integrate CFS OOS data into FAF.
- An updated TPF applicable within FAF to convert O-D flow of commodity weight to O-D flow of number of tucks.

This report documents the improved methods to integrate the CFS OOS into the FAF and provides an updated TPF applicable within FAF to convert annual tons to daily trucks.

OUT OF SCOPE COMMODITIES

Out-of-scope commodities comprise 30 percent of the FAF4 by value.[1] Thus, improvements to the estimation of these commodity flows can substantially increase the quality of the FAF4. As a first step, the project team evaluated the FAF4 methods of integrating CFS OOS data, performed a comprehensive review of other available applicable techniques, and identified activities for further testing and implementation. Broadly, this initial evaluation technical approach consisted of three key steps:

1. Reviewed the existing OOS commodity methods employed by FAF4.
2. Reviewed more recent OOS commodity initiatives conducted as part of academic research or State and regional planning efforts with the goal of developing short- and long-term improvements.
3. Developed options for improvements of OOS commodity data that were reviewed by a technical panel of experts.

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[1] Oak Ridge National Laboratory, *Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.

Following the evaluation of current FAF4 methods for integrating CFS OOS data and identifying alternative methodological approaches and data modeling these flows, the next step was to develop and test alternative methodologies that potentially offered short-term improvements for estimating OOS commodity flows. These improvements to the estimation of OOS commodity flows can substantially increase the quality of the FAF4 and improve its usefulness to the state and local transportation agencies that depend on the FAF4 to support freight planning initiatives.

TRUCK PAYLOAD FACTORS

The second objective of this project was to evaluate existing Truck Payload Factors (TPF), payload parameters and application approaches, explore the possibility of further analysis of available Vehicle Inventory and Use Survey (VIUS) data, comprehensive review of other available applicable techniques, identify new data sources, and identified activities for further testing and implementation. VIUS has provided the information for the current payload factors, TPFs, used in the FAF's highway assignment, but while VIUS had previously been collected concurrently with the FAF releases, the VIUS has not been collected or updated since 2002. Changes in the miles traveled by trucks and changes in truck technology have occurred in the ensuing 15 years. In order to properly reflect these changes in the truck assignments of FAF4, as well as subsequent releases of the FAF, a methodology was developed to make the truck payload factors more reflective and representative of current conditions. Broadly, the technical approach contained three key steps:

1. Reviewed the existing Truck Payload Factors (TPF), often known as payload factors, employed by FAF4.
2. Reviewed more recent TPF commodity initiatives conducted as part of research efforts with the goal of developing short- and long-term improvements.
3. Summarized the findings and developed a set of improvement for implementation.

The remainder of the report is organized as follows: chapter 2 performs a comprehensive review of the existing out-of-scope methods employed by the FAF4; chapter 3 reviews alternative methods and other research efforts that may provide improvements over current methods; chapter 4 presents a summary of findings from the review of existing and alternative methods and provides draft short- and long-term improvement activities to be implemented in chapters 5 to 10.

Chapters 11 through 14 focus on the truck payload factors, which includes the review of alternative methods, methods development, methods implementation, and validation.

The report concludes with a summary and potential future improvement activities for capturing OOS commodities.

CHAPTER 2. EXISTING FREIGHT ANALYSIS FRAMEWORK VERSION 4 COMMODITY FLOW SURVEY OUT-OF-SCOPE METHODS

This chapter contains a review of the existing Freight Analysis Framework Version 4 (FAF4) methodologies for incorporating Commodity Flow Survey (CFS) out-of-scope (OOS) commodities. The Oak Ridge National Laboratory report *The FAF4 Building the FAF4 Regional Database: Data Sources and Estimation Methodologies* along with additional information provided by Federal Highway Administration (FHWA), is the foundation for the assessment. Each CFS OOS commodity receives its own, distinct analysis within the review.

FARM-BASED SHIPMENTS

This OOS category covers farm-based agricultural shipments from the field to grain elevator, distribution or processing center, or slaughterhouse. Under FAF4, truck is the assumed mode for transporting all farm-based agricultural shipments.

Data

FAF4 uses five (5) primary data sources to estimate flows of farm-based shipments:

1. 2012 Census of Agriculture.
2. Agricultural Statistics 2013.
3. United States Department of Agriculture (USDA) Statistical Bulletins.
4. 2002 Vehicle Inventory and Use Survey.
5. 2012 CFS Published Statistics.[2]

The Census of Agriculture is a census conducted every five years by the USDA. It coincides with the Economic Census, which occurs in years ending in “2” and “7.”[3] The Census of Agriculture provides statistical information at the national, State, and county levels. All agricultural production establishments (e.g., farms, ranches, nurseries, greenhouses, etc.) are included in the census. The latest available data is from the 2012 Agriculture Census.

The *Agricultural Statistics* is an annual publication prepared by the National Agricultural Statistics Service (NASS) of the USDA.[4] It provides information on agricultural production, supplies, consumption, facilities, costs, and returns. The latest available data is published in *Agricultural Statistics 2013* and contains preliminary estimates for 2012 and projections for 2013. The NASS also issues a series of Statistical Bulletins that contain final estimates for

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[2] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 19–20, September 2016.

[3] U.S. Department of Agriculture, https://www.agcensus.usda.gov.

[4] U.S. Department of Agriculture, Agricultural Statistics, 2013. https://www.nass.usda.gov/Publications/Ag_Statistics/2013/Agricultural_Statistics_2013.pdf.

agricultural data series based on the review of the 2012 Census of Agriculture and other information.[5]

Farm-based commodity flows are also estimated using information from the Vehicle Inventory and Use Survey (VIUS) conducted as part of the Economic Census.[6] The VIUS collects information on the physical and operational characteristics of the private and commercial truck population in the U.S. However, this survey program was discontinued prior to the 2007 Economic Census making the 2002 VIUS the latest available data in this series.

Lastly, farm-based commodity flows are also estimated using information from published statistics from the Commodity Flow Survey (CFS) which produces data on the movement of goods by their Standard Classification of Transported Goods (SCTG) commodity code.[7] Tonnage and value by origin information from the 2012 CFS for shipments of live animals and fish (SCTG 01); cereal grains including seeds (SCTG 02); agricultural products except for animal feed, cereal grains, and forage products (SCTG 03); animal feed, eggs, honey, and other products of animal origin (SCTG 04); meat, poultry, fish, seafood, and their preparations (SCTG 05); other prepared foodstuffs, fats and oils (SCTG 07); and tobacco products (SCTG 09).

Methodology

As shown in figure 1, generally the methodology for estimating farm-based commodity flows involves: (1) estimating agricultural production at the statewide level, (2) estimating agricultural production at the Freight Analysis Framework (FAF) zone level, and (3) estimate the origin-destination flows of farm-based shipments.[8] This section of the technical memorandum describes in detail the estimation process for farm-based shipments.

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[5] U.S. Department of Agriculture, Final Estimates Statistical Bulletins, https://www.nass.usda.gov/Publications/Statistical_Bulletins/index.php.

[6] U.S. Census Bureau, Vehicle Inventory and Use Survey, https://www.census.gov/econ/overview/se0501.html.

[7] U.S. Census Bureau, Commodity Flow Survey, https://www.census.gov/programs-surveys/cfs.html.

[8] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 20–23, September 2016.

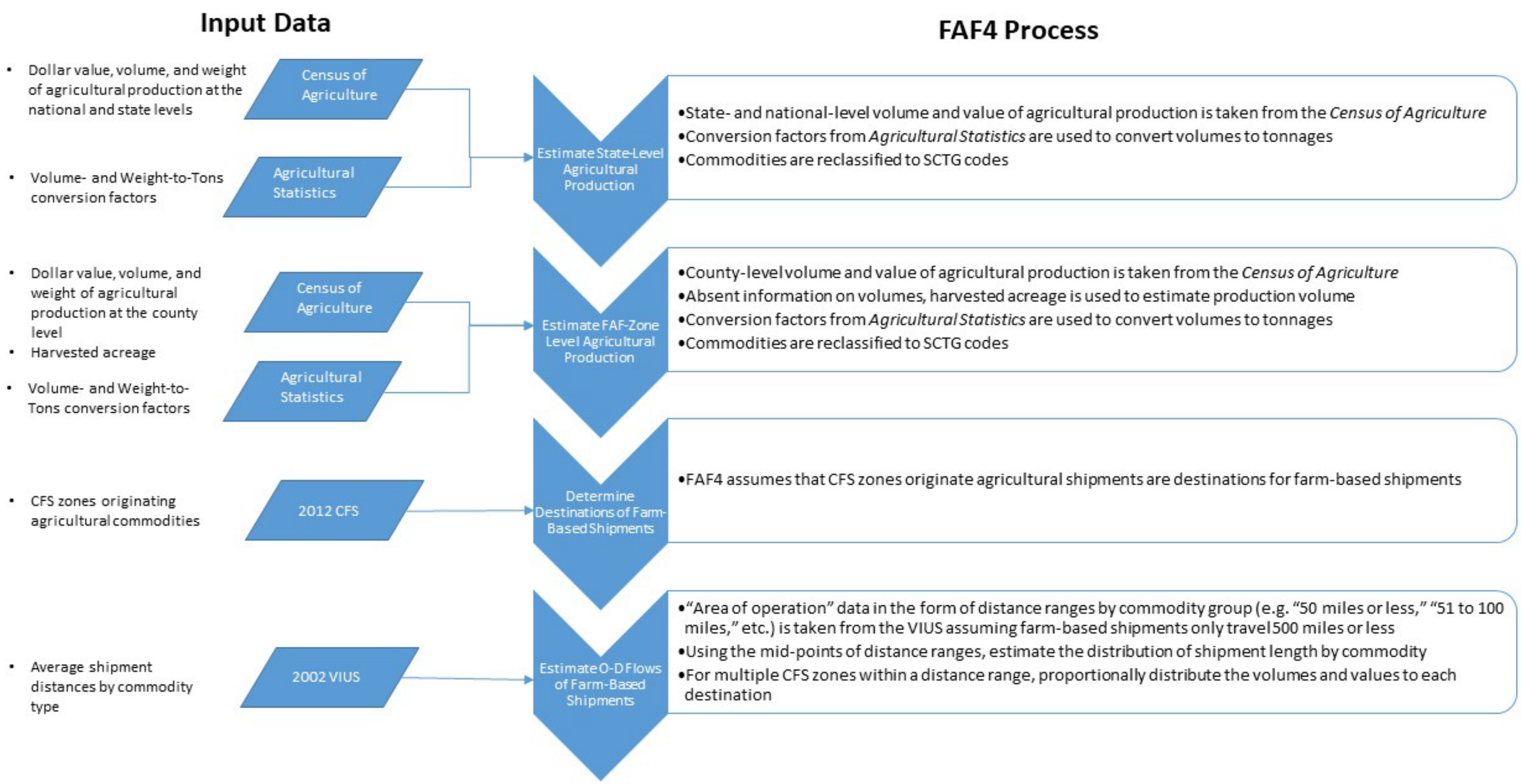

Figure 1. Flow chart. Methodology for farm-based shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

Estimate Agricultural Production at the Statewide Level

Estimating agricultural production at the statewide level begins with obtaining the dollar value of agricultural production at the national and State levels from the Census of Agriculture.[9] Specifically, as shown in figure 2 FAF4 uses "Table 2. Market Value of Agricultural Products Sold Including Direct Sales: 2012 and 2007" of the Agriculture Census to estimate State and national-level agricultural production.

The FAF4 then estimates the tonnages associated with the production of agricultural commodities. Though the Agriculture Census estimates the volumes and/or weights of agricultural production at the national and State levels, different units of measurements are used across commodities as shown in figure 3. For example, wheat is measured in bushels, cotton is measured in bales, rice is measured in hundredweight, and so on. In order to convert the production by volume or weight into tonnages, FAF4 utilizes conversion factors found in Agricultural Statistics 2013 (see figure 4).[10] The FAF4 then reclassifies the USDA commodity groupings from the Agricultural Census into SCTG codes in order to be consistent with all other FAF4 commodity flows (see appendix A).

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[9] U.S. Department of Agriculture, Agriculture Census, 2012. Table 2. Market Value of Agricultural Products Sold Including Direct Sales: 2012 and 2007. https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf.

[10] U.S. Department of Agriculture, Agricultural Statistics, 2013. https://www.nass.usda.gov/Publications/Ag_Statistics/2013/Agricultural_Statistics_2013.pdf.

Table 2. **Market Value of Agricultural Products Sold Including Landlord's Share and Direct Sales: 2012 and 2007**

[For meaning of abbreviations and symbols, see introductory text.]

Item	Unit	2012	Percent of total in 2012	2007
Total sales (see text)	farms	2,109,303	100.0	2,204,792
	$1,000	394,644,481	100.0	297,220,491
Average per farm	dollars	187,097	(X)	134,807
By value of sales:				
Less than $1,000 (see text)	farms	602,119	28.5	688,833
	$1,000	71,054	(Z)	84,357
$1,000 to $2,499	farms	186,191	8.8	211,494
	$1,000	309,382	0.1	350,588
$2,500 to $4,999	farms	191,422	9.1	200,302
	$1,000	687,586	0.2	718,027
$5,000 to $9,999	farms	214,245	10.2	218,531
	$1,000	1,521,953	0.4	1,552,543
$10,000 to $19,999	farms	188,459	8.9	190,402
	$1,000	2,657,519	0.7	2,682,120
$20,000 to $24,999	farms	56,495	2.7	57,883
	$1,000	1,250,401	0.3	1,277,703
$25,000 to $39,999	farms	106,087	5.0	107,046
	$1,000	3,339,063	0.8	3,367,661
$40,000 to $49,999	farms	46,786	2.2	47,686
	$1,000	2,078,716	0.5	2,112,835
$50,000 to $99,999	farms	129,366	6.1	125,456
	$1,000	9,250,546	2.3	8,961,255
$100,000 to $249,999	farms	138,883	6.6	147,500
	$1,000	22,822,425	5.8	24,212,940
$250,000 to $499,999	farms	94,072	4.5	93,373
	$1,000	33,964,264	8.6	33,409,883
$500,000 to $999,999	farms	75,953	3.6	60,777
	$1,000	54,685,873	13.9	42,690,783
$1,000,000 or more	farms	79,225	3.8	55,509
	$1,000	262,005,697	66.4	175,799,795
$1,000,000 to $2,499,999	farms	56,300	2.7	40,390
	$1,000	87,935,245	22.3	60,549,290
$2,500,000 to $4,999,999	farms	14,426	0.7	9,578
	$1,000	49,020,022	12.4	32,299,503
$5,000,000 or more	farms	8,499	0.4	5,541
	$1,000	125,050,429	31.7	82,951,002
Value of sales by commodity or commodity group:				
Crops, including nursery and greenhouse crops	farms	1,032,285	48.9	986,080
	$1,000	212,397,074	53.8	143,657,928
Grains, oilseeds, dry beans, and dry peas	farms	503,315	23.9	479,467
	$1,000	131,135,151	33.2	77,215,262
Corn	farms	361,744	17.1	347,540
	$1,000	67,250,120	17.0	39,909,600
Wheat	farms	147,022	7.0	159,527
	$1,000	15,761,545	4.0	10,623,640
Soybeans	farms	301,343	14.3	285,089
	$1,000	38,745,118	9.8	20,283,986
Sorghum	farms	22,908	1.1	27,142
	$1,000	1,764,352	0.4	1,651,798
Barley	farms	18,099	0.9	18,326
	$1,000	1,228,191	0.3	701,047
Rice	farms	5,585	0.3	6,085
	$1,000	2,895,121	0.7	2,020,231
Other grains, oilseeds, dry beans, and dry peas	farms	58,168	2.8	55,228
	$1,000	3,488,622	0.9	2,024,959
Tobacco	farms	10,001	0.5	16,228
	$1,000	1,491,208	0.4	1,268,114
Cotton and cottonseed	farms	18,143	0.9	18,591
	$1,000	6,137,649	1.6	4,898,608
Vegetables, melons, potatoes, and sweet potatoes	farms	72,267	3.4	69,100
	$1,000	16,851,235	4.3	14,683,058
Fruits, tree nuts, and berries	farms	105,737	5.0	112,690
	$1,000	25,869,700	6.6	18,625,459
Fruits and tree nuts	farms	86,675	4.1	(NA)
	$1,000	22,427,436	5.7	(NA)
Berries	farms	24,553	1.2	(NA)
	$1,000	3,442,264	0.9	(NA)
Total sales (see text) - Con.				
Value of sales by commodity or commodity group - Con.				
Crops, including nursery and greenhouse crops - Con.				
Nursery, greenhouse, floriculture, and sod (see text)	farms	52,751	2.5	50,784
	$1,000	14,517,593	3.7	16,632,734
Cut Christmas trees and short rotation woody crops	farms	12,976	0.6	13,374
	$1,000	332,870	0.1	384,594
Cut Christmas trees	farms	12,068	0.6	(NA)
	$1,000	305,547	0.1	(NA)
Short rotation woody crops	farms	1,065	0.1	(NA)
	$1,000	27,323	(Z)	(NA)
Other crops and hay (see text)	farms	478,632	22.7	434,502
	$1,000	16,061,669	4.1	9,950,098
Maple syrup (see text)	farms	8,063	0.4	(NA)
	$1,000	79,473	(Z)	(NA)
Livestock, poultry, and their products	farms	1,004,564	47.6	1,080,312
	$1,000	182,247,407	46.2	153,562,563
Poultry and eggs	farms	137,541	6.5	148,911
	$1,000	42,751,468	10.8	37,065,947
Cattle and calves	farms	740,978	35.1	798,290
	$1,000	76,380,153	19.4	61,209,970
Milk from cows (see text)	farms	50,556	2.4	(NA)
	$1,000	35,512,120	9.0	(NA)
Hogs and pigs	farms	55,882	2.6	74,789
	$1,000	22,492,611	5.7	18,056,981
Sheep, goats, wool, mohair, and milk (see text)	farms	114,746	5.4	(NA)
	$1,000	939,662	0.2	(NA)
Horses, ponies, mules, burros, and donkeys	farms	114,255	5.4	114,317
	$1,000	1,390,703	0.4	2,061,862
Aquaculture	farms	5,533	0.3	6,409
	$1,000	1,552,375	0.4	1,415,271
Other animals and other animal products (see text)	farms	46,971	2.2	43,226
	$1,000	1,228,315	0.3	1,199,649
Value of landlord's share of total sales (see text)	farms	99,241	4.7	97,706
	$1,000	7,205,804	1.8	6,429,386
Value of agricultural products sold directly to individuals for human consumption (see text)	farms	144,530	6.9	136,817
	$1,000	1,309,827	0.3	1,211,270
Average per farm	dollars	9,063	(X)	8,853
By value of sales:				
$1 to $499	farms	37,398	1.8	35,440
	$1,000	7,770	(Z)	7,217
$500 to $999	farms	20,170	1.0	20,547
	$1,000	13,685	(Z)	14,013
$1,000 to $4,999	farms	52,750	2.5	49,957
	$1,000	121,750	(Z)	113,960
$5,000 to $9,999	farms	14,452	0.7	13,060
	$1,000	97,308	(Z)	88,174
$10,000 to $24,999	farms	11,045	0.5	10,032
	$1,000	164,774	(Z)	151,063
$25,000 to $49,999	farms	4,244	0.2	3,903
	$1,000	143,722	(Z)	133,328
$50,000 or more	farms	4,471	0.2	3,878
	$1,000	760,819	0.2	703,515

Figure 2. Sample chart. Market value of agricultural products sold including direct sales: 2012 and 2007.
(Source: U.S. Department of Agriculture, Agriculture Census, 2012. Table 2. Market Value of Agricultural Products Sold Including Direct Sales: 2012 and 2007. https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf.)

Table 24. Selected Crops Harvested: 2012

[For meaning of abbreviations and symbols, see introductory text.]

Item		United States	Alabama	Alaska	Arizona	Arkansas	California
Harvested cropland	farms	1,288,875	21,283	495	5,587	25,535	53,372
	acres	314,964,600	2,158,026	31,315	890,130	7,316,469	8,007,461
Irrigated	farms	261,281	1,584	226	4,830	4,896	47,972
	acres	52,092,384	109,717	2,392	854,515	4,795,969	7,371,411
Barley for grain	farms	18,667	8	18	177	-	264
	acres	3,283,905	653	4,445	44,662	-	81,954
	bushels	215,059,358	12,304	212,116	5,005,919	-	5,312,595
Irrigated	farms	4,657	-	-	177	-	144
	acres	851,693	-	-	44,662	-	44,819
Farms by acres harvested:							
1 to 24 acres		5,982	5	6	23	-	60
25 to 99 acres		5,303	1	4	38	-	59
100 to 249 acres		3,614	-	3	62	-	68
250 to 499 acres		2,174	2	2	35	-	30
500 to 999 acres		1,079	-	1	12	-	26
1,000 acres or more		515	-	2	7	-	21
Corn for grain	farms	348,530	1,983	-	80	1,712	733
	acres	87,413,045	285,328	-	29,480	695,003	180,672
	bushels	10,333,410,157	25,998,347	-	5,910,931	124,688,804	31,922,610
Irrigated	farms	41,251	167	-	80	1,436	733
	acres	12,819,069	26,084	-	27,901	591,157	175,863
Farms by acres harvested:							
1 to 24 acres		72,836	828	-	17	91	163
25 to 99 acres		101,838	570	-	16	297	211
100 to 249 acres		75,245	282	-	23	394	152
250 to 499 acres		48,492	153	-	8	412	103
500 to 999 acres		32,605	89	-	7	374	63
1,000 acres or more		17,514	61	-	9	144	41
Corn for silage or greenchop	farms	86,365	129	-	133	47	1,895
	acres	7,196,628	8,371	-	36,620	4,208	487,570
	tons	113,153,064	103,506	-	1,012,718	29,156	12,575,973
Irrigated	farms	9,807	11	-	133	13	1,802
	acres	1,643,756	487	-	36,620	652	461,898
Farms by acres harvested:							
1 to 24 acres		32,575	64	-	16	7	249
25 to 99 acres		35,586	40	-	31	22	538
100 to 249 acres		12,369	16	-	47	15	512
250 to 499 acres		3,667	7	-	23	3	329
500 to 999 acres		1,538	2	-	9	-	180
1,000 acres or more		630	-	-	7	-	87
Cotton, all	farms	18,155	925	-	388	701	630
	acres	9,384,080	376,464	-	197,455	586,351	367,766
	bales	16,534,302	710,958	-	585,658	1,253,037	1,201,860
Irrigated	farms	9,130	117	-	388	635	630
	acres	3,813,454	22,206	-	197,455	498,860	367,766
Farms by acres harvested:							
1 to 24 acres		833	76	-	12	8	31
25 to 99 acres		2,902	171	-	67	68	102
100 to 249 acres		4,273	236	-	124	118	180
250 to 499 acres		4,058	194	-	71	140	153
500 to 999 acres		3,521	160	-	54	167	90
1,000 acres or more		2,568	88	-	60	200	74
Dry edible beans, excluding limas	farms	6,896	1	-	149	-	308
	acres	1,642,797	(D)	-	13,009	-	39,511
	cwt	31,424,290	(D)	-	244,530	-	955,995
Irrigated	farms	2,984	-	-	60	-	269
	acres	473,506	-	-	12,461	-	36,866
Farms by acres harvested:							
1 to 24 acres		949	1	-	108	-	95
25 to 99 acres		1,902	-	-	6	-	93
100 to 249 acres		1,962	-	-	20	-	69
250 to 499 acres		1,165	-	-	10	-	38
500 to 999 acres		669	-	-	3	-	11
1,000 acres or more		249	-	-	2	-	2
Forage - land used for all hay and all haylage, grass silage, and greenchop (see text)	farms	813,583	16,039	226	1,390	20,158	7,903
	acres	55,775,162	807,058	24,155	324,562	1,286,688	1,670,027
	tons, dry equivalent	127,345,016	1,856,452	29,461	2,288,772	1,639,109	9,363,421
Irrigated	farms	82,453	164	5	1,315	372	5,498
	acres	9,325,503	7,549	1,298	322,816	14,090	1,346,666
Farms by acres harvested:							
1 to 24 acres		358,682	7,091	59	643	6,727	2,621
25 to 99 acres		315,682	6,920	94	291	9,746	2,274
100 to 249 acres		99,035	1,630	49	169	2,965	1,435
250 to 499 acres		26,409	317	17	107	555	728
500 to 999 acres		9,826	59	5	104	132	487
1,000 acres or more		3,949	22	2	76	33	358
Oats for grain	farms	35,038	233	8	32	45	240
	acres	1,078,698	15,069	903	2,708	6,006	25,065
	bushels	65,646,178	750,562	56,810	183,262	578,583	2,246,420
Irrigated	farms	1,261	4	-	20	5	145
	acres	59,132	(D)	-	2,304	(D)	15,901
Farms by acres harvested:							
1 to 24 acres		23,991	76	3	19	13	86
25 to 99 acres		8,949	104	2	5	13	75
100 to 249 acres		1,658	47	1	3	11	54
250 to 499 acres		322	6	2	5	5	16
500 to 999 acres		99	-	-	-	3	7
1,000 acres or more		19	-	-	-	-	2
Peanuts for nuts	farms	6,561	772	-	-	36	15
	acres	1,621,631	217,940	-	-	13,594	27
	pounds	6,660,492,899	834,701,569	-	-	59,109,271	84,093
Irrigated	farms	2,501	101	-	-	36	15
	acres	521,673	13,730	-	-	13,441	27

Figure 3. Sample chart. Selected crops harvested: 2012.
(Source: U.S. Department of Agriculture, "Table 24. Selected Crops Harvested: 2012," Chapter 2: State Level Data, Census of Agriculture, Volume 1. https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_024_024.pdf.)

WEIGHTS, MEASURES, AND CONVERSION FACTORS
(See explanatory text just preceding this table)

WEIGHTS AND MEASURES

Commodity	Unit[1]	Approximate net weight	
		U.S.	Metric
		Pounds	*Kilograms*
Alfalfa seed	Bushel	60	27.2
Apples	......do	48	21.8
Do	Loose pack	38–42	17.2–19.1
Do	Tray pack	40–45	18.1–20.4
Do	Cell pack	37–41	16.8–18.6
Apricots	Lug (brentwood)[2]	24	10.9
Western	4–basket crate[3]	26	11.8
Artichokes:			
Globe	Ctn, by count and loose pack	20–25	9.1–11.3
Jerusalem	Bushel	50	22.7
Asparagus	Crate (NJ)	30	13.6
Avocados	Lug[4]	12–15	5.4–6.8
Bananas	Fiber folding box[5]	40	18.1
Barley	Bushel	48	21.8
Beans:			
Lima, dry	......do	56	25.4
Other, dry	......do	60	27.2
	Sack	100	45.4
Lima unshelled	Bushel	28–32	12.7–14.5
Snap	......do	28–32	12.7–14.5
Beets:			
Topped	Sack	25	11.3
Bunched	½ crate 2 dz-bchs	36–40	16.3–18.1
Berries frozen pack:			
Without sugar	50–gal. barrel	380	172
3 + 1 pack	......do	425	193
2 + 1 pack	......do	450	204
Blackberries	12, ½-pint basket	6	2.7
Bluegrass seed	Bushel	14–30	6.4–13.6
Broccoli	Wirebound crate	20–25	9.1–11.3
Broomcorn (6 bales per ton)	Bale	333	151
Broomcorn seed	Bushel	44–50	20.0–22.7
Brussels sprouts	Ctn, loose pack	25	11.3
Buckwheat	Bushel	48	21.8
Butter	Block	55,68	25,30.9
Cabbage	Open mesh bag	50	22.7
Do	Flat crate (1¾ bu)	50–60	22.7–27.2
Do	Ctn, place pack	53	24.0
Cantaloups	Crate[6]	40	18.1
Carrots	Film plastic Bags, mesh sacks & cartons holding 48 1 lb. film bags	55	24.9
Without tops	Burlap sack	74–80	33.6–36.3
Castor beans	Bushel	41	18.6
Castor oil	Gallon	[7]8	3.6
Cauliflower	W.G.A. crate	50–60	22.7–27.2
Do	Fiberboard box wrapper leaves removed film-wrapped, 2 layers	23–35	10.4–15.9
Celery	Crate[8]	60	27.2
Cherries	Lug (Campbell)[9]	16	7.3
Do	Lug	20	9.1
Clover seed	Bushel	60	27.2
Coffee	Bag	132.3	60
Corn:			
Ear, husked	Bushel	[10]70	31.8
Shelled	......do	56	25.4
Meal	......do	50	22.7
Oil	Gallon	[7]7.7	3.5
Syrup	......do	11.72	5.3
Sweet	Wirebound crate	50	22.7
Do	Ctn, packed 5 oz. ears	50	22.7
Do	WDB crate, 4½–5 oz. (from FL & NJ)	42	19.1
Cotton	Bale, gross	[11]500	227
Do	Bale, net	[11]480	218
Cottonseed	Bushel	[12]32	14.5
Cottonseed oil	Gallon	[7]7.7	3.5
Cowpeas	Bushel	60	27.2
Cranberries	Barrel	100	45.4
Do	¼–bbl. box[13]	25	11.3
Cream, 40–percent butterfat	Gallon	8.38	3.80
Cucumbers	Bushel	48	21.8
Dewberries	24–qt. crate	36	16.3
Eggplant	Bushel	33	15.0
Eggs, average size	Case, 30 dozen	47.0	21.3
Escarole	Bushel	25	11.3
Figs, fresh	Box single layer[14]	6	2.7
Flaxseed	Bushel	56	25.4
Flour, various	Bag	100	45.4
Do	Ctn or Crate, Bulk	30	13.6
Garlic	Ctn of 12 tubes or 12 film bag pkgs 12 cloves each	10	4.5
Grapefruit:			
Florida and Texas	½–box mesh bag	40	18.1
Florida	1⅗ bu. box	85	38.6
Texas	1⅗ bu. box	80	36.3
California and Arizona	Box[15]	[16]67	30.4
Grapes:			
Eastern	12–qt. basket	20	9.1
Western	Lug	28	12.7
Do	4–basket crate[17]	20	9.1
Hempseed	Bushel	44	20.0
Hickory nuts	......do	50	22.7
Honey	Gallon	11.84	5.4
Honeydew melons	⅔ Ctn	28–32	12.7–14.5
Hops	Bale, gross	200	90.7

See footnotes on page ix.

Figure 4. Sample chart. Conversion factors.
(Source: U.S. Department of Agriculture, Agricultural Statistics, 2013. https://www.nass.usda.gov/Publications/Ag_Statistics/2013/Agricultural_Statistics_2013.pdf.)

Disaggregate Agricultural Production from the State-level to the Freight Analysis Framework Zone-Level

Agricultural production at the FAF zone level is estimated using a procedure similar to the one implemented at the State level. The 2013 Agricultural Census has similar information on agricultural production by value and weight and/or volume at the county level (see figure 5 for an example using data from the State of Georgia). County-level estimates are aggregated to FAF zone levels for those States that are divided into multiple FAF zones. For commodities for which production weight or volume data is not provided, FAF4 uses the amount of harvested acreage to estimate total tonnage. The FAF4 does this by distributing the State-level totals to counties in proportion to their share of State-level harvested acreage.

Table 24. **Selected Crops Harvested: 2012**

[For meaning of abbreviations and symbols, see introductory text.]

Item		Georgia	Appling	Atkinson	Bacon	Baker	Baldwin	Banks	Barrow
Harvested cropland	farms	22,347	351	146	193	98	56	252	170
	acres	3,609,788	66,779	31,989	27,023	49,766	2,679	9,242	4,817
Irrigated	farms	4,990	113	50	78	55	7	16	16
	acres	1,112,359	7,498	(D)	(D)	(D)	15	(D)	59
Barley for grain	farms	22	-	-	-	-	-	-	-
	acres	646	-	-	-	-	-	-	-
	bushels	32,210	-	-	-	-	-	-	-
Irrigated	farms	13	-	-	-	-	-	-	-
	acres	271	-	-	-	-	-	-	-
Farms by acres harvested:									
1 to 24 acres		10	-	-	-	-	-	-	-
25 to 99 acres		11	-	-	-	-	-	-	-
100 to 249 acres		1	-	-	-	-	-	-	-
250 to 499 acres		-	-	-	-	-	-	-	-
500 to 999 acres		-	-	-	-	-	-	-	-
1,000 acres or more		-	-	-	-	-	-	-	-
Corn for grain	farms	2,619	17	28	28	34	-	11	9
	acres	311,125	839	3,756	752	8,388	-	197	63
	bushels	52,451,141	113,688	644,588	74,100	1,792,331	-	21,427	1,890
Irrigated	farms	1,207	3	16	3	27	-	-	3
	acres	179,983	(D)	1,095	(D)	6,185	-	-	15
Farms by acres harvested:									
1 to 24 acres		947	9	6	20	3	-	9	9
25 to 99 acres		718	6	10	5	14	-	1	-
100 to 249 acres		610	1	6	3	8	-	1	-
250 to 499 acres		230	1	6	-	6	-	-	-
500 to 999 acres		86	-	-	-	1	-	-	-
1,000 acres or more		28	-	-	-	2	-	-	-
Corn for silage or greenchop	farms	238	8	-	3	2	-	3	-
	acres	31,216	1,687	-	1,023	(D)	-	50	-
	tons	653,545	24,888	-	(D)	(D)	-	780	-
Irrigated	farms	103	5	-	2	1	-	-	-
	acres	17,467	522	-	(D)	(D)	-	-	-
Farms by acres harvested:									
1 to 24 acres		73	2	-	-	-	-	2	-
25 to 99 acres		64	1	-	1	1	-	1	-
100 to 249 acres		68	3	-	-	1	-	-	-
250 to 499 acres		19	-	-	1	-	-	-	-
500 to 999 acres		11	2	-	1	-	-	-	-
1,000 acres or more		3	-	-	-	-	-	-	-
Cotton, all	farms	2,616	72	40	21	30	-	-	-
	acres	1,279,400	29,030	17,081	11,833	17,141	-	-	-
	bales	2,719,600	54,307	33,100	20,526	42,491	-	-	-
Irrigated	farms	1,330	12	17	2	20	-	-	-
	acres	402,259	2,114	4,095	(D)	11,800	-	-	-
Farms by acres harvested:									
1 to 24 acres		114	5	2	-	4	-	-	-
25 to 99 acres		396	16	7	6	5	-	-	-
100 to 249 acres		478	14	11	4	4	-	-	-
250 to 499 acres		683	13	1	3	4	-	-	-
500 to 999 acres		626	16	16	6	8	-	-	-
1,000 acres or more		319	8	3	2	5	-	-	-
Forage - land used for all hay and all haylage, grass silage, and greenchop (see text)	farms	13,404	159	71	55	25	44	233	145
	acres	602,994	5,948	3,733	3,948	4,169	2,546	8,508	4,613
	tons, dry equivalent	1,486,225	12,546	13,459	11,276	11,289	4,251	17,815	8,967
Irrigated	farms	510	4	2	3	7	-	6	1
	acres	26,915	119	(D)	62	353	-	28	(D)
Farms by acres harvested:									
1 to 24 acres		6,706	111	21	27	3	17	109	77
25 to 99 acres		5,206	37	37	20	17	19	110	62
100 to 249 acres		1,191	3	11	4	2	7	13	6
250 to 499 acres		242	7	2	3	-	1	1	-
500 to 999 acres		48	1	-	1	1	-	-	-
1,000 acres or more		11	-	-	-	2	-	-	-
Oats for grain	farms	316	-	6	2	11	-	3	-
	acres	20,087	-	240	(D)	480	-	120	-
	bushels	992,230	-	14,400	(D)	19,000	-	3,201	-
Irrigated	farms	54	-	-	-	3	-	-	-
	acres	2,893	-	-	-	300	-	-	-
Farms by acres harvested:									
1 to 24 acres		116	-	-	-	6	-	-	-
25 to 99 acres		145	-	6	2	2	-	3	-
100 to 249 acres		48	-	-	-	3	-	-	-
250 to 499 acres		5	-	-	-	-	-	-	-
500 to 999 acres		1	-	-	-	-	-	-	-
1,000 acres or more		1	-	-	-	-	-	-	-
Peanuts for nuts	farms	2,833	79	34	13	67	-	-	-
	acres	731,946	22,542	5,593	3,242	21,031	-	-	-
	pounds	3,236,937,533	86,861,603	21,529,716	10,421,668	102,747,138	-	-	-
Irrigated	farms	1,388	13	16	4	43	-	-	-
	acres	270,783	1,873	1,003	189	10,676	-	-	-
Farms by acres harvested:									
1 to 24 acres		219	4	1	-	4	-	-	-
25 to 99 acres		582	13	13	3	19	-	-	-
100 to 249 acres		953	23	13	1	19	-	-	-
250 to 499 acres		768	29	6	9	12	-	-	-
500 to 999 acres		229	7	-	-	7	-	-	-
1,000 acres or more		82	3	1	-	6	-	-	-
Sorghum for grain	farms	371	-	1	-	2	-	1	-
	acres	39,082	-	(D)	-	(D)	-	(D)	-
	bushels	1,924,241	-	(D)	-	(D)	-	(D)	-
Irrigated	farms	79	-	-	-	-	-	-	-
	acres	6,519	-	-	-	-	-	-	-

Figure 5. Sample chart. Selected crops harvested: 2012—State of Georgia example. (Source: U.S. Department of Agriculture, "Table 24. Selected Crops Harvested: 2012," Chapter 2: County Data, Georgia: State and County Data, Census of Agriculture, Vol. 1, Geographic Area Series, Part 10, AC-12-A-10. https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Georgia/st13_2_024_024.pdf.)

Estimate Origin-Destination Flows of Farm-Based Shipments

The FAF4 uses VIUS 2002 data to estimate the distribution of average shipment distances using information on the typical “area of operation” for trucks carrying agricultural products. The VIUS reports areas of operation as: off-the-road; 50 miles or less; 51 to 100 miles; 101 to 200 miles; 201 to 500 miles; 501 miles or more; not reported; and not applicable (i.e., vehicle not in use). The FAF4 assumes that farm-based shipment activity is largely local, thus the “501 miles or more” category is not included in the estimation process. In addition, the FAF4 only considers CFS areas that shipped out products associated with the farm-based commodity as eligible destinations for the commodity flow. For example, CFS areas with shipments of “tobacco products” that originated from their locations were considered as potential destinations for “tobacco harvested” from a farm.

Using the mid-points of the remaining range categories and the distribution of operating ranges for agricultural products, the FAF4 develops a distribution of shipment lengths for each of the corresponding SCTG commodity-carrying truck groups by State.

When multiple FAF4 regions are within the same distance range from a given “production” area (i.e., FAF4 origin of the farm-based shipment), the estimated shipment total is divided proportionally among all involved destination FAF4 regions. This method is applied to both values and tonnages of farm-based shipments.

Results

The FAF4 estimates that farm-based agricultural shipments accounted for nearly 1 billion tons of commodity flows at the national level as shown in table 1. This amounts to nearly $385.4 billion in value. Furthermore, farm-based agricultural shipments account for more than 5.6 percent of all commodity movements by weight at the national level.[11] Thus, any improvement to the methodology for estimating farm-based agricultural shipments or the data that support its estimation will result in a substantial impact to the estimate for total agricultural shipments.

[11] At the national level, in 2012 an estimated 16,996,146.11 KTons of commodities valued at $17,729,210.22 (million $) were moved in the U.S. (https://faf.ornl.gov/fafweb/Extraction1.aspx).

Table 1. National total for farm-based agricultural shipments in 2012.

SCTG	Commodity Description	Weight (thousand ton)	Value (million $)
01	Animal and fish (live)	90,460	146,746
02	Cereal grains	451,736	88,797
03	Agricultural products (including tobacco)	257,583	111,073
04	Animal feed, eggs, honey and other animal products	55,472	3,261
07	Other prepared foodstuffs (milk)	104,171	35,501
Total		959,422	385,378

(Source: Oak Ridge National Laboratory, "Table 5-1. National Total for Farm-Based Agricultural Shipments in 2012," *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

FISHERIES

Out-of-scope fishery shipments are those that occurred prior to the first point of processing or before arriving to the distribution center. Once shipments reach those points, they become in-scope and are covered under the commodity flow survey. Fishery shipments fall under commodity code SCTG 01.

Data

The primary data source for OOS fishery shipments is the *Fisheries of the United States* report published annually by the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) and also from data series published by the NMFS on which the report is based (such as landings at major U.S. ports).[12,13,14] It contains statistics on the value and tonnage of fishery landings with landings from U.S. territorial seas, the U.S. Exclusive Economic Zone, and on the high seas. The information in the report comes from NMFS field offices with cooperation from coastal States. Statistics on U.S. commercial landings are available for major U.S. ports (see figure 6), regions (i.e., New England, Middle Atlantic, Chesapeake, South Atlantic, Gulf, Pacific Coast, Great Lakes, and Hawaii), and States.

[12] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* page 25, September 2016.

[13] https://www.st.nmfs.noaa.gov/Assets/commercial/fus/fus15/documents/FUS2015.pdf.

[14] https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/other-specialized-programs/total-commercial-fishery-landings-at-major-u-s-ports-summarized-by-year-and-ranked-by-dollar-value/index.

2016 Commercial Fishery Landings by Port Ranked by Dollars

Rank	Port	Millions of Pounds	Millions of Dollars
1	New Bedford, MA	106.6	326.5
2	Dutch Harbor, AK	770.0	198.0
3	Empire-Venice, LA	440.0	122.0
4	Naknek, AK	170.0	108.0
5	Kodiak, AK	417.0	107.0
6	Honolulu, HI	32.3	106.0
7	Aleutian Islands (Other), AK	508.0	105.0
8	Alaska Penninsula (Other), AK	243.0	85.0
9	Cape May-Wildwood, NJ	46.6	84.7
10	Bristol Bay (Other), AK	54.0	76.0
11	Stonington, ME	23.2	68.0
12	Key West, FL	16.0	67.0
13	Hampton Roads Area, VA	12.3	61.0
14	Westport, WA	108.3	59.2
15	Point Judith, RI	53.4	55.7
16	Sitka, AK	56.0	55.0
17	Brownsville-Port Isabel, TX	18.0	53.0
18	Gloucester, MA	63.4	52.4
19	Dulac-Chauvin, LA	32.0	48.0
20	Newport, OR	77.3	47.8
21	Galveston, TX	15.0	45.0
22	Bayou La Batre, AL	22.0	45.0
23	Astoria, OR	93.6	42.3
24	Vinalhaven, ME	10.5	42.3
25	Seward, AK	27.0	42.0
26	Palacios, TX	15.0	39.0
27	Portland, ME	49.8	38.1
28	Cordova, AK	35.0	38.0
29	Petersburg, AK	41.0	37.0
30	Shelton, WA	9.4	36.4
31	Ketchikan, AK	65.0	36.0
32	Port Arthur, TX	15.0	33.0
33	Provincetown-Chatham, MA	26.5	32.8
34	Point Pleasant, NJ	26.3	32.1

Figure 6. Sample chart. Example of commercial fishery landings at major U.S. ports. (Source: National Marine Fisheries Service, National Oceanic and Atmospheric Administration. https://www.st.nmfs.noaa.gov/pls/webpls/MF_LPORT_YEARD.RESULTS.)

Methodology

As shown in figure 7, the FAF4 estimation process uses the State-level statistics on tonnage and value from the *Fisheries of the United States* report to estimate production at the State level.[15] NMFS data on fishery landings at the top 104 ports by value are then used to disaggregate production data to FAF4 zones. Lastly, origin-destination flows of fishery is estimated, assuming that all shipments occur within the FAF4 zone in which the port is located. The remainder of this section describes in detail the specific steps involved in the estimation of fishery shipments.

[15] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 25–26, September 2016.

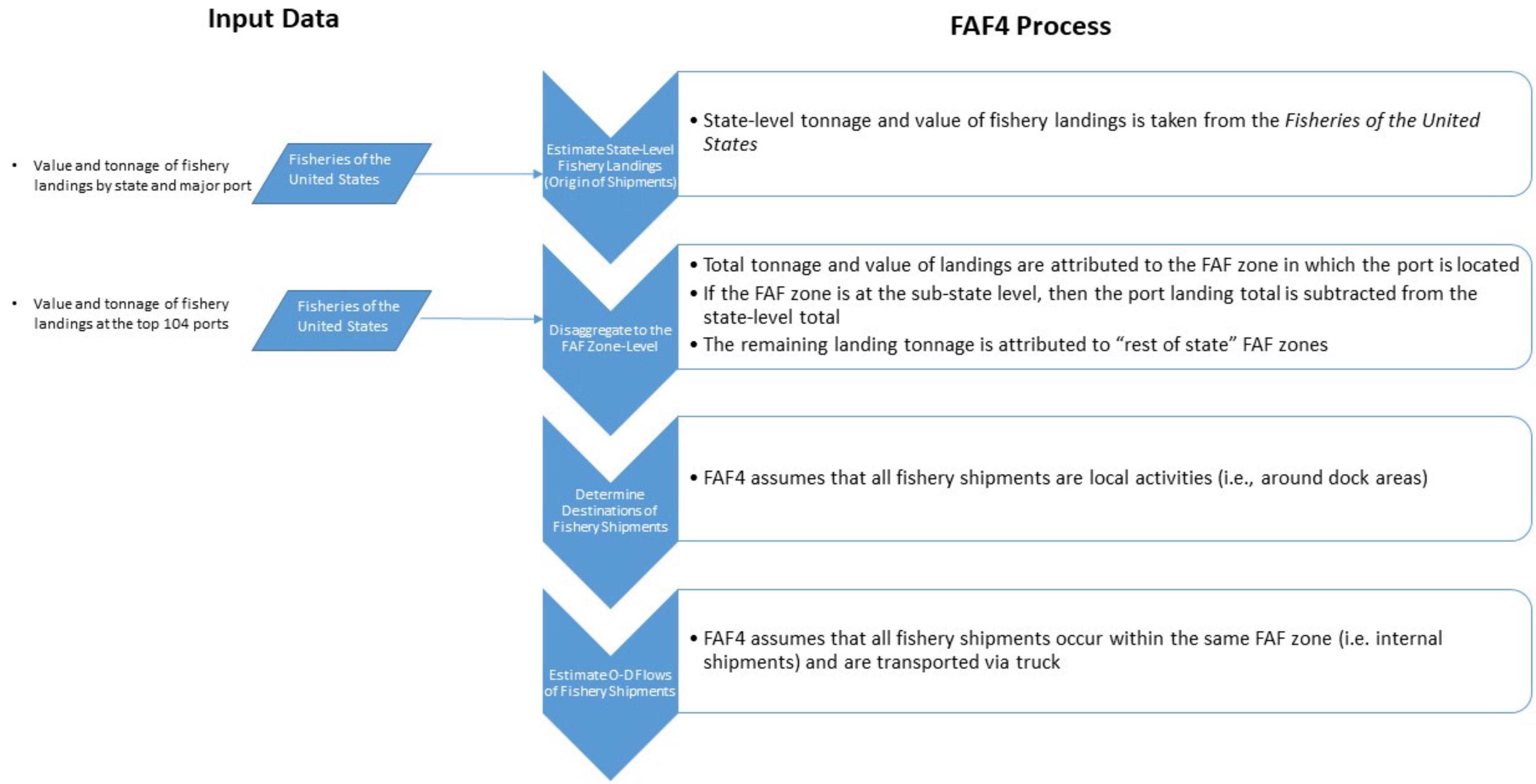

Figure 7. Flow chart. Methodology for fishery shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

Estimate State-Level Fishery Landings

The FAF4 uses the State-level statistics on tonnage and value from the *Fisheries of the United States* report to estimate production at the State level. According to these data, commercial fishery landings totaled approximately 4.8 million tons and were valued at over $5.1 billion in 2012.

Disaggregate Fishery Landings from the State- to the Freight Analysis Framework Zone-Level

National Marine Fisheries Service data on fishery landings at the top 104 ports by value are used to disaggregate production data to FAF4 zones. The total tonnage and value of landings are attributed to the FAF4 zone in which the port is located. If the FAF4 zone is at the sub-State level, then the port landing total is subtracted from the State-level total and that residual amount is allocated to the "rest of State" zones.

Estimate Origin-Destination Flows of Fishery Shipments

Under FAF4, fishery shipments are assumed to be local activities (i.e., around dock areas). Thus, shipments are assumed to be within the same FAF4 zone. Furthermore, all fishery movements are assumed to occur by truck.

Results

Consistent with the *Fisheries of the United States* report, the FAF4 estimates approximately 4.8 million tons of fishery shipments valued at over $5.1 billion in 2012. Though the Oak Ridge National Laboratory (ORNL) report does not specify to which commodity code fishery shipments are assigned, most likely it is SCTG 01 (Live animals/fish). In 2012, SCTG 01 commodity flows accounted for over 100 million tons valued at over $1.66 billion. This implies that fishery shipments comprise under 5 percent of SCTG 01 flows by weight and about 3 percent by value. For all commodity flows, fishery shipments represent less than 0.03 percent by weight and value. Thus, an improvement in the methods or data supporting the estimation of this OOS commodity is not likely to result in a substantial impact for the broader commodity group or at the national level. However, as articulated in the Oak Ridge National Laboratory report *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, though fishery shipments are small at the national level they are substantial in weight in value for States with major commercial fishing industries such as Alaska.

LOGGING

In the FAF4, logging industry shipments fall within commodity code SCTG 25. This covers shipments from field (forests) to processing facilities (timber cutting and/or transporting).

Data

FAF4 uses three (3) primary data sources for estimating Logging OOS commodity flows:

1. USDA Forest Service's *Forestry Inventory Data Online* (FIDO).
2. USDA Forest Service's *Timber Product Output (TPO) Reports*.
3. State and Region Price Reports.[16]

The FIDO is an online tool maintained by the USDA Forest Service under the Forest Inventory and Analysis (FIA) National Program.[17] It is managed by the USDA Forest Service's Research and Development office. The FIA is actually comprised of multiple tools for inventorying and monitoring forests and grasslands and estimating changes in forest land over space and time. The FAF4 collects from the FIDO the quantity of harvest removals (in board feet) by location and species type to determine the weight of the logs heading to process facilities.

TPO Reports are also produced by the USDA Forest Service.[18] For the States of California and Nevada, specifically, the TPO Reports are used to obtain the quantity of soft and hard wood from the published "2012 State Level Core Tables."

[16] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 26–27, September 2016.

[17] https://www.fia.fs.fed.us/tools-data/.

[18] https://www.fia.fs.fed.us/program-features/tpo/.

Core Table 5. ◆ Volume of industrial timber harvested by County, timber product, and major species group, [user title]

State	County	All Products		Saw Logs		Veneer Logs		Pulpwood		Composite Products		Post-poles-pilings		[1]Other Industrial	
		Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood
								thousand cubic feet							
CA	Amador	2,470	0	2,470	0	0	0	0	0	0	0	0	0	0	0
CA	Butte	9,629	0	9,575	0	0	0	0	0	0	0	53	0	0	0
CA	Calaveras	7,574	0	7,574	0	0	0	0	0	0	0	0	0	0	0
CA	Del Norte	3,545	0	3,545	0	0	0	0	0	0	0	0	0	0	0
CA	El Dorado	9,155	0	9,155	0	0	0	0	0	0	0	0	0	0	0
CA	Fresno	1,246	0	1,245	0	0	0	0	0	0	0	0	0	1	0
CA	Glenn	652	0	644	0	0	0	0	0	0	0	8	0	0	0
CA	Humboldt	39,543	6	38,511	6	694	0	0	0	0	0	305	0	33	0
CA	Inyo	626	0	626	0	0	0	0	0	0	0	0	0	0	0
CA	Kern	522	0	522	0	0	0	0	0	0	0	0	0	0	0
CA	Lake	36	0	36	0	0	0	0	0	0	0	0	0	0	0
CA	Lassen	10,505	0	10,494	0	0	0	0	0	0	0	11	0	0	0
CA	Madera	2,975	0	2,975	0	0	0	0	0	0	0	0	0	0	0
CA	Mariposa	823	0	823	0	0	0	0	0	0	0	0	0	0	0
CA	Mendocino	18,257	0	18,240	0	0	0	0	0	0	0	17	0	0	0
CA	Modoc	4,485	0	2,080	0	2,393	0	0	0	0	0	12	0	0	0
CA	Nevada	3,497	0	3,497	0	0	0	0	0	0	0	0	0	0	0
CA	Placer	3,930	0	3,930	0	0	0	0	0	0	0	0	0	0	0
CA	Plumas	15,118	0	15,098	0	0	0	0	0	0	0	20	0	0	0
CA	San Bernardino	221	0	221	0	0	0	0	0	0	0	0	0	0	0
CA	San Mateo	822	0	822	0	0	0	0	0	0	0	0	0	0	0
CA	Santa Clara	643	0	643	0	0	0	0	0	0	0	0	0	0	0
CA	Santa Cruz	1,431	0	1,431	0	0	0	0	0	0	0	0	0	0	0
CA	Shasta	39,875	0	32,415	0	7,264	0	0	0	0	0	195	0	0	0
CA	Sierra	5,610	0	5,610	0	0	0	0	0	0	0	0	0	0	0
CA	Siskiyou	26,563	0	11,388	0	15,175	0	0	0	0	0	0	0	0	0
CA	Sonoma	1,508	0	1,508	0	0	0	0	0	0	0	0	0	0	0
CA	Tehama	10,425	0	10,265	0	0	0	0	0	0	0	160	0	0	0
CA	Trinity	11,075	0	10,970	0	0	0	0	0	0	0	105	0	0	0
CA	Tulare	915	0	914	0	0	0	0	0	0	0	0	0	1	0
CA	Tuolumne	7,815	0	7,815	0	0	0	0	0	0	0	0	0	0	0
CA	Yuba	1,815	0	1,812	0	0	0	0	0	0	0	4	0	0	0
All Counties		243,304	6	216,853	6	25,526	0	0	0	0	0	890	0	35	0

MBF = Thousand board feet (1/4 inch rule); MMBF= Million board feet (1/4 inch rule); MCF = Thousand cubic feet; MMCF= Million cubic feet; Cords= standard cords 4'x4'x8'.
Tons = Green tons.
Numbers in rows and columns may not add to totals due to rounding.

[1]Fuelwood notes:
Southern and Northern Regions:
Residential Fuelwood is consumed for private use (U.S. Department of Energy estimates). Industrial fuelwood is included in Other Industrial.
Rocky Mountain/Interior West and Pacific Northwest Regions:
Fuelwood includes industrial fuelwood from TPO mill surveys and residential firewood from Dept. of Energy estimates.

Figure 8. Sample chart. Core Table 5: Volume of industrial timber harvested by county, timber product, and major species group—California.
(Source: USDA Forest Service, https://www.fs.usda.gov/srsfia/.)

The FAF4 uses information on prices of soft and hard woods provided in various State or Region Price Reports to determine the value and tonnage of Logging OOS commodities. Example reports include the *Timber Mart, Bureau of Business and Economic Research* at the University of Montana, and the Texas Forest Service's *Stumpage Prices Trends*.

Table 2. Stumpage prices—Northeast, dollars per thousand board feet (mbf) international ¼.

Species by Region	Minus 1 Std Dev	Average	Plus 1 Std Dev	N#
Northern Red Oak	$325	$524	$724	19
White Oak	$193	$321	$449	16
Mixed Oak	$171	$310	$450	18
Black Cherry	$602	$940	$1,278	12
White Ash	$191	$352	$513	15
Hard Maple	$265	$390	$516	13
Soft Maple	$174	$283	$392	20
Yellow-Poplar	$134	$196	$258	3
Misc. Hardwoods	$78	$132	$185	18
White Pine	$0	$73	$0	1
Hemlock	$10	$42	$73	2

(Source: Pennsylvania State University, College of Agricultural Sciences, Penn State Extension, https://extension.psu.edu/timber-market-report-2018-2nd-quarter.)

Methodology

As shown in figure 9, the FAF4 estimation process first develops State and county totals of board feet produced using statistics published in the FIDO and TPO reports.[19] The FAF4 then estimates the value of Logging OOS commodities using information from the State and region price reports. After that, county-level estimates of tonnage and value produced are aggregated to the FAF4 zone level. Finally, origin-destination flows are estimated assuming that logging shipments are internal to the FAF4 zone in which the timber-producing site is located. The remainder of this section describes in detail the specific steps involved in the estimation of logging commodity flows.

19 Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* page 27, September 2016.

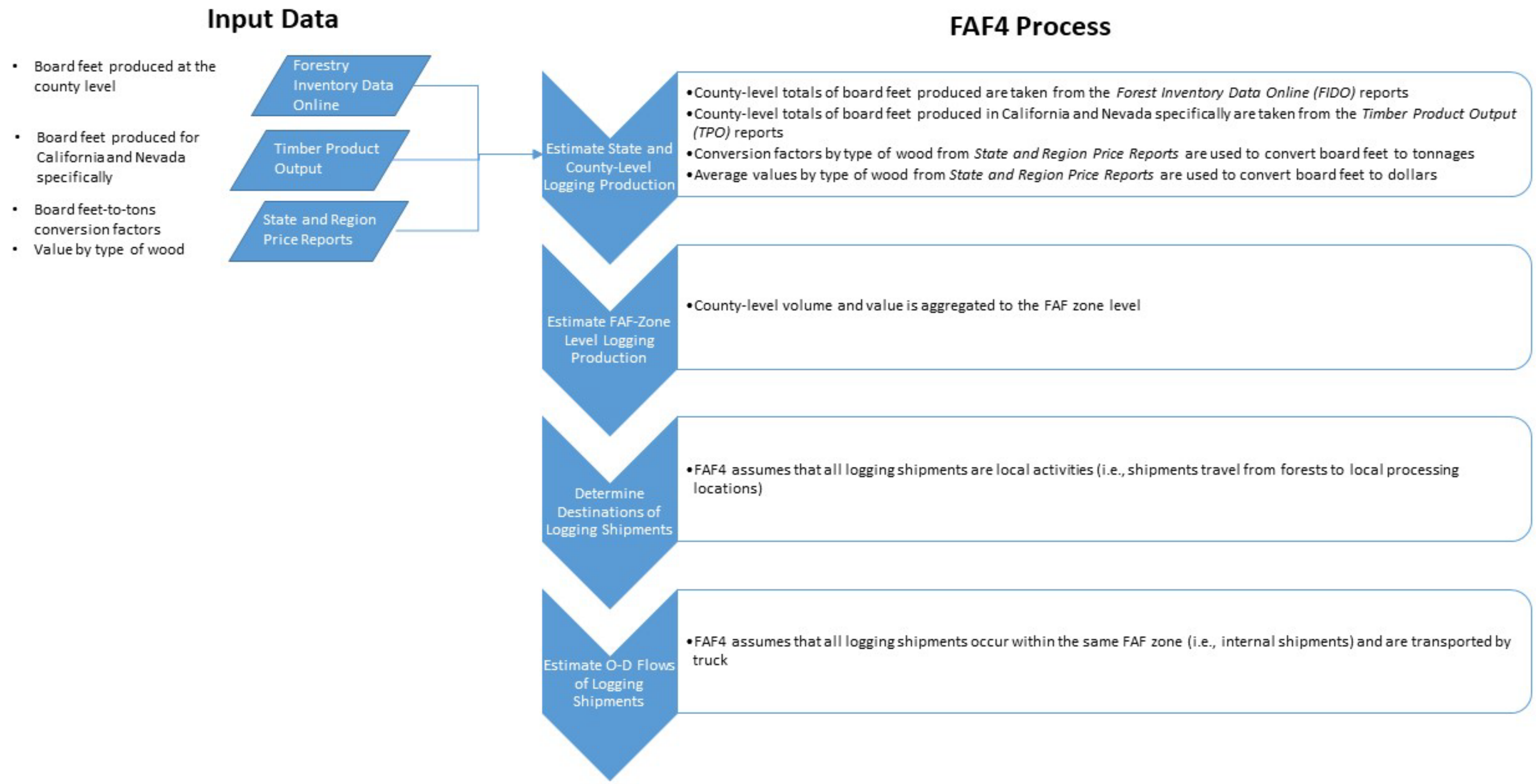

Figure 9. Flow chart. Methodology for logging shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

Estimate County-Level Logging Production

The FAF4 first estimates State and county totals of board feet produced using statistics published in the FIDO and TPO reports. The FIDO contains the amount of board feet produced at the county level. These county level totals of board feet are converted to tonnage based on the location and type of wood—softwood or hardwood—using information from the *State and Region Price Reports*. Information from these reports are used to account for the fact that the weight of softwoods and hardwoods can vary across the U.S.

The FAF4 then estimates the value of Logging OOS commodities using information from the State and region price reports. Like weight, the reports are used to account for variations in price across the U.S.

Aggregate County-Level Logging Production to the Freight Analysis Framework Zone-Level

County-level estimates of tonnage and value produced are then aggregated to the FAF4 zone level.

Estimate Origin-Destination Flows of Logging Shipments

Under FAF4, the movement of OOS logging shipments is assumed to occur only at the local level (i.e., shipments travel from forests to local processing locations). Thus, OOS logging shipments are estimated to consist solely of intra-zone movements. Furthermore, the FAF4 assumes that all OOS logging shipments occur by truck.[20] This assumption is supported with the observation from the Waybill Carload Sample data that only about 2 million tons of rail shipments fall under this commodity category, which is less than 1 percent of the estimated total shipment tonnage.

Results

The FAF4 estimates 239 million tons of OOS logging shipment activity worth over $6.4 billion in 2012.[21] In 2012, SCTG 25 commodity flows accounted for over 297 million tons valued at over $13 billion. This implies that OOS logging shipments comprise over 80 percent of SCTG 25 flows by weight and nearly 50 percent by value. For all commodity flows, OOS logging shipments represent just over 1 percent by weight and less than 1 percent by value.

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[20] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* page 27, September 2016.

[21] Ibid.

MUNICIPAL SOLID WASTE AND CONSTRUCTION AND DEMOLITION DEBRIS

Municipal Solid Waste

Municipal solid waste (MSW) products are collected from homes, schools, hospitals, and businesses and includes:

- Containers and packaging (e.g., soft drink bottles and cardboard boxes).
- Durable goods (e.g., furniture and appliances).
- Nondurable goods (e.g., newspapers, trash bags, and clothing).
- Other wastes (e.g., food scraps and yard trimmings).

MSW products are disposed in landfills and are also processed in incinerators and resource recovery facilities.

Data

Data for estimating MSW flows primarily comes from three sources:

1. State Solid Waste Management Reports.
2. BioCycle—State of Garbage in America.
3. U.S. Environmental Protection Agency (EPA) Municipal Solid Waste in the United States: 2012 Facts and Figures.[22]

Several States produce annual reports on their solid waste management facilities and activities. Typically, these reports are produced by their environmental and/or health departments and include information on the volume of waste and recycling generation, import and export of waste across State borders, and allocation of waste to landfills at the county and State levels. A total of 34 State reports were used in the FAF4.

[22] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 29–30, September 2016.

TABLE 1
Disposal Information on Municipal Solid Waste Landfills
Calendar Year 2008

(I) ID	(II) County	(III) Name of Facility	(IV) Owner	(V) Permitted Acreage	(VI) Total Waste Received		(VII) Out of State Waste Received		(VIII) Est. Life Remaining
					tons/year	tons/day*	tons/year	%	years
1	Adams	**Plantation Oaks Landfill**	Waste Mgt. of MS, Inc.	80	**131,081**	423	9,535	7.27	48
2	Chickasaw	**Prairie Bluff Landfill**	Waste Mgt. of MS, Inc.	236	**145,087**	468	27,126	18.70	150
3	Clay	**Golden Triangle Reg. Landfill**	Golden Triangle Reg. SWMA	265	**165,376**	533	0	0.00	170
4	Harrison	**Pecan Grove Landfill**	Waste Mgt. of MS, Inc.	176	**415,149**	1,339	6,553	1.58	29
5	Jefferson	**Jefferson Co. Landfill**	Southern Landfill Mgt. Inc.	177	**19,704**	64	4,461	22.64	324
6	Kemper	**Kemper Co. Solid Waste Landfill**	Kemper Co. Landfill Company	20	**22,040**	71	8,937	40.55	3
7	Lauderdale	**Pine Ridge Landfill**	Waste Mgt. of MS, Inc.	100	**130,988**	423	22,125	16.89	30
8	Leflore	**Leflore County Landfill**	Leflore Co. B.O.S.	56	**100,162**	323	0	0.00	15
9	Madison	**Canton Sanitary Landfill**	City of Canton	139	**58,586**	189	0	0.00	125
10	Madison	**Little Dixie Landfill**	BFI Waste Sys. of N. America	150	**346,525**	1,118	1,011	0.29	19
11	Pearl River	**Central Landfill**	Trans American Waste	80	**121,075**	391	74,180	61.27	28
12	Perry	**Pine Belt Regional Landfill**	Pine Belt SWMA	49	**149,192**	481	0	0.00	8
13	Pontotoc	**Three Rivers Regional Landfill**	Three Rivers SWMA	207	**201,855**	651	0	0.00	40
14	Scott	**Clearview Env. Control Facility**	Chambers of MS, Inc.	149	**348,662**	1,125	611	0.18	39
15	Tippah	**Northeast MS Regional Landfill**	NE Mississippi SWMA	32	**270,290**	872	179,174	66.29	22
16	Tunica	**Tunica Landfill**	Waste Mgt. of Tunica, Inc.	203	**383,959**	1,239	280,811	73.14	49
17	Washington	**Big River Landfill**	BFI Waste Sys. of N. America	183	**140,123**	452	4,033	2.88	148
18	Winston	**City of Louisville Landfill**	City of Louisville	39	**21,942**	71	0	0.00	107
				Total	**3,171,796**	**10,232**	**618,557**	**19.50**	

Figure 10. Sample chart. Disposal information on municipal solid waste landfills in Mississippi. (Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologie*s, September 2016.)

Because not every State provides annual reports on solid waste activities, the FAF4 also uses data from the *State of Garbage in America Survey*. This survey was conducted by the Earth Engineering Center of Columbia University and the BioCycle Journal on a bi-annual basis from 2002 to 2010. The survey was not conducted in 2012 and the 2013 effort was led solely by Columbia University. The survey is administered to the waste management agencies in all 50 States on the topics of the generation and disposition of MSW. There are two primary objectives to the survey: (1) compile and analyze waste management data provided by State waste management agencies; and (2) resolve the large data discrepancy between landfilling data provided by State waste management agencies and the U.S. EPA reports on MSW Facts and Figures.

Table 2. Estimated tonnage of MSW reported, recycled, composted, combusted via waste-to-energy (WTE) and landfilled (2008 data unless noted)[1,2]

State	Population (2008)	Reported MSW Generation (tons/yr)	MSW Recycled (tons/yr)	MSW Composted (tons/yr)	MSW To WTE tons/yr)	MSW Landfilled (tons/yr)	Estimated MSW Generation (tons/yr)	Per Capita Estimated Generation (tons/capita*/yr)
Alabama	4,661,900	4,498,671	472,000[3]	n/a	316,659[4]	4,498,671[4]	5,287,330	1.13
Alaska	686,293	591,400[5]	28,646[6]	–[7]	0	614,607	643,253	0.94
Arizona	6,500,180	6,718,581	917,373[8]	65,954	0	5,801,208	6,784,535	1.04
Arkansas	2,855,390	3,711,017	483,896[9]	501,221	0	3,711,017	4,696,134	1.64
California	36,756,666	n/a	24,724,726[10]	7,641,910	627,039	28,216,903	61,210,578	1.67
Colorado	4,939,456	8,493,576	540,141	110,719	0	6,824,960	7,475,820	1.51
Connecticut	3,501,252	3,423,725	607,691	302,928	2,190,873	387,542	3,489,034	1.00
Delaware	873,092	1,059,175	168,701	122,357	0	741,143	1,032,201	1.18
District of Columbia[6]	591,833	n/a	21,142	–[7]	12,791	997,150	1,031,083	1.74
Florida	18,328,340	32,326,416[11]	2,403,281[9]	n/a	3,770,416	17,161,312	23,335,009	1.27
Georgia	9,685,744	12,623,173	682,266[3]	40,000	41,350	10,765,486[12]	11,529,102	1.19
Hawaii	1,288,198	2,297,680	574,294	256,046	589,982	2,297,680	3,718,002[13]	2.89
Idaho	1,523,816	1,668,578	150,172	n/a	0	1,518,406	1,668,578	1.09
Illinois	12,901,563	23,441,094	1,003,390	497,421	0	15,150,000	16,650,811	1.29
Indiana	6,376,792	n/a	480,176[3]	375,625	586,493	8,012,706	9,455,000	1.48
Iowa	3,002,555	4,003,953[13]	924,364[3]	247,574	69,537[4]	2,652,855	3,894,330	1.30
Kansas	2,802,134	3,494,097	727,853	147,888	0	2,597,584	3,473,325	1.24
Kentucky[6]	4,269,245	n/a	1,185,541[9]	258,752	63,700	4,827,483	6,335,476	1.48
Louisiana	4,410,796	5,656,995	29,800	565,166	259,000	4,981,510	5,835,476	1.32
Maine	1,316,456	1,535,489	333,132[9]	28,969	607,463	217,290	1,186,854	0.90
Maryland	5,633,597	6,477,317	1,461,164	781,293	847,659[4]	3,461,764	6,551,880	1.16
Massachusetts	6,497,967	8,360,000	2,300,000	680,000	3,133,200	2,236,800	8,350,000	1.29
Michigan	10,003,422	12,095,000	844,328[3]	–[7]	1,081,011	12,086,000[14]	14,011,339	1.40
Minnesota	5,220,393	5,926,951	2,589,954	17,630	1,187,600	6,530,938	10,326,122	1.98
Mississippi	2,938,618	n/a	129,839[6]	15,161	0	2,553,238	2,698,238	0.92
Missouri	5,911,605	7,529,041	951,860[3]	–[7]	0	3,899,961	4,851,821	0.82
Montana	967,440	n/a	66,662[9]	54,098	0	1,317,324	1,438,084	1.49
Nebraska	1,783,432	n/a	322,500[3]	–[7]	0	2,242,879	2,565,379	1.44
Nevada	2,600,167	3,640,579	229,128[3]	85,721	0	3,299,832	3,614,681	1.39
New Hampshire	1,315,809	1,315,627	89,739[9]	23,438	254,040	877,148	1,244,365	0.95
New Jersey	8,682,661	6,687,781	2,012,583[9]	1,913,678	1,400,000[4]	7,842,764	13,169,025	1.52
New Mexico	1,984,356	2,028,463	230,865	45,279	0	1,755,747	2,031,891	1.02
New York	19,490,297	16,990,152	3,060,363	627,949	3,681,134	9,556,442	16,925,888	0.87
North Carolina	9,222,414	n/a	668,498	589,139	107,837	7,264,586	8,630,060	0.94
North Dakota	641,481	687,348	26,695	22,783	0	687,394	736,872	1.15
Ohio	11,485,910	15,291,980	2,037,688	876,813	0	10,337,719	13,252,219	1.15
Oklahoma[6]	3,642,361	n/a	170,000	–[7]	0	4,224,393	4,394,393	1.21
Oregon	3,790,060	4,972,389	1,421,850	339,877	181,666	2,689,119	4,632,513	1.22
Pennsylvania[15]	12,448,279	n/a	4,677,083	748,723	1,951,447	9,666,692	17,043,945	1.37
Rhode Island	1,050,788	1,075,931	101,883	48,380	0	864,583	1,014,846	0.97
South Carolina	4,479,800	4,452,348	914,056	167,457	212,118	3,155,304	4,448,935	0.99
South Dakota	804,194	573,754	71,041	62,850	0	565,148	699,039	0.87
Tennessee	6,214,888	5,681,594	251,112	50,000	74,327	5,039,337	5,414,776	0.87
Texas	24,326,974	n/a	2,634,275	4,360,000	0	22,170,707	29,164,982	1.20
Utah	2,736,424	n/a	51,159	161,628	126,739	2,241,353	2,580,879	0.94
Vermont	621,270	425,957	120,499	36,112	33,246	394,610	584,467	0.94
Virginia	7,769,089	15,589,091	2,716,198	379,826	2,135,407[6]	9,627,472	14,858,903	1.91
Washington	6,549,224	9,039,590	1,461,403[9]	640,619	332,301	4,986,236	7,420,559	1.13
West Virginia[6]	1,814,468	n/a	337,661	–[7]	0	1,772,720	2,110,381	1.16
Wisconsin	5,627,967	n/a	831,552	540,600	51,250	3,727,151	5,150,553	0.92
Wyoming	532,668	729,089	43,745	65,668[8]	0	729,647	839,060	1.58
Total	**304,059,724**	**245,113,602**	**69,283,968**	**24,497,252**	**25,926,285**	**269,780,521**	**389,488,026**	**1.28**

n/a = not available. [1]Estimated MSW Generation, MSW Recycled, WTE and Landfilled have been adjusted to exclude C & D and other non-MSW materials where possible. [2]All State disposal figures have been adjusted for import/export; imported waste is excluded, exported waste is included. [3]From Berenyi GAA Survey report (multiplied by 2). [4]Includes non-MSW. [5]Estimated as 75% of the total waste generated. [6]2006 data. [7]Included with recycling figure. [8]Likely to be underreported. [9]Adjusted for when States reported a metals recycling figure higher than the estimated generated metal wastes according to EPA waste characterization study. Figure is adjusted to 100% the metal generation according to this EPA characterization estimate (8.4% of 1.38 * population). [10]California recycling tonnage is an estimate of the total tonnage recycled, adjusted for industrial and agricultural sources, but not C&D. [11]Includes C&D and WTE ash. [12]Includes C&D, Agricultural and Industrial Waste. [13]Includes (some) C&D. [14]Assuming 3.3 gate cubic yards per ton. [15]2005 data.

recycled materials are sent directly to paper and other recycling plants and do not pass through MRFs for processing. Thus, states that did not report a recycling number were assigned a tonnage equal to two times the MRF tonnage in the state, as reported by the GAA survey.

2. *Overestimate of recycled tonnages*: As discussed earlier, for any recycled material where the state-reported tonnage was in excess of the EPA's average estimate of waste generation, the recycling of that material was set to 100 percent of the generated material.

3. *Data not reported*: In a few cases where tonnages were not reported (recycled, composted, waste-to-energy, landfilled) or numbers were obviously too low or too high, cross-reference was made to the 2006 data, as reported in the 2008 State of Garbage in America survey.

4. *Underreporting of recycled tonnages*: When the recycling tonnage appeared to be underreported by the state, and the GAA MRF number was not higher than that provided by the state, the data is marked as "Likely to be underreported."

National estimated MSW generation dropped between 2006 and 2008, from 413 million tons to 389.5 million tons.

NATIONAL AND REGIONAL PICTURE

Table 1 summarizes the State of Garbage survey data from 1989 through 2008. The overall results of the 2010 State of Garbage in America survey (2008 data) are: An estimated 389.5 million tons of MSW were generated, most of which (270 million tons) were sent to landfills. This represented 69

Table 3. Quantity of materials recycled per state in 2008, per category (tons/year)

State	Single Stream Commingled Recyclables	Dual Stream PMG-Containers[1]	Dual Stream Paper Fiber	Individual Materials Recycled: Paper Fiber	Iron/Steel Scrap[2]	Plastics	Glass	Aluminum	Other Metals	Tires	Others
Arizona	157,151	–	–	372,523	4,979	18,495	22,101	13,294	240,191	88,640	–
Arkansas	–	–	–	425,372	617,231	29,374	2,227	225,090	112,524	26,923	–
Colorado	12,443	–	–	366,990	1,009,572	11,912	81,049	26,939	–	40,808	–
Connecticut	–	–	–	461,735	98,068[3]	15,900	24,837	7,054	–	97	–
Delaware	37,687	–	–	91,741	23,674	2,006	4,729	49	–	8,815	–
Florida	–	–	–	2,144,375	52,075	86,279	125,836	35,400	2,592,318	46,791	–
Idaho	150,172	–	–	–	–	–	–	–	–	–	–
Illinois	9,158,265	–	–	–	–	–	–	–	–	–	–
Kansas	–	–	–	422,092	214,810	9,342	9,058	5,017	50,543	9,580	7,411[4]
Kentucky	–	–	–	231,326	1,437,226	4,617	4,688	12,295	102,751	942,361	–
Louisiana	29,800	–	–	–	–	–	–	–	–	–	–
Maine	–	–	–	245,294	87,399	15,963	43,402	2,232	96,541	28,473	–
Maryland	–	149,711	921,775	–	–	5,949	190	–	218,635	36,737	53,604[5]
Massachusetts	–	–	–	1,180,000	740,000	100,000	240,000	–	–	–	–
Minnesota	992,046	–	–	901,879	517,441	52,197	126,391	–	–	–	–
Mississippi	–	–	–	–	–	–	–	–	–	93,592	–
Missouri	6,318,111	–	–	–	–	–	–	–	–	–	–
Montana	–	–	–	47,569	111,190	803	282	1,709	54,724[6]	–	–
Nevada	–	–	–	247,197	424,726	30,737	7,565	4,580	424,726	6,975	–
New Hampshire	39,640	–	–	37,871	211,590	2,375	9,853	807	–	–	–
New Jersey	–	–	–	761,400	1,894,833	86,855	326,572	107,869	11,028[7]	39,081	–
New Mexico	30,012	–	–	104,937	87,149	2,848	471	3,979	432	1,037	–
New York	–	81,130	–[8]	1,723,468	234,778	100,929	168,693	14,116	–[9]	–	–
North Carolina	–	–	–	342,008	69,242	23,947	69,446	–[10]	–	147,055	16,800[11]
North Dakota	21,907	–	–	3,728	990	46	–	24	–	–	–
Ohio	161,018	–	–	828,359	721,502	48,501	39,833	118,818	469	119,188	–
Oregon	–	–	–	773,547	354,558	39,796	101,763	32,885	9,155[12]	19,029	–
Pennsylvania	–	–	–	557,578	19,074	56,625	57,447	47,603	1,062,090	49,730	–
Rhode Island	–	40,111	59,715	–	2,057	–	–	–	–	–	–
South Carolina	–	–	–	487,553	30,633	19,885	14,914	6,158	254,338	53,537	–
South Dakota	–	–	–	44,267	19,535[13]	2,005	–	974	4,260	–	–
Tennessee[14]	–	–	–	97,791	57,923	6,358	11,920	2,793	–	74,327	–
Texas	2,634,275	–	–	–	–	–	–	–	–	–	–
Utah	51,159	–	–	–	–	–	–	–	–	–	–
Vermont	4,722	14,556	60,391	–	34,830[15]	–	–	–	–	6,000	–
Virginia	–	–	–	872,416	718,219	29,413	26,526	–	–	67,161	–
Washington	–	–	–	1,283,907	1,067,478[16]	43,295	94,077	12,842	104,866	40,124	–
West Virginia	–	–	–	22,165	3,217	688	777	623	105	–	–
Wisconsin	–	–	–	601,860	22,616[17]	34,251	95,752	7,994	17,829[18]	51,250[19]	–
Wyoming	43,745[20]	–	–	–	–	–	–	–	–	–	–

[1]Plastic-Metal-Glass containers. [2]Can include automobiles, white goods, steel cans, etc. [3]48,070 tons from WTE metals recovered, 5,971 from steel cans. [4]Electronic waste, lead acid batteries and textiles. [5]Miscellaneous MSW recyclables. [6]White goods. [7]Vehicle batteries. [8]Included with 81,130 tons. [9]Included with iron and steel scrap. [10]Included in iron and steel scrap. [11]Other materials and special wastes. [12]Tin cans. [13]Data from a few larger scrap metal yards; does not include restricted use/C&D landfill sites. [14]Numbers represent MSW recycled, postconsumer and residential programs only. [15]Does not include large amount from salvage yards (unregulated). [16]Includes commercial/industrial ferrous metals, large appliances (white goods) and tin cans. [17]Food and beverage containers, white goods, batteries, electronics. [18]Scrap metal only. [19]50% of 102,500 estimated tons generated. [20]All materials shipped from recycling facilities combined.

Figure 11. Example survey. BioCycle state of garbage survey.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

The FAF4 also uses data from the *Advancing Sustainable Materials Management: Fact Sheet* (formerly known as *Municipal Solid Waste in the United States: Facts and Figures*) produced annually by the U.S. EPA. The Fact Sheet contains annual estimates on MSW generated and disposed at the national level. The 2014 and 2015 versions were expanded to include construction and demolition debris.

Table 1. Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling of Materials in MSW, 2015*
(in millions of tons and percent of generation of each material)

Material	Weight Generated	Weight Recycled	Weight Composted	Weight Combusted with Energy Recovery	Weight Landfilled	Recycling as Percent of Generation	Composting as Percent of Generation	Combustion as Percent of Generation	Landfilling as Percent of Generation
Paper and paperboard	68.05	45.32	-	4.45	18.28	66.6%	-	6.5%	26.9%
Glass	11.47	3.03	-	1.47	6.97	26.4%	-	12.8%	60.8%
Metals									
Steel	18.17	6.06	-	2.14	9.97	33.3%	-	11.8%	54.9%
Aluminum	3.61	0.67	-	0.50	2.44	18.5%	-	13.9%	67.6%
Other nonferrous metals†	2.22	1.50	-	0.06	0.66	67.6%	-	2.7%	29.7%
Total metals	**24.00**	**8.23**	-	**2.70**	**13.07**	**34.3%**	-	11.2%	54.5%
Plastics	34.50	3.14	-	5.35	26.01	9.1%	-	15.5%	75.4%
Rubber and leather	8.48	1.51	-	2.49	4.48	17.8%	-	29.4%	52.8%
Textiles	16.03	2.45	-	3.05	10.53	15.3%	-	19.0%	65.7%
Wood	16.30	2.66	-	2.58	11.06	16.3%	-	15.8%	67.9%
Other materials	5.16	1.43	-	0.69	3.04	27.7%	-	13.4%	58.9%
Total materials in products	**183.99**	**67.77**	-	**22.78**	**93.44**	**36.8%**	-	**12.4%**	**50.8%**
Other wastes									
Food, other‡	39.73	-	2.10	7.38	30.25	-	5.3%	18.6%	76.1%
Yard trimmings	34.72	-	21.29	2.63	10.80	-	61.3%	7.6%	31.1%
Miscellaneous inorganic wastes	3.99	-	-	0.78	3.21	-	-	19.5%	80.5%
Total other wastes	**78.44**	-	**23.39**	**10.79**	**44.26**	-	**29.8%**	**13.8%**	**56.4%**
Total municipal solid waste	**262.43**	**67.77**	**23.39**	**33.57**	**137.70**	**25.8%**	**8.9%**	**12.8%**	**52.5%**

* Includes waste from residential, commercial and institutional sources.
† Includes lead from lead-acid batteries.
‡ Includes collection of other MSW organics for composting.

Details might not add to totals due to rounding.
Negligible = Less than 5,000 tons or 0.05 percent.
A dash in the table means that data are not available.

Figure 12. Sample chart. Example of municipal solid waste data from the Advancing Sustainable Materials Management: Fact Sheet.
(Source: U.S. EPA, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management.)

Methodology

As shown in figure 13, the FAF4 first uses the State Annual Reports to produce MSW tonnages at the county and State levels.[23] For States that do not publish annual reports, the FAF4 uses data from the BioCycle survey. The FAF4 aggregates the MSW tonnages to the FAF4 zone level for States with county-level estimates of MSW production. For States that do not have county-level data, the FAF4 disaggregates MSW production to the FAF4 zone level using population shares.

[23] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 30–31, September 2016.

Lastly, the FAF4 develops the origin-destination MSW flows using information from the State Annual Reports and assumptions on local movements of MSW shipments. Greater details on the MSW estimation process are included in the remainder of this section.

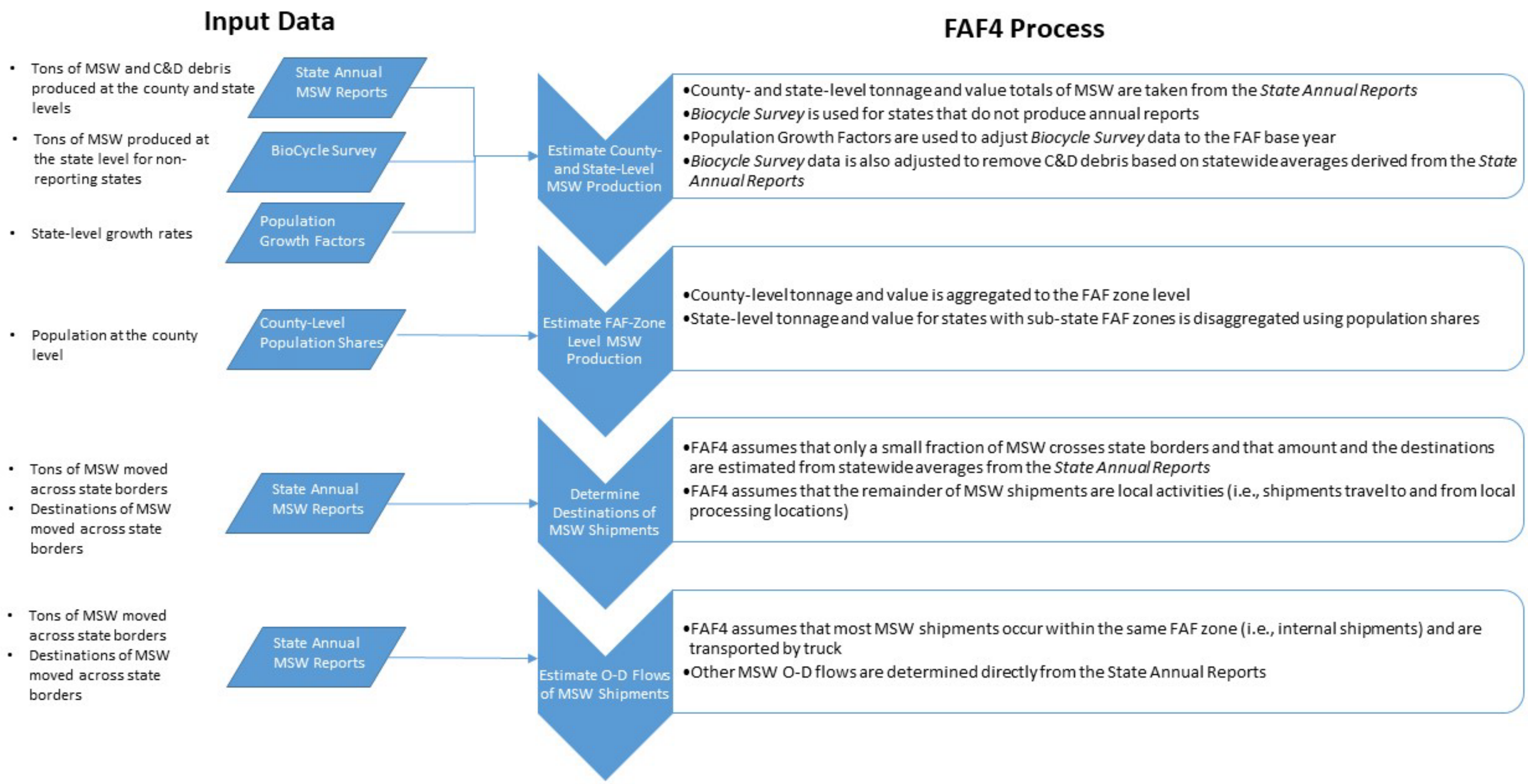

Figure 13. Flow chart. Methodology for municipal solid waste shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

Estimate County- and State-Level Municipal Solid Waste Production

The FAF4 uses the State Annual Reports to produce MSW tonnages at the county and State levels. For States that do not publish annual reports, the FAF4 uses data from the BioCycle survey. Using 2011 data, population growth factors were applied to estimate 2012 MSW production levels.

Because *BioCycle* data includes construction and demolition (C&D) debris with its MSW estimates, the FAF4 estimates the amount of C&D debris and removes this from the State-level estimates in order to avoid double-counting. Based on State-provided C&D debris data, the FAF4 estimates that on average C&D debris account for about 23 percent of *BioCycle*-reported State-level numbers. Using this factor, the FAF4 adjusts the *BioCycle*-based estimates to remove the C&D portion of MSW volumes. In total, the FAF4 estimated that 309 million tons of MSW was produced and subsequently landfilled and recycled. Furthermore, the FAF4 methodology assumes that as a commodity, MSW has no value.

Estimate Freight Analysis Framework Zone-Level Municipal Solid Waste Production

For States with county-level estimates of MSW production, those values are aggregated to the FAF4 zone level. For States that do not have county-level data, the FAF4 disaggregates MSW production to the FAF4 zone level using population shares.

Estimate Origin-Destination Flows of Municipal Solid Waste Shipments

MSW is sometimes moved between landfills across State borders. The FAF4 uses the State Annual Reports to determine the Origin-Destination (O-D) and associated tonnage of MSW being moved. Overall, the FAF4 estimates that the amount of MSW moved across State borders is relatively small—about 7 percent. The remainder of MSW movements are assumed to occur within States as internal movements.

Results

The FAF4 estimated that about 309 million tons of MSW was moved in 2012. About 23 million tons were estimated to move by truck across State borders.

Construction and Demolition Debris

Debris from construction and demolition activities is one of the largest components of the U.S. solid waste stream. C&D shipments originate from the construction of residential and nonresidential buildings, utility systems, roadways and bridges, among others. These types of shipments generally consist of bulky heavy material, such as concrete, wood, metals, glass, and salvaged building components. Though the majority of C&D debris is recycled, the statistical tracking of tonnage has been limited.

Data

The FAF4 uses similar data sources for C&D debris flows as used for MSW flows:

1. State Solid Waste Management Reports.
2. BioCycle—State of Garbage in America.
3. Construction and Demolition Recycling Association (CDRA)—*The Benefits of Construction and Demolition Materials Recycling in the United States*.[24]

State-produced annual reports on solid waste management facilities and activities also sometimes contain information on C&D debris. However, among the reporting States few actually produce this information. Because not every State provides annual reports on solid waste activities and because even fewer provide information in these reports on C&D activities, the FAF4 also uses data from the *State of Garbage in America Survey* to supplement these reports.

In 2014, the Department of Environmental Engineering at the University of Florida produced a white paper for the Construction and Demolition Recycling Association titled *The Benefits of Construction and Demolition Materials Recycling in the United States*. Using industry data from the literature and industry surveys, the white paper estimated the amount of C&D debris generated in the United States. For 2012, the analysis year used by FAF4, the white paper estimated that approximately 480 million tons of C&D debris was generated. It also estimated that over 70 percent of C&D debris was recovered and recycled in 2012. The breakdown of the components in the C&D debris stream is as follows:

- 100 million tons mixed C&D with a 35 percent recycling rate.
- 310 million tons bulk aggregate (primarily concrete) with an 85 percent recycling rate.
- 70 million tons of reclaimed asphalt pavements with a 99 percent recycling rate.

Methodology

As shown in figure 14, the FAF4 first uses the State Annual Reports to produce C&D tonnages at the county and State levels.[25] For States that do not publish annual reports, the FAF4 uses data from the BioCycle survey. The FAF4 then aggregates the C&D tonnages to the FAF4 zone level for States with county-level estimates. For States that do not have county-level data, the FAF4 disaggregates C&D production to the FAF4 zone level using population shares. Lastly, the FAF4 develops the origin-destination C&D flows using information from the State Annual Reports and assumptions on local movements of C&D shipments. Greater details on the C&D estimation process are included in the remainder of this section.

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[24] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* page 32, September 2016.

[25] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 32–33, September 2016.

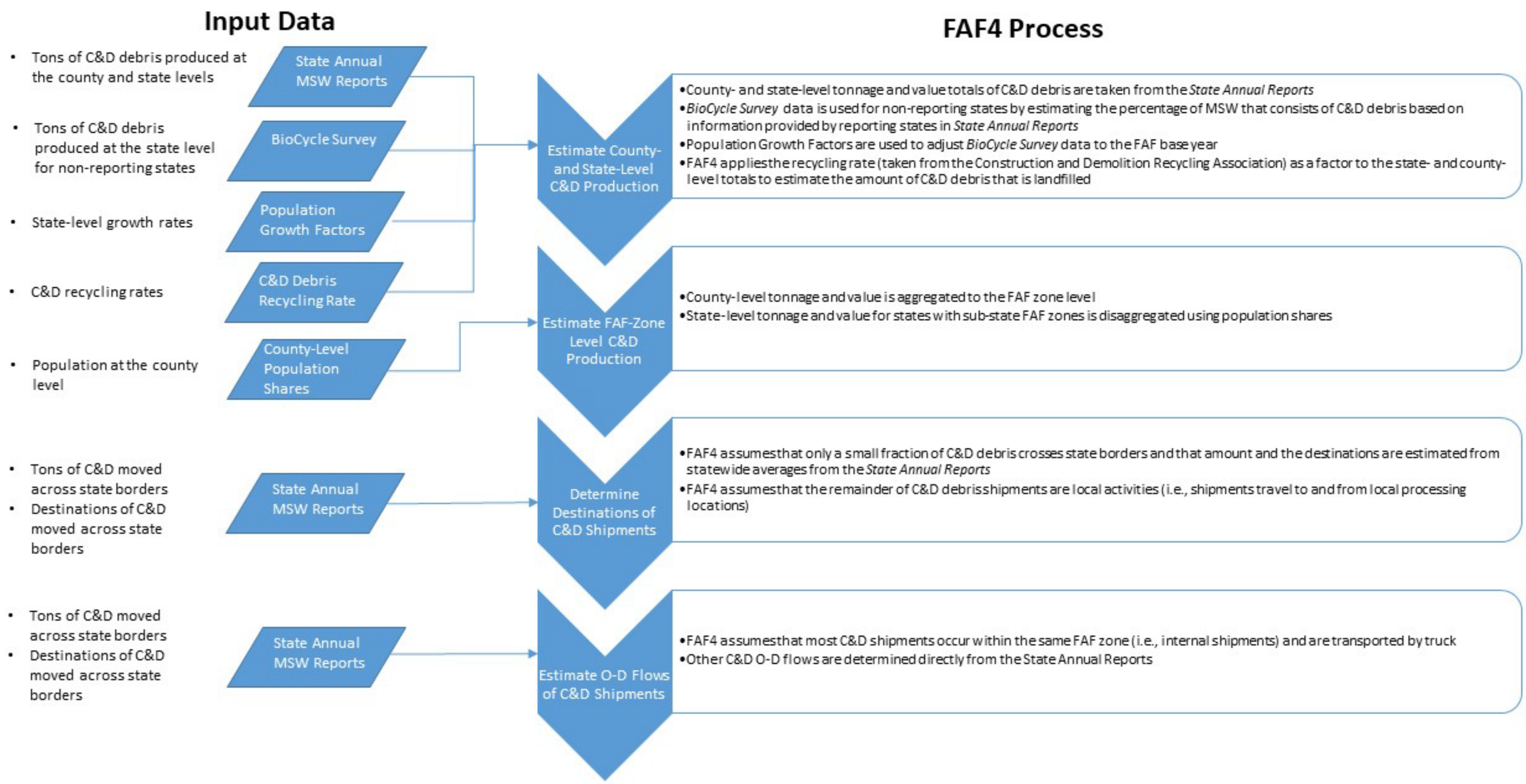

Figure 14. Flow chart. Methodology for construction and demolition shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

Estimate County- and State-Level Construction and Demolition Production

As discussed in the section on Municipal Solid Waste, from the State annual reports the FAF4 estimates that approximately 23 percent of reported MSW flows consist of C&D debris. The FAF4 then applies that factor to the BioCycle-reported State and county totals for those States that do not provide annual reports.

The CDRA white paper estimates that 70 percent of all C&D debris is recycled. The FAF4 applies this factor to individual State totals of C&D debris to estimate how much is landfilled and the amount that is recycled. It is noted that both the CDRA and BioCycle estimate State-level totals which are inconsistent with each other (e.g., the CDRA reported 480 million total tons while BioCycle reported 448 million tons in 2012). The FAF4 assumes that BioCycle estimate is more accurate.

Estimate Freight Analysis Framework Zone-Level Construction and Demolition Production

For States with county-level data on C&D debris flows, the FAF4 aggregates this information to the FAF4 zone level. Where county-level data is not available, the State-level tonnage is disaggregated to the FAF4 zone level using population shares calculated from the Census. The FAF4 uses population-based shares as opposed to economic-based shares (e.g., sales or employment data) because population-based shares are believed to better reflect the locations of demolition sites where C&D debris is actually generated.

Estimate Origin-Destination Flows of Construction and Demolition Shipments

Furthermore, the FAF4 assumes that the majority of C&D debris flows occur within FAF4 zones. State annual reports are used to estimate the amount of C&D debris flows that move across State borders as well as their origins and destinations.

Results

Consistent with the BioCycle reported total, the FAF4 estimates 448 million tons of C&D shipment activity in 2012.

RETAIL

Retail shipments are those shipments that originate or terminate at a retail establishment.

Data

There are three main sources of data for retail OOS commodity movements:

1. Census Annual Retail Trade Survey.
2. Economic Census Receipts.
3. County Business Patterns.[26]

The *Annual Retail Trade Survey*, published by the U.S. Bureau of Census in the table "U.S. Retail Trade Sales—Total and E-commerce: 2013-1998," is one of the primary data sources for estimating retail sector commodity flows. The FAF4 used the "2012 revised" sales estimates by 3-digit North American Industry Classification System (NAICS) code as national control totals for industries associated with the retail sector. The 2012 total retail trade sales were estimated at $4.306 trillion including $229 billion from e-commerce.

Economic Census Receipts are another primary source of data for retail OOS commodity flows. The Census publishes State-level data on sales receipts based on information collected in the 2012 Economic Census.[27] The Census defines receipts as the operating revenue for goods produced or distributed, or for services provided excluding taxes collected. The Economic Census is conducted every five years in years ending with "2" or "7." The 2012 Economic Census estimated a total of $4.238 trillion in receipts was generated from the retail sector (NAICS 44-45). Receipt data at the 3-digit NAICS level is released only for 26 States and for most of the retail sectors in Washington D.C. For all other States, receipt data is published at the 2-digit NAICS (44-45) level.

The final main source of information for retail OOS commodity flows is the Census' *County Business Patterns* (CBP) data series.[28] The CBP data includes information on number of establishments, total employment number, first quarter payroll, and total annual payroll for each county within the U.S. figure 15 shows examples of records extracted from the *Complete County File* of CBP 2012. As shown in figure 15, CBP data is provided at various NAICS levels. Employment payroll data from the CBP data series is used to distribute State-level estimates of retail shipments to the FAF regions.

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[26] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 35–36, September 2016.

[27] United States Census Bureau, Economic Census, https://www.census.gov/programs-surveys/economic-census.html.

[28] United States Census Bureau, County Business Patterns, https://www.census.gov/programs-surveys/cbp.html.

FIPS State Code	FIPS County Code	Industry Code (6-digit NAICS)	Total Mid-March Employees	Total First Quarter Payroll ($1,000)	Total Annual Payroll ($1,000)	Total Number of Establishments
fipstate	fipscty	naics	emp	qp1	ap	est

fipstate	fipscty	naics	empflag	emp_nf	emp	qp1_nf	qp1	ap_nf	ap	est
1	1	------		G	9908	G	65428	G	280188	817
1	1	11----		H	30	H	264	G	1102	6
1	1	113///		H	30	H	264	G	1102	6
1	1	1133//		H	30	H	264	G	1102	6
1	1	11331/		H	30	H	264	G	1102	6
1	1	113310		H	30	H	264	G	1102	6

Figure 15. Sample chart. Example of county business patterns data.
(Source: U.S. Census Bureau, https://www.census.gov/programs-surveys/cbp.html; Federal Highway Administration.)

Methodology

Though most goods purchased at retail establishments are carried home by their customers, the FAF4 assumes that some items will be delivered.[29] As shown in figure 16, the FAF4 estimates the amount of retail sales that result in deliveries based on assumed shares according to the 3-digit NAICS industry code to which the retail establishment corresponds. Next, the FAF4 distributes the total State-level shipment values involved in each NAICS sector considered for retail OOS flows. After that, commodity-specific value-to-weight ratios are applied to derive estimates for shipment weights at the State level. The State-level estimates of values and weights are distributed to each FAF4 zone within the given State. Lastly, the origin-destination flows of retail shipments are estimated assuming that all retail flows are local (i.e., within a FAF4 zone). The remainder of this section provides more information on the steps involved in the estimation of retail commodity flows and the data they utilize.

[29] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 36–37, September 2016.

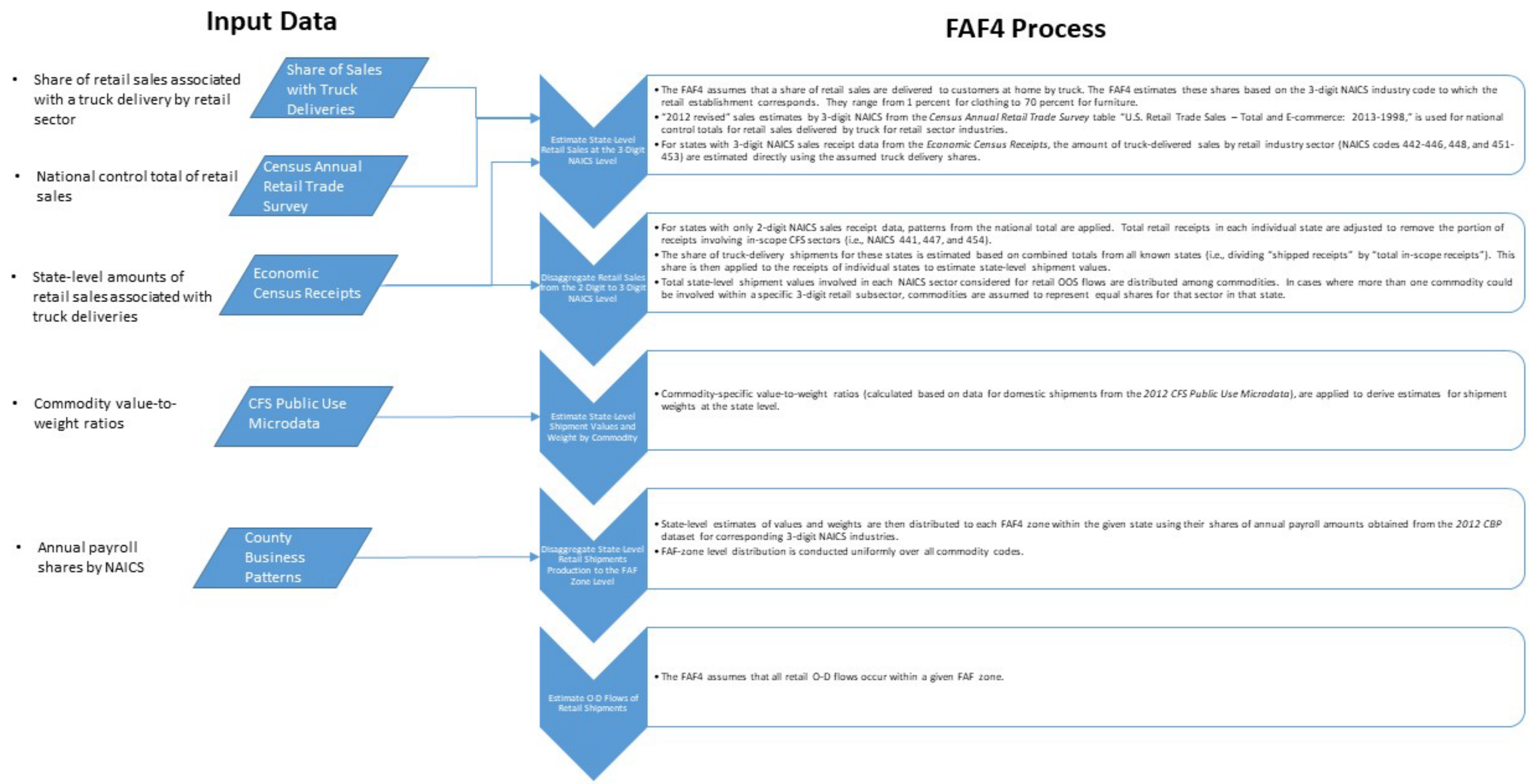

Figure 16. Flow chart. Methodology for retail shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

Estimate State-Level Retail Sales with Truck Deliveries

While it is assumed that most goods purchased at retail establishments are carried home by their customers, some items will be delivered via store-owned vans (or pick-up trucks) or delivered by mail or package carriers. Certain large items like appliances or furniture will be delivered by truck to the customer's home. Since data is lacking on actual shares of sales associated with truck deliveries, the FAF4 estimates these shares based on the 3-digit NAICS industry code to which the retail establishment corresponds. They range from 1 percent for clothing to 70 percent for furniture.

As mentioned in the discussion of data used to estimate this commodity flow, the Census reports receipts data at the 3-digit NAICS code level for 26 States and Washington, D.C. and at the 2-digit level for all others. For the States with 3-digit NAICS sales receipt data, the total retail receipts associated with industry sectors involving truck deliveries (NAICS codes 442-446, 448, and 451-453) are estimated directly using the assumed shares. For all other States, patterns from the national total are applied. Specifically, total retail receipts in each individual State are reduced by 43 percent to remove the portion of receipts involving in-scope CFS sectors (i.e., NAICS 441, 447, and 454). The share of truck-delivery shipments for these States was assumed at 8.4 percent, as calculated based on combined totals from all known States (i.e., dividing "shipped receipts" by "total in-scope receipts"). This share was then applied to the receipts of individual States to estimate State-level shipment values.

Disaggregate Total Retail Sales Shipped by States from the 2-Digit to the 3-Digit North American Industry Classification System Level

Next, the FAF4 distributes the total State-level shipment values involved in each NAICS sector considered for retail OOS flows. In cases where more than one commodity could be involved within a specific 3-digit retail subsector, commodities are assumed to represent equal shares for that sector in that State.

Estimate State-Level Shipment Values and Weight by Commodity

Once the shipment values are separated by commodity code, commodity-specific value-to-weight ratios (as calculated based on data for domestic shipments from the 2012 CFS Public Use Microdata (PUM), are applied to derive estimates for shipment weights at the State level.

Disaggregate State-Level Retail Shipment Production to the Freight Analysis Framework Zone Level

The State-level estimates of values and weights are distributed to each FAF4 zone within the given State using their shares of annual payroll amounts obtained from the 2012 CBP dataset. The calculation of shares considered only payroll information associated with the corresponding 3-digit NAICS codes for retail. This FAF-zone level distribution is conducted uniformly over all commodity codes.

Estimate Retail Shipment Origin-Destination Flows

Since most purchases at retail stores occur in regions where the customer resides, retail OOS commodity flows are assumed to be internal to the corresponding FAF4 zone. Furthermore, shipments in this OOS area are assumed to occur exclusively by truck.

Results

The FAF4 estimated that a total of $206 billion, weighing 224 million tons, of CFS OOS retail goods were transported by truck in 2012.

SERVICES

Like the retail sector, the FAF4 assumes that firms in service industry sectors generate freight shipments in the form of truck deliveries to customers.

Data

There are three main sources of data for services OOS commodity movements:

1. Service Annual Survey Data and Report.
2. Economic Census Receipts.
3. County Business Patterns.[30]

The *Service Annual Survey* published by the U.S. Bureau of Census provides national estimates of annual revenues and expenses of establishments classified in select service industries. The estimates published by the Census are developed using a probability sample of firms in the United States that have paid employees. The *2012 Service Annual Survey* data are summarized by industry classification based on the 2007 NAICS. From the *2012 Service Annual Survey*, the FAF4 uses the "Estimated E-Commerce Revenue for Employer Firms: 1998 through 2012" table and supplements that information with other tables from the same report to generate estimates for the OOS Services sector. Information from the "Estimated E-Commerce Revenue for Employer Firms: 1998 through 2012" table is used to develop control totals at the national level for industries associated with the services sector by 3- to 5-digit NAICS codes as shown in table 3.

Table 3. National total for farm-based agricultural shipments in 2012.

NAICS	Description
51912	Libraries and Archives
5322	Consumer Goods Rental
5324	Commercial and Industrial Machinery and Equipment Rental and Leasing
562	Waste Management and Remediation Services

30 Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 37–38, September 2016.

Table 3. National total for farm-based agricultural shipments in 2012 (continuation).

NAICS	Description
6216	Home Health Care Services
7111	Performing Arts Companies
7112	Spectator Sports
71211	Museums
7223	Special Food Services
8123	Dry Cleaning and Laundry Services

(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 9, 2016 (Revised April 11, 2017).)

Economic Census Receipts are another primary source of data for OOS Services commodity flows. The Census publishes State-level data on sales receipts based on information collected in the 2012 Economic Census.[31] The 2012 Economic Census estimated a total of $11.7 trillion in receipts was generated from the services sector (NAICS 51-81). Receipt data at the 3-digit NAICS level is released only for a limited number of States.

The final main source of information for OOS Services commodity flows is the Census' *County Business Patterns* (CBP) data series.[32] Employment payroll data from the CBP data series is used to distribute State-level estimates to the CFS areas.

Methodology

Similar to the process for retail shipments, the FAF4 first estimates the amount of service sales that result in a shipment by truck as shown in figure 17.[33] Next, the FAF4 distributes the total State-level shipment values involved in each NAICS sector considered for OOS Service flows among the relevant NAICS industries. The FAF4 then estimates the State-level shipment values and weights by commodity group. After that, the State-level estimates of values and weights are distributed to each FAF4 zone within the given State. Lastly, the FAF4 determines the O-D flows of the corresponding commodities.

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31 United States Census Bureau, Economic Census, https://www.census.gov/programs-surveys/economic-census.html.

32 United States Census Bureau, County Business Patterns, https://www.census.gov/programs-surveys/cbp.html.

33 Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 38–40, September 2016.

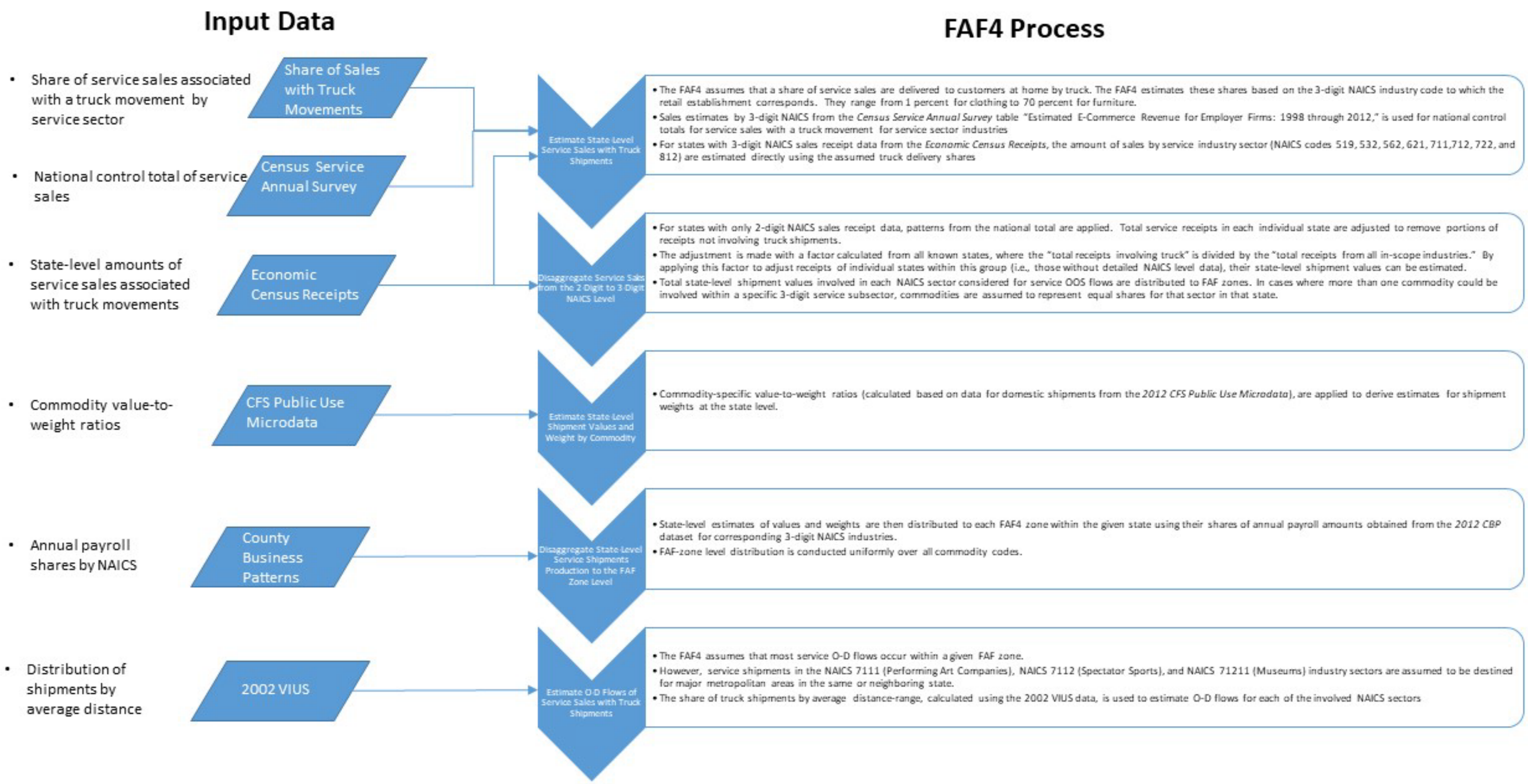


Figure 17. Flow chart. Methodology for service shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologie*s, September 2016.)

Estimate State-Level Service Sales with Truck Shipments

As mentioned in the discussion of data for service commodity flows, the Census reports receipts data at the 3-digit NAICS code level for a limited number of States and at the 2-digit level for all others. For the States with 3-digit NAICS receipt data, the total receipts associated with relevant service industry sectors (identified in table 3) are estimated directly using assumed shares of truck shipments as was done for the retail sector. Data from the table "Estimated E-Commerce Revenue for Employer Firms: 1998 through 2012" in the Census Service Annual Survey is used in this step.

Disaggregate Service Sales from the 2-Digit to the 3-Digit North American Industry Classification System Level

For all other States, patterns from the national total are applied. In addition, total service receipts in each individual State are adjusted to remove the portion of receipts involving NAICS not involving truck deliveries. This adjustment was made with a factor calculated from all known States, where the "total receipts involving truck" is divided by the "total receipts from all in-scope industries." By applying this factor to adjust receipts of individual States within this group (i.e., those without detailed NAICS level data), their State-level shipment values can be estimated.

Next, the FAF4 distributes the total State-level shipment values involved in each NAICS sector considered for OOS Service flows. In cases where more than one commodity could be involved within a specific 3-digit service subsector, commodities are assumed to represent equal shares for that sector in that State.

Estimate State-Level Shipment Values and Weight by Commodity

Once the shipment values are separated by commodity code, commodity-specific value-to-weight ratios as calculated based on data for domestic shipments from the 2012 CFS PUM, are applied to derive estimates for shipment weights at the State level.

Disaggregate State-Level Service Shipments Production to the Freight Analysis Framework Zone Level

After that, the State-level estimates of values and weights are distributed to each FAF4 zone within the given State using their shares of annual payroll amounts obtained from the 2012 CBP dataset. The calculation of shares considered only payroll information associated with the corresponding 3-digit NAICS codes for services. This FAF-zone level distribution is conducted uniformly over all commodity codes.

Estimate Origin-Destination Flows of Service Sales with Truck Shipments

Lastly, the FAF4 determines the O-D flows of the corresponding commodities. For most industries in this OOS sector, the FAF4 assumes that the services are consumed within the same zones that they are produced. Thus, many of the flows are assumed to be internal, within-zone movements.

However, industry sectors under NAICS 7111, 7112, and 71211 (Performing Art Companies, Spectator Sports, and Museums, respectively) are services requiring movements of goods to regions beyond their originating zones. The FAF4 assumes that these sectors would only be traveling to major metropolitan areas in the same or neighboring State. "Rest of State" FAF zones were not considered as destination choices. The share of truck shipments by average distance-range, calculated using the 2002 VIUS data, is used to estimate O-D flows for each of the involved NAICS sectors.

Results

The FAF4 estimated a total of $119 billion weighing 71 million tons of services-associated shipments transported by truck in 2012.

HOUSEHOLD AND BUSINESS MOVES

Trucking services provided by the household and business (HH&B) moving industry is covered under NAICS 484210, *Used Household and Office Goods Moving*. Though NAICS 4842 is covered under the 2012 CFS, as a shipper-based survey, shipments of household and business goods are not captured in the CFS. This is because the businesses in this industry sector do not typically produce freight or warehousing services.

Data

There are four primary sources of data for OOS HH&B commodity flows:

1. U.S. Census Bureau American *Community Survey County-to-County Migration Files.*
2. U.S. Bureau of Economic Analysis *Consumer Durable Goods Current-Cost Net Stock.*
3. Trade publications from the American Moving and Storage Association.
4. Commodity Flow Survey Value-to-Weight Factors.[34]

The American Community Survey (ACS) program combines consecutive yearly datasets to increase the sample size and provide reliable estimates for smaller geographic areas (e.g., county and Census tract). The 5-year ACS datasets provide estimates for county-to-county migration flow. For FAF4, the 2008–2012 release of ACS county-level migration data was used.

The data provided in the ACS county-to-county flow files include county of current residence, county of residence 1 year ago, and the number of movers between the two years. County-level total population and total number of housing units in 2012 are also obtained from the ACS. The population total and number of housing units by county are used in FAF4 to estimate average household size for each FAF region. Table 4 provides an example of the calculation.

[34] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 40–42, September 2016.

Table 4. Example of household flow calculation.

Origin Federal Information Processing Standards (FIPS)	Destination FIPS	Person Flow	Population	Households	Household Size	Household Flow
01001	01003	27	55,514	22,352	2.484 = 55,514 ÷ 22,352	11 = 27 ÷ 2.484

(Source: Federal Highway Administration.)

Consumer durable goods are generally defined as tangible products that can be stored or inventoried that have an average life of three or more years. The Bureau of Economic Analysis (BEA) publishes the *Current-Cost Net Stock* of consumer durable goods as shown in table 5 (refer to Appendix E for the query used to generate table 5). The FAF4 uses the information in this report to identify the commodities associated with moves and the value of goods being moved.

Table 5. Current-cost net stock of consumer durable goods (billions of dollars; year-end estimates).

	2010	2011	2012	2013	2014	2015	2016	2017
Consumer durable goods	4535.4	4644.7	4727.5	4779.6	4860.5	5005.8	5149.3	5294.1
Motor vehicles and parts	1287.5	1316.7	1356.9	1393.4	1444.8	1501.2	1553.6	1585.4
Autos	533.2	539.9	553.8	558.5	566.9	567.6	565.8	545.7
Light trucks	741.5	763.2	789.1	820.6	863.2	918.4	972.1	1023.6
Motor vehicle parts and accessories	12.8	13.6	14.1	14.4	14.8	15.3	15.7	16.1
Furnishings and durable household equipment	1395.8	1432.6	1457.4	1451.3	1458.3	1489.9	1520.6	1558
Furniture and furnishings[1]	855.1	876.4	891.4	889.1	903.6	929.9	955.4	981.6
Household appliances[2]	239.1	256	265	261.4	253.8	254.1	253.6	259.6
Glassware, tableware, and household utensils[3]	199.1	192.6	188.9	184	179.2	181.2	182.5	180.7
Tools and equipment for house and garden	102.4	107.6	112.1	116.8	121.8	124.7	129	136.1
Recreational goods and vehicles	1060.6	1056.1	1062.5	1075	1088.6	1123.4	1139.7	1185.1
Video, audio, photographic, and information processing equipment and media	440.9	443.9	445.2	453.1	459.8	472.3	471.3	491.6

Table 5. Current-cost net stock of consumer durable goods (billions of dollars; year-end estimates) (continuation).

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Sporting equipment, supplies, guns, and ammunition	253.3	252.4	261.8	267.4	272.9	284.2	289.8	302.2
Sports and recreational vehicles[4]	207.4	208.3	209.5	211.8	215.9	226.1	240.3	254.4
Recreational books	135.5	128.2	122.1	118.3	115.1	115.2	111.9	110.1
Musical instruments	23.5	23.3	23.8	24.3	24.8	25.6	26.3	26.8
Other durable goods	791.5	839.3	850.7	859.9	868.7	891.2	935.4	965.6
Jewelry and watches	384.7	413.2	408.6	407.7	399.8	412.8	438.8	447.3
Therapeutic appliances and equipment	154.3	159.6	164.2	168.5	174.3	179.5	186.6	195.7
Educational books	70.2	71	72.4	71.5	72.1	71.8	73	70.4
Luggage and similar personal items	135.3	143	150.1	155.1	161.2	162.5	166.2	173
Telephone and facsimile equipment	46.9	52.5	55.4	57.1	61.3	64.7	70.8	79.3

(Source: Table 8.1 Current-Cost Net Stock of Consumer Durable Goods, Fixed Assets Accounts Tables, National Data, https://www.bea.gov/iTable/iTable.cfm?ReqID=10&step=1#reqid=10&step=1&isuri=1, Bureau of Economic Analysis, accessed October 18, 2018.)

Note: [1] Consists of furniture, clocks, lamps, lighting fixtures, and other household decorative items, carpets and other floor coverings, and window coverings. [2] Consists of major household appliances and small electric household appliances, except built-in appliances, which are classified as part of residential structures. [3] Consists of dishes, flatware, and nonelectric cookware and tableware. [4] Consists of motorcycles, bicycles and accessories, and pleasure boats, aircraft, and other recreational vehicles.

While the ACS captures population migration flows in terms of changes in counties of residence, it does not capture business moves. To estimate business moves, the FAF4 uses data published by the American Moving and Storage Association (AMSA). In 2014, AMSA reported that shipments from “corporate and other Federal Government” moves accounted for about 38 percent of total household goods shipments that occurred in that year. Furthermore, AMSA reported that about 40 percent of the interstate household goods moves were carried out by the consumer themselves and not by professional movers or by use of a rental truck. The FAF4 used that percentage to adjust the ACS-based estimates to remove household moves that did not involve a truck.

The Current-Cost Net Stock of consumer durable goods obtained from the BEA provides an estimate of the value of goods being moved, not their weight. Thus, to estimate commodity weights for the HH&B goods, value-to-weight ratios calculated from the 2012 CFS PUM data for domestic shipments are applied. Since most HH&B goods moved are typically “used” items, as compared to “new” CFS goods, a depreciation rate of 30 percent was applied to discount the CFS-based value-to-weight factors for estimating the associated weights of HH&B goods.

Table 6. Example value-to-weight factor from 2012 commodity flow survey public use microdata.

SCTG	Value-to-Weight Factor ($ per pound)	Adjusted Value-to-Weight Factor ($ per pound)	Adjusted Value-to-Weight Factor (M$ per Kton)
	(A)	(B) = 1.03 * (A)	(C) = (B) * 2
35	9.830	6.881	13.762
36	3.910	2.737	5.474
39	2.890	2.023	4.046
40	3.320	2.324	4.648
43	1.840	1.288	2.576

(Source: U.S. Census Bureau, 2012 Commodity Flow Survey; Federal Highway Administration.)

Methodology

As shown in figure 18, the FAF4 methodology for estimating HH&B moves begins by estimating the total number of moves and value of moves between FAF4 zones.[35] It does so by making assumptions in assigning commodity codes to the associated durable goods and in determining the share of specific commodities being moved by truck (versus items that are transported by the consumer by nonfreight modes). Furthermore, the FAF4 assumes that intra-county moves are self-moves that did not involve moving trucks. The assignment of the commodity code is done by examining the types of consumer durable goods specified in the BEA Current-Cost Net Stock table. The process identified five SCTG codes that were involved in this OOS area: SCTG 35 (electronic equipment), SCTG 36 (motorcycles and bicycles), SCTG 39 (furniture), SCTG 40 (sporting goods), and SCTG 43 (miscellaneous). Additional details on the estimation methodology for HH&B moves are provided in the remainder of this section.

[35] Oak Ridge National Laboratory, The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies, pages 42–43, September 2016.

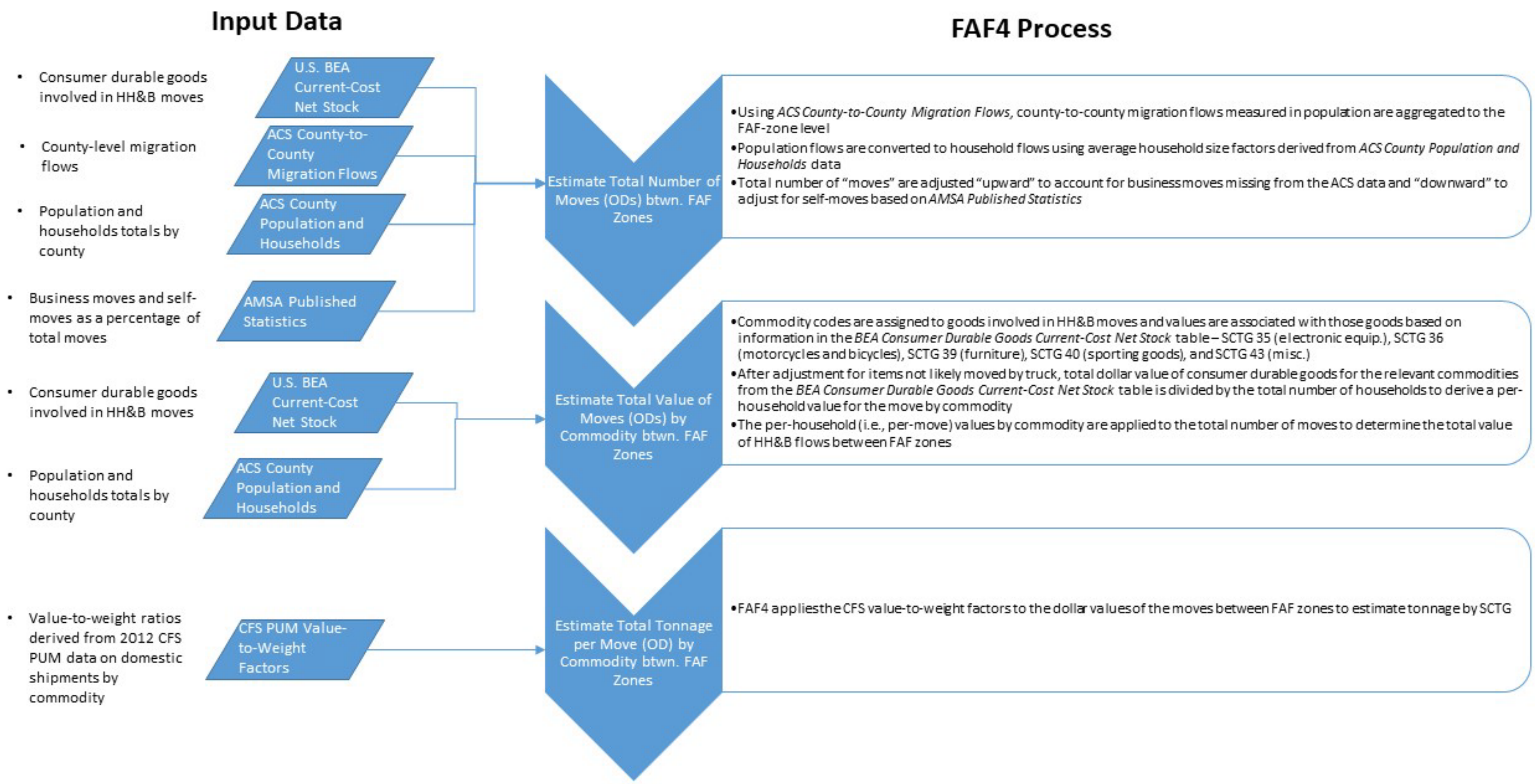


Figure 18. Flow chart. Methodology for household and business moves.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

Estimate Total Number of Moves (Origin-Destinations) between Freight Analysis Framework Zones

With these assumptions in-place, the HH&B flows estimation process begins by obtaining county-to-county migration flows from the ACS. These flows are then aggregated to the FAF-zone level. Population flows are converted to household moves by applying the average household size factors generated using Census population and housing unit data for each region as demonstrated in table 4. Households are assumed to move as one unit (as opposed to individual household members making individual moves).

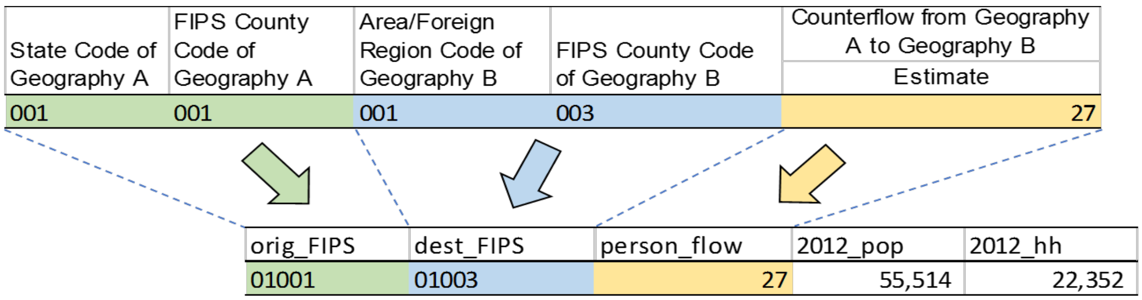


Figure 19. Sample chart. Example record of American Community Survey county migration flows. (Source: U.S. Census Bureau, American Community Survey, County-to-County Migration Flows.)

The resulting FAF-zone totals are then adjusted to account for business and self-moves based on the AMSA published statistics. The total FAF-zone moves are adjusted "upward" to include business moves, those associated with "corporate and other Federal Government" entities. It is adjusted downward to exclude unassisted consumer moves.

Estimate Total Value of Moves (Origin-Destinations) by Commodity between Freight Analysis Framework Zones

The total value per move is then estimated using data from the 2012 BEA Current-Cost Net Stock table. The national total in that table is divided by the total number of households to derive a per-household value for each of the commodity codes at the national level after adjusting to eliminate items that are unlikely to be transported in a moving truck. These national per-household values are then multiplied by the total number of mover-households from each region to obtain values of SCTGs associated with the HH&B OOS flows.

Estimate Total Tonnage per Move (Origin-Destinations) by Commodity between Freight Analysis Framework Zones

With the total value per move in hand, the FAF4 then estimates weight. This is done by applying the CFS value-to-weight factors to the dollar values of the moves to estimate shipment weights by SCTG.

Results

The FAF4 estimates that 29 million tons, valued at over $128 million, of HH&B goods were generated in 2012. More than half (about 56 percent) of the total value of these shipments are for common household items of SCTG 39 (furniture) and 35 (electronic). All HH&B are assumed to move by truck.

CRUDE PETROLEUM

The CFS does not include shipments from NAICS subsector 211 (Oil and Gas Extraction). This includes shipments from the field or marine terminals, international pipelines to refineries or long-term storage facilities which is covered under SCTG 16 Crude Petroleum Oil. The FAF4 considers both foreign and domestic crude petroleum shipments under this OOS component.

Data

There are three primary data sources that the FAF4 relies on for OOS Crude Petroleum flows:

1. U.S. Department of Energy (COE) Energy Information Administration (EIA).
2. Surface Transportation Board Carload Waybill Sample.
3. U.S. Bureau of Census County Business Patterns.[36]

Data from the Energy Information Administration

The EIA publishes several tables and databases that provide the fundamental data necessary for the estimation methodology for OOS Crude Petroleum flows. These include:

- Movement of Crude Oil by Rail.
- Company-Level Imports.
- Crude Petroleum Production.
- Exports by Destination Country.
- Exports by Petroleum Administration for Defense District (PADD).
- Movements by Tanker, Pipeline, Barge, and Rail between PADDs.
- Refinery Net Input.

The first data discussed is the *Movement of Crude by Rail* table which contains monthly and annual rail crude oil movements as well as providing crude movement regions.[37] This table provides detailed movements among PADDs as well as trade between PADDs and Canada. The FAF4 uses the data in this table as control totals for domestic, U.S. exports to Canada, and U.S. imports from Canada on crude by rail.

[36] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 46–48, September 2016.

[37] U.S. Energy Information Administration, https://www.eia.gov/petroleum/transportation/#tabs-summary-1, accessed October 18, 2018.

U.S. Movements of Crude Oil By Rail

With Data through July 2018 | **Release Date:** September 28, 2018 | **Next Release Date:** October 31, 2018

Summary - mbbl/d | Summary - mbbl | Changes by PADD

Crude oil movements by rail, July 2018
thousand barrels/day

	Receipts						
Shipments	**PADD 1**	**PADD 2**	**PADD 3**	**PADD 4**	**PADD 5**	**United States**	**Canada**
PADD 1	0	0	0	0	0	0	0
PADD 2	24	7	15	0	139	185	0
PADD 3	0	0	36	0	0	36	0
PADD 4	0	0	6	0	1	8	0
PADD 5	0	0	0	0	0	0	0
United States	24	7	57	0	141	228	0
Canada	33	30	113	0	24	199	NA
Total	57	37	169	0	164	428	NA

NA = data not available
PADD = Petroleum Administration for Defense District
Notes: Includes movements to and from Canada. A zero may indicate volume of less than 0.5 thousand barrels per day.
Source: U.S. Energy Information Administration estimates based on analysis of data from the Surface Transportation Board and others.

Figure 20. Sample chart. Movements of crude oil by rail.
(Source: U.S. Energy Information Administration,
https://www.eia.gov/petroleum/transportation/#tabs-summary-1.)

The EIA's *Company-Level Imports* database contains monthly statistics on imports of crude and petroleum products at the company level.[38] Specific information provided in this database includes importing company name and country, product name, port of entry location, and import quantity, among others. The *Crude Petroleum Production* table contains information on the annual production of crude petroleum by State and PADD.

[38] U.S. Energy Information Administration, https://www.eia.gov/petroleum/imports/companylevel/.

Crude oil imports (Top 15 countries)
(thousand barrels per day)

Country	Jul-18	Jun-18	YTD 2018	Jul-17	YTD 2017
Canada	3,562	3,985	3,721	3,289	3,440
Saudi Arabia	876	835	795	795	1,136
Mexico	661	833	649	588	607
Venezuela	505	552	491	655	697
Iraq	485	421	621	756	619
Colombia	295	231	344	332	346
Ecuador	288	173	180	160	208
Angola	178	193	107	187	105
Algeria	158	53	77	89	91
Brazil	157	248	151	329	202
Kazakhstan	125	36	28	-	-
Russia	107	119	64	67	44
Norway	88	41	48	18	24
Egypt	79	29	31	22	10
Kuwait	63	92	101	206	173

Total imports of petroleum (Top 15 countries)
(thousand barrels per day)

Country	Jul-18	Jun-18	YTD 2018	Jul-17	YTD 2017
Canada	4,157	4,545	4,328	3,824	4,035
Saudi Arabia	876	847	811	795	1,139
Mexico	681	876	709	668	702
Venezuela	625	643	575	686	748
Iraq	485	421	624	756	624
Russia	454	439	382	358	378
Colombia	319	240	375	357	373
Ecuador	288	173	182	166	209
Algeria	243	147	171	215	211
Angola	188	193	112	189	110
Brazil	179	283	187	376	222
Norway	166	85	93	64	75
United Kingdom	164	151	140	113	127
Kazakhstan	125	36	43	8	11
Korea, South	124	108	94	103	111

Note: The data in the tables above exclude oil imports into the U.S. territories.

Figure 21. Sample chart. Company level imports.
(Source: U.S. Energy Information Administration,
https://www.eia.gov/petroleum/imports/companylevel/, accessed October 18, 2018.)

Due to Federal law, U.S. companies are limited in their ability to export crude oil.[39] The *Exports by Destination* table published by the EIA detail the amount and destination of exported crude

[39] Energy Policy and Conservation Act of 1975, https://energylaw.uslegal.com/energy-policy-and-conservation/ and the Government Publishing Office PL94-163.

oil.[40] In 2012, the only exported crude petroleum from the U.S. was a total of approximately 24.7 million barrels to Canada and about 5 thousand barrels to Mexico.

Similarly, the *Exports by PADD* table provides the annual volume of crude petroleum (in thousand barrels) exported from each PADD.[41] This provides control totals for exported crude by PADD. The *Movements by Tanker, Pipeline, Barge, and Rail between PADD Districts* table contains the annual volumes of crude petroleum movements between PADDs.[42]

The EIA publishes annual data on refinery net inputs for crude petroleum by PADD and refining regions, which are at the sub-PADD level. These data represent the total crude petroleum (domestic plus foreign) input to crude petroleum distillation units and other refinery processing units.

Carload Waybill Sample

The Carload Waybill Sample, published by the Surface Transportation Board, is a stratified sample of carload waybills for all U.S. rail traffic submitted by those rail carriers terminating 4,500 or more revenue carloads annually.[43] The FAF4 uses the Carload Waybill Sample in its estimation of crude oil imports and exports by rail.

County Business Patterns

Payroll data from the County Business Patterns database in used by the FAF4 to estimate crude petroleum production shares at the county level. The CBP payroll shares for the “Crude Petroleum and Natural Gas Extraction” industry (NAICS 211111) are used to disaggregate total State-level production volume to the county level. Table 7 shows an example of CBP payroll data with the payroll shares calculated for NAICS 211111 businesses by county.

Table 7. County business patterns payroll data for Texas, 2016 (North American Industry Classification System 211111).

County	No. of Establishments	Paid Employees for Pay Period including March 12	Annual Payroll ($1,000)	Percent of Total Annual Payroll
Harris	466	17923	$3,370,662.00	45.95%
Midland	311	6999	$884,934.00	12.06%
Tarrant	135	3218	$428,786.00	5.85%
Montgomery	51	1535	$375,324.00	5.12%

40 U.S. Energy Information Administration, https://www.eia.gov/dnav/pet/pet_move_expc_a_EP00_EEX_mbbl_a.htm.

41 U.S. Energy Information Administration, https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbbl_a.htm.

42 U.S. Energy Information Administration, https://www.eia.gov/dnav/pet/pet_move_ptb_a_EPC0_TNR_mbbl_a.htm.

43 2012 Surface Transportation Board Carload Waybill Sample Reference Guide, https://www.stb.gov/stb/docs/Waybill/2012%20STB%20Waybill%20Reference%20Guide%20-%20FINAL.pdf.

Table 7. County business patterns payroll data for Texas, 2016 (NAICS 211111) (continuation).

County	No. of Establishments	Paid Employees for Pay Period including March 12	Annual Payroll ($1,000)	Percent of Total Annual Payroll
Dallas	286	2398	$325,526.00	4.44%
Smith	48	436	$54,356.00	0.74%
Gaines	8	328	$54,164.00	0.74%
Collin	41	365	$43,162.00	0.59%
Ector	38	368	$42,309.00	0.58%
Winkler	8	260	$41,149.00	0.56%
Subtotal	***1,392***	***33,830***	***$5,620,372.00***	***76.62%***
All Other Counties	**1,388**	**17,279**	**$1,715,112.00**	**23.38%**
Texas	**2,780**	**51,109**	**$7,335,484.00**	**100.00%**

(Source: U.S. Census Bureau, 2016 County Business Patterns.)

Methodology

As shown in figure 22, the FAF4 methodology for estimating crude petroleum commodity flows begins by using the U.S. EIA data on crude petroleum movements between PADDs to establish control totals for domestic movements at the PADD level.[44] Those totals are then disaggregated to the FAF-zone level. Next, the FAF4 estimates the amount of crude petroleum imported by rail and other modes. It likewise estimates the amount of crude petroleum exported by rail and by truck. The remainder of this section provides greater details on the specific steps involved in the crude petroleum estimation methodology.

[44] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 49–50, September 2016.

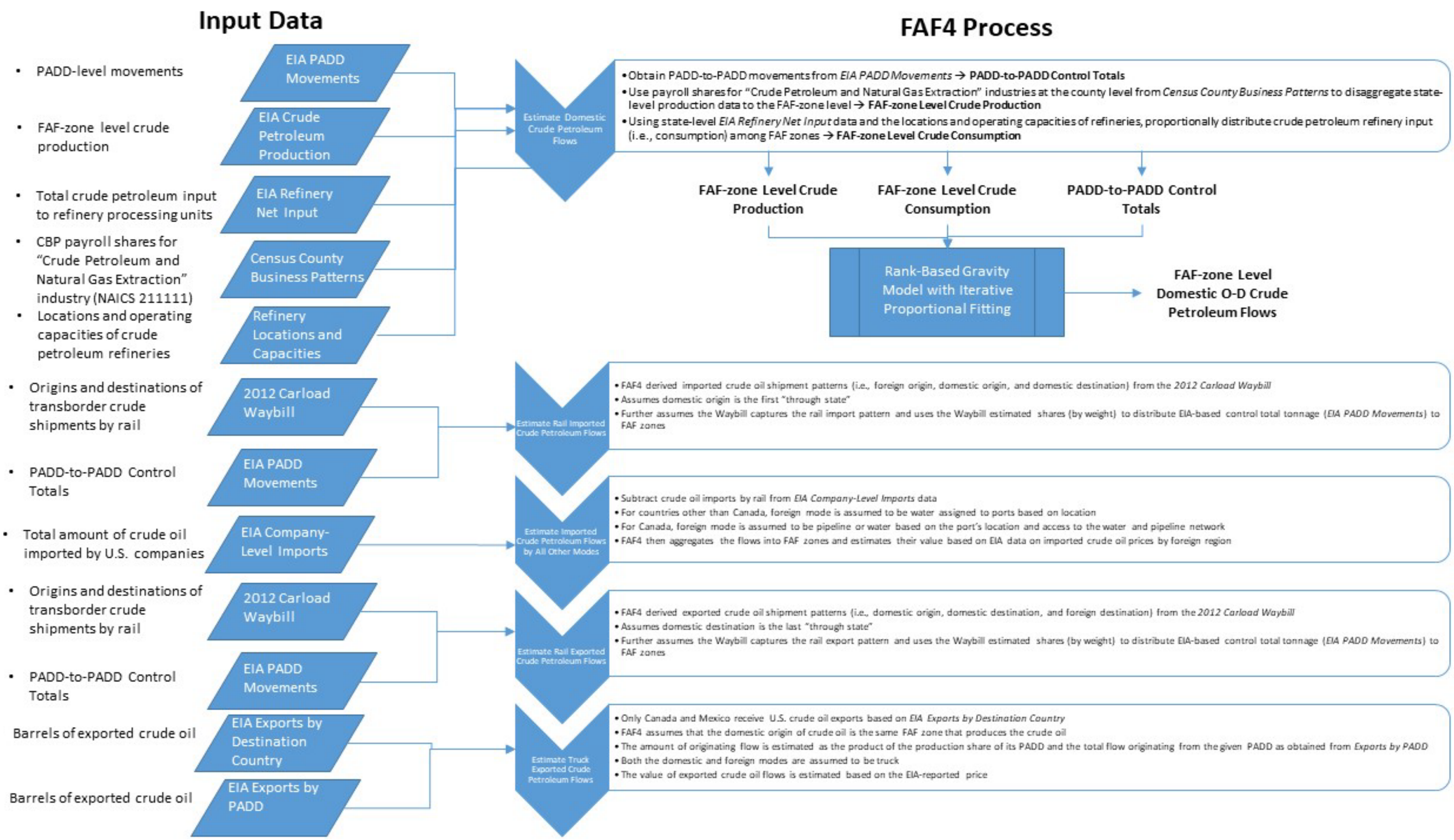


Figure 22. Flow chart. Methodology for crude petroleum shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies*, September 2016.)

Estimate Domestic Crude Petroleum Flows

The FAF4 first uses the EIA data on movements between PADDs to establish control totals for domestic movements of oil at the PADD level. Those totals are disaggregated to the FAF-zone level using the following process which is conducted separately in O-D matrices for each mode:

1. Obtain the PADD-level crude petroleum movements by mode using the *Movements by Tanker, Pipeline, Barge, and Rail between PADD Districts* table.

2. Estimate the FAF-zone level crude production so that it can be used as a production factor in a gravity model. According to the EIA crude petroleum production data, 31 States produced crude petroleum in 2012. The CBP payroll shares for the "Crude Petroleum and Natural Gas Extraction" industry (NAICS 211111) are used to disaggregate total State-level production volume to the county level, and then are aggregated to generate FAF-zone level crude petroleum production estimates.

3. Estimate refinery input (i.e., consumption) at the FAF-zone level. Refinery inputs are used as an attraction factor in the gravity model. Because the refinery input data is at the State level, FAF-zone level consumption is estimated by distributing State-level consumption among refineries proportional to their operating capacities. Refinery input is then aggregated to the FAF-zone level.

4. Execute the rank-based gravity model and apply the iterative proportional fitting (IPF) to estimate FAF regional-level movements. This process used PADD-to-PADD movements as the control totals. With each PADD-to-PADD pair, the rank-based gravity model is used to first generate an initial O-D flow matrix. It is then followed by the IPF model to obtain final estimates. These processes are repeated for all PADD-to-PADD pairs by mode.

Estimate Rail Imported Crude Petroleum Flows

The FAF4 process for determining the flow of imported crude oil by rail begins by deriving imported crude oil shipment patterns from the 2012 Waybill data. The Waybill data was used to determine foreign origin, domestic origin, and domestic destination for each imported shipment. The domestic origin of an import shipment was estimated based on the first "through state" from the Waybill. Assuming the Waybill data captured the import pattern by rail, the waybill-estimated by weights are used to distribute EIA-based control totals. The shares are calculated based on Waybill estimates for each foreign origin-PADD pair and then applied to EIA numbers to get estimated shipment weights for the FAF.

Estimate Crude Petroleum Imported Flows by All Other Modes

The FAF4 process for determining the flow of imported crude oil by all other modes begins by subtracting imports by rail from EIA-company level imports data. Then, the FAF4 assigns the remaining imports by foreign- and domestic-mode. The foreign mode was determined by reviewing the foreign country and port location for countries other than Canada (the import mode was assumed to be water) and for Canada (where the import mode can be water or pipeline depending on the port location's access to the water network and pipeline network). The domestic mode was assigned on the condition that the mode must be able to serve both the port (domestic origin) and facility location (domestic destination). After the mode assignment, the company-level imports totals are aggregated into FAF regions. Finally, the value of crude oil is calculated using EIA data on imported crude oil prices for each region.

Estimate Rail Exported Crude Petroleum Flows

The process for estimating exports by rail is similar to the process used for imports. The weight shares are calculated based on Waybill estimates for each origin PADD-foreign country pair and applied to EIA numbers to get estimated weights for the FAF. The value of crude oil is calculated based on EIA data on reported crude price.

Estimate Truck Exported Crude Petroleum Flows

The remaining crude exports are assumed to be transported via truck. Based on EIA data obtained from the *Exports by Destination* table, only Canada and Mexico received crude petroleum from the U.S. in 2012. The domestic origin of exported crude is assumed to be in the FAF region that produces crude oil. The amount of originating flow was estimated using the product of the production share of its PADD and the total flow originating from the given PADD, as obtained from the Exports by PADD table. Both domestic mode and foreign mode are assigned as truck for these shipments. The value of crude oil is then calculated based on the EIA-reported price to complete the resulting matrix.

Results

The FAF4 estimated a total of $553 billion weighing 869 million tons of crude petroleum shipments were transported by rail and truck in 2012.

NATURAL GAS

Like crude petroleum, natural gas movements associated with extraction (NAICS 211: Oil and Gas Extraction) are not included in the CFS sampling frame and is thus considered an OOS commodity.

Data

The principal data sources used to generate natural gas tonnage and value estimates include publications from the EIA and the Federal Energy Regulatory Commission (FERC). Specifically, the FAF4 utilizes:

1. U.S. Department of Energy (COE) Energy Information Administration (EIA) *2012 Natural Gas Annual*.
2. COE Energy Information Administration (EIA) *Natural Gas* data website.

3. FERC *Pipeline Economics*.[45]
4. Other databases including population data, CBP, vehicle population data, and electric generating units.

The *2012 Natural Gas Annual* produced each year by the EIA provides the baseline State-level data on interstate movements of natural gas for the FAF4. Specifically, table 12 of this report entitled "Interstate movements and movements across U.S. borders of natural gas by State" is utilized. For domestic shipments, only the interstate shares are considered. Other data are also used to disaggregate the data from the table into FAF regions:

- *Natural gas receipt/ delivery points database*—The FAF4 uses an EIA dataset on the locations of delivery points (transport to end-use customers), receipt points (used to "gather" the natural gas), and interconnection points used to transport natural gas throughout the U.S. The FAF4 treats these receipt/delivery points as natural gas shipment starting locations (production). The sum of "scheduled capacity" from all receipt/delivery points within a given FAF4 zone is used to calculate shares of production and then applied to disaggregate interstate movements from the State level to the FAF4 zone level.

- *Natural gas consumption by end use*—The EIA's *Natural Gas* website contains total "volumes delivered to consumers" by State and end-use sectors of residential, commercial, industrial, vehicle, and electric power. Other data used to disaggregate State-level natural gas consumption to the FAF4 zone level include population data, CBP, vehicle population data, and electric generating units.

Data on intrastate natural gas movements also comes from "table 13. Additions to and withdrawals from gas storage by State" in the *2012 Natural Gas Annual*. Information on dry production and withdrawals from underground storage by individual States is used to create control totals for intrastate natural gas movements. The same auxiliary data used to support the disaggregation on interstate natural gas movement data is used for intrastate movements.

[45] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 51–53, September 2016.

Table 12. Interstate movements and movements across U.S. borders of natural gas by state, 2017
(million cubic feet)

State	State or Country From/To	Receipts/ Imports From	Deliveries/ Exports To	Volume Net[a]
Alabama				
	Florida	0	1,287,210	-1,287,210
	Georgia	0	1,308,619	-1,308,619
	Gulf of Mexico	57,299	0	57,299
	Louisiana	0	17	-17
	Mississippi	3,074,116	902,510	2,171,606
	North Carolina	0	4	-4
	Tennessee	973,490	3,915	969,575
	Total	**4,104,905**	**3,502,274**	**602,631**
Arizona				
	California	47,331	845,896	-798,565
	Colorado	0	1	-1
	Mexico	3,244	121,931	-118,688
	New Mexico	1,258,174	0	1,258,174
	Utah	0	21	-21
	Total	**1,308,749**	**967,849**	**340,899**
Arkansas				
	Louisiana	388,311	391,120	-2,809
	Mississippi	216,359	855,414	-639,055
	Missouri	12,441	167,081	-154,641
	Oklahoma	378,051	0	378,051
	Texas	54,920	0	54,920
	Total	**1,050,081**	**1,413,615**	**-363,534**
California				
	Arizona	845,896	47,331	798,565
	Hawaii	0	7	-7
	Mexico	9,022	127,951	-118,929
	Nevada	528,442	43,108	485,334
	Oregon	678,247	0	678,247
	Total	**2,061,608**	**218,398**	**1,843,210**
Colorado				
	Arizona	1	0	1
	Kansas	3,154	164,794	-161,640
	Nebraska	717,432	727,049	-9,617
	New Mexico	420	298,657	-298,237
	North Dakota	31	0	31
	Oklahoma	0	103,762	-103,762
	Texas	0	2	-2
	Utah	9,788	59,406	-49,619
	Wyoming	701,599	1,074,973	-373,374
	Total	**1,432,424**	**2,428,642**	**-996,218**
Connecticut				
	Massachusetts	3,054	0	3,054
	New York	555,527	107,817	447,710
	Rhode Island	0	214,901	-214,901
	Total	**558,581**	**322,717**	**235,864**
Delaware				
	Maryland	0	5,863	-5,863
	Pennsylvania	74,701	0	74,701
	Total	**74,701**	**5,863**	**68,838**
District of Columbia				
	Maryland	20,912	0	20,912
	Virginia	8,539	0	8,539
	Total	**29,451**	**0**	**29,451**

See footnotes at end of table.

Figure 23. Sample chart. Interstate movements and movements across U.S. borders of natural gas.
(Source: U.S. Energy Information Administration, “Table 12. Interstate Movements and Movements Across U.S. Borders of Natural Gas, 2013–2017,” Natural Gas Annual: 2017, September 28, 2018.)

Table 13. Additions to and withdrawals from gas storage by state, 2017
(million cubic feet)

	Underground Storage			LNG Storage			Net Change
State	**Injections**	**Withdrawals**	**Net**	**Additions**	**Withdrawals**	**Net**	**in Storage**
Alabama	27,737	31,307	-3,570	270	432	-162	-3,733
Alaska	14,954	11,369	3,585	0	0	0	3,585
Arkansas	4,560	3,931	629	0	47	-47	582
California	164,662	170,349	-5,688	71	73	-2	-5,690
Colorado	66,841	66,532	309	0	0	0	309
Connecticut	0	0	0	277	1,265	-988	-988
Delaware	0	0	0	79	90	-11	-11
Georgia	0	0	0	5,527	1,193	4,334	4,334
Idaho	0	0	0	597	120	477	477
Illinois	235,564	243,975	-8,410	260	628	-368	-8,778
Indiana	17,312	17,243	69	608	593	15	85
Iowa	66,933	67,262	-329	1,370	1,953	-583	-912
Kansas	100,227	106,369	-6,142	0	0	0	-6,142
Kentucky	66,373	81,503	-15,130	0	0	0	-15,130
Louisiana	437,422	463,620	-26,198	0	150	-150	-26,347
Maine	0	0	0	40	41	-1	-1
Maryland	17,815	16,770	1,045	513	493	20	1,065
Massachusetts	0	0	0	5,873	8,382	-2,509	-2,509
Michigan	377,675	425,036	-47,361	0	0	0	-47,361
Minnesota	1,199	1,447	-248	1,329	1,726	-397	-646
Mississippi	209,156	230,972	-21,817	0	0	0	-21,817
Missouri	2,293	2,541	-248	0	0	0	-248
Montana	24,340	26,699	-2,360	0	0	0	-2,360
Nebraska	7,847	9,113	-1,266	252	345	-93	-1,358
Nevada	0	0	0	204	210	-6	-6
New Hampshire	0	0	0	121	124	-3	-3
New Jersey	0	0	0	4,744	4,104	640	640
New Mexico	11,146	22,897	-11,752	0	0	0	-11,752
New York	93,013	89,893	3,120	1,040	1,231	-191	2,929
North Carolina	0	0	0	5,337	5,957	-620	-620
Ohio	145,821	155,415	-9,594	0	0	0	-9,594
Oklahoma	110,685	133,690	-23,004	0	0	0	-23,004
Oregon	11,442	11,657	-214	636	391	245	31
Pennsylvania	395,884	405,622	-9,738	5,652	5,728	-76	-9,814
Rhode Island	0	0	0	413	561	-149	-149
South Carolina	0	0	0	850	1,125	-275	-275
Tennessee	223	178	45	5,058	4,291	767	811
Texas	423,589	488,933	-65,344	12	0	12	-65,332
Utah	35,248	37,842	-2,594	0	0	0	-2,594
Virginia	10,266	11,178	-912	663	738	-76	-987
Washington	28,788	29,921	-1,133	738	781	-42	-1,175
West Virginia	200,592	194,966	5,627	0	0	0	5,627
Wisconsin	0	0	0	80	96	-16	-16
Wyoming	27,027	32,249	-5,222	0	0	0	-5,222
Total	**3,336,635**	**3,590,479**	**-253,844**	**42,613**	**42,868**	**-256**	**-254,100**

Notes: Geographic coverage is the Lower 48 States and the District of Columbia. Totals may not equal sum of components due to independent rounding.
Sources: U.S. Energy Information Administration (EIA), Form EIA-191, *"Monthly Underground Gas Storage Report,"* and Form EIA-176, *"Annual Report of Natural and Supplemental Gas Supply and Disposition."*

Figure 24. Sample chart. Additions to and withdrawals from gas storage by State. (Source: U.S. Energy Information Administration, "Table 13. Additions to and withdrawals from gas storage by State, 2017," Natural Gas Annual: 2017, September 28, 2018.)

The *2012 Natural Gas Annual* is also the primary data source for estimating imported natural gas flows. Specifically, table 9 entitled *"Summary of U.S. natural gas imports by point of entry, 2008–2012"* of the report is used. The table provides volume (in millions of cubic feet) and average prices of natural gas transported by pipeline and liquefied natural gas (LNG). The report does not specify the mode of transport for imported LNG. However, the FAF4 assumes that LNG imported from countries other than Canada and Mexico arrives by ship.

In addition to imports by point of entry, the EIA also reports on natural gas imports by State. The FAF4 assumes that an imported natural gas shipment is delivered to U.S. destinations within the same State where its point of entry is located. This assumption is based on the observation that natural gas is mostly transported by pipeline domestically. Furthermore, the FAF4 assumes that the destinations of imported natural gas are processing plants. The FAF4 utilizes a database of natural gas processing plant locations to determine the destinations of natural gas shipments.

Table 9. Summary of U.S. natural gas imports by point of entry, 2013-2017
(volumes in million cubic feet, prices in dollars per thousand cubic feet)

	2013		2014		2015		2016		2017	
	Volume	Price	Volume	Price	Volume	Price	Volume	Price	Volume	Price
Pipeline (Canada)										
Eastport, ID	686,449	3.34	608,147	4.14	673,531	2.34	[R]726,750	1.87	760,648	2.10
Calais, ME	55,248	4.86	79,590	9.70	43,070	11.22	28,725	4.90	21,773	6.29
Detroit, MI	165	4.44	188	5.26	0	--	0	--	1,095	3.04
Marysville, MI	2,337	4.15	4,650	6.86	1,961	2.73	1,753	2.32	462	2.98
Port Huron, MI	0	--	0	--	0	--	779	2.33	2,755	3.15
St. Clair, MI	6,019	3.96	16,409	8.80	9,024	2.91	28,009	2.70	5,423	3.16
Noyes, MN	238,970	3.87	324,613	5.59	229,043	2.88	307,928	2.50	483,502	2.69
Warroad, MN	4,835	3.94	3,997	5.95	3,968	3.32	4,335	2.30	4,489	2.83
Babb, MT	17,235	3.13	17,421	4.05	20,708	2.34	23,733	1.70	27,325	1.77
Port of del Bonita, MT	241	3.46	200	4.39	206	2.16	152	1.55	119	1.63
Port of Morgan, MT	695,152	3.23	518,386	4.41	509,242	2.40	565,210	1.86	518,575	2.22
Sweetgrass, MT	1,160	3.67	0	--	0	--	0	--	0	--
Whitlash, MT	5,387	3.07	5,128	4.04	4,651	2.13	4,075	1.52	3,931	1.72
Pittsburg, NH	63,446	6.63	52,160	10.55	77,866	5.18	68,545	3.42	65,257	4.19
Champlain, NY	7,228	7.22	4,922	13.60	4,446	5.57	3,408	3.10	3,137	4.06
Grand Island, NY	5,758	3.92	1,413	9.80	4,940	4.23	1,760	2.54	2,676	3.12
Massena, NY	4,147	6.04	3,819	7.34	3,049	5.65	2,770	5.22	2,843	5.75
Niagara Falls, NY	1,650	4.04	2,957	5.08	2,539	3.20	3,281	2.68	2,631	3.48
Waddington, NY	214,671	5.58	187,219	8.54	175,194	5.00	197,095	3.10	138,414	4.12
Crosby, ND	0	--	29	4.16	85	1.68	1	0.97	0	--
Portal, ND	12	4.03	0	--	0	--	0	--	130	3.22
Sherwood, ND[a]	432,497	3.59	433,227	5.02	419,749	2.39	493,099	2.08	497,643	2.50
Sumas, WA	333,050	3.62	359,343	4.32	429,642	2.36	440,933	2.14	406,456	2.68
Highgate Springs, VT	9,769	5.33	10,557	6.59	12,445	5.20	14,574	3.61	13,406	3.35
Total	**2,785,427**	**3.73**	**2,634,375**	**5.22**	**2,625,359**	**2.84**	**[R]2,916,913**	**2.18**	**2,962,689**	**2.55**
Pipeline (Mexico)										
Ogilby, CA	23	3.59	0	--	0	--	169	3.39	328	3.61
Otay Mesa, CA	0	--	0	--	0	--	0	--	427	3.53
Galvan Ranch, TX	1,046	2.66	1,426	3.45	933	1.71	748	1.50	591	2.12
Total	**1,069**	**2.68**	**1,426**	**3.45**	**933**	**1.71**	**917**	**1.85**	**1,346**	**2.93**
Total Pipeline	**2,786,496**	**3.73**	**2,635,801**	**5.21**	**2,626,291**	**2.84**	**[R]2,917,831**	**2.18**	**2,964,035**	**2.55**
LNG (Canada)										
Blaine, WA	0	--	0	--	0	--	12	7.10	22	8.22
Champlain, NY	0	--	63	10.69	26	8.78	197	8.55	38	9.24
Highgate Springs, VT	555	12.72	63	9.45	400	8.70	675	8.04	1,446	8.70
Portal, ND	0	--	0	--	1	29.03	0	--	0	--
Sumas, WA	0	--	5	8.42	11	6.22	39	6.42	62	6.68
Total	**555**	**12.72**	**132**	**10.00**	**437**	**8.69**	**924**	**8.07**	**1,569**	**8.63**
LNG (Egypt)										
Elba Island, GA	0	--	0	--	0	--	0	--	0	--
Total	**0**	**--**	**0**	**--**	**0**	**--**	**0**	**--**	**0**	**--**
LNG (France)										
Everett, MA	0	--	0	--	0	--	0	--	0	--
Total	**0**	**--**	**0**	**--**	**0**	**--**	**0**	**--**	**0**	**--**
LNG (Nigeria)										
Cove Point, MD	2,590	15.74	0	--	0	--	0	--	5,992	6.52
Total	**2,590**	**15.74**	**0**	**--**	**0**	**--**	**0**	**--**	**5,992**	**6.52**

Figure 25. Sample chart. Natural gas imports by point of entry.
(Source: U.S. Energy Information Administration, "Table 9. Summary of U.S. natural gas imports by point of entry, 2013–2017," Natural Gas Annual: 2017, September 28, 2018.)

The FAF4 relies on the same data sources for export natural gas movements as import natural gas movements. The same entry points for imports serve as exit points for exports. However, unlike imports, LNG transported to Canada and Mexico can be transported by land modes while for all other countries ship is the assumed mode.

Similar to the assumptions on imports of natural gas, the FAF4 assumes that exported natural gas originates in the same State as its point of exit. Thus, receipt points where the gathering system connects to the transmission pipeline are treated as the domestic origins for export flows. The database on receipt point locations discussed earlier for imports are used to identify origin FAF4 zones for exported flows.

Table 10. Summary of U.S. natural gas exports, 2013-2017
(volumes in million cubic feet, prices in dollars per thousand cubic feet)

	2013		2014		2015		2016		2017	
	Volume	**Price**	**Volume**	**Price**	**Volume**	**Price**	**Volume**	**Price**	**Volume**	**Price**
Exports										
Pipeline										
Canada	911,007	4.17	769,258	6.10	700,647	3.15	771,094	2.60	917,087	3.12
Mexico	658,368	3.91	728,513	4.65	1,054,271	2.81	1,377,305	2.64	1,543,056	3.26
Total Pipeline Exports	**1,569,375**	**4.06**	**1,497,771**	**5.40**	**1,754,918**	**2.95**	**2,148,399**	**2.63**	**2,460,144**	**3.20**
LNG										
Exports										
By Vessel										
Argentina	0	--	0	--	0	--	16,661	4.47	16,276	4.64
Bahamas	0	--	0	--	0	--	0	--	2	10.40
Barbados	0	--	0	--	0	--	100	10.12	200	10.40
Brazil	0	--	0	--	0	--	9,196	4.39	17,648	4.15
Chile	0	--	0	--	0	--	29,405	5.30	25,746	5.43
China	0	--	0	--	0	--	17,221	4.16	103,410	4.32
Dominican Republic	0	--	0	--	0	--	2,945	5.41	8,691	4.15
Egypt	0	--	0	--	0	--	3,606	6.46	6,781	4.93
India	0	--	0	--	0	--	16,915	4.92	20,919	4.84
Italy	0	--	0	--	0	--	3,328	6.32	6,493	3.95
Japan	0	--	13,310	15.74	8,262	7.50	11,137	3.76	53,218	6.13
Jordan	0	--	0	--	0	--	9,870	5.11	36,321	4.40
Kuwait	0	--	0	--	0	--	7,068	4.40	20,213	4.38
Lithuania	0	--	0	--	0	--	0	--	6,844	3.84
Malta	0	--	0	--	0	--	0	--	867	4.70
Mexico	0	--	0	--	0	--	R27,845	R4.63	140,321	4.93
Netherlands	0	--	0	--	0	--	0	--	3,042	6.35
Pakistan	0	--	0	--	0	--	0	--	3,166	3.14
Poland	0	--	0	--	0	--	0	--	3,440	4.26
Portugal	0	--	0	--	0	--	3,700	3.58	19,523	5.65
South Korea	0	--	0	--	0	--	10,166	5.75	130,185	4.18
Spain	0	--	0	--	0	--	2,930	4.92	29,329	4.94
Taiwan	0	--	0	--	8,257	7.49	0	--	9,004	4.77
Thailand	0	--	0	--	0	--	0	--	3,113	3.14
Turkey	0	--	0	--	0	--	8,762	3.53	24,855	4.84
United Arab Emirates	0	--	0	--	0	--	3,391	4.18	13,408	3.87
United Kingdom	0	--	0	--	0	--	0	--	3,410	3.87
By Truck										
Canada	71	14.35	99	14.48	41	12.36	2	7.50	5	8.05
Mexico	128	10.84	181	12.50	195	10.44	375	4.63	691	8.74
Re-Exports										
By Vessel										
Argentina	0	--	0	--	0	--	612	4.51	0	--
Brazil	0	--	2,664	15.51	5,533	15.19	1,433	3.64	0	--
Egypt	0	--	0	--	2,947	16.71	0	--	0	--
India	0	--	0	--	0	--	547	3.98	0	--
Japan	0	--	0	--	0	--	0	--	0	--
Mexico	2,725	13.45	0	--	0	--	0	--	422	5.00
Portugal	0	--	0	--	0	--	0	--	0	--
Turkey	0	--	0	--	3,145	15.99	0	--	0	--
Total LNG Exports	**2,924**	**13.36**	**16,255**	**15.66**	**28,381**	**10.92**	**186,841**	**4.71**	**707,542**	**4.69**
CNG										
Canada	115	6.20	217	12.40	214	5.73	208	3.30	171	4.76
Total CNG Exports	**115**	**6.20**	**217**	**12.40**	**214**	**5.73**	**208**	**3.30**	**171**	**4.76**
Total Exports	**1,572,413**	**4.08**	**1,514,242**	**5.51**	**1,783,512**	**3.07**	**2,335,448**	**2.79**	**3,167,857**	**3.54**

-- Not applicable.

R Revised data.

Note: Totals may not equal sum of components due to independent rounding. Prices are in nominal dollars.

Sources: Office of Fossil Energy, U.S. Department of Energy, *Natural Gas Imports and Exports*, and EIA estimates of dry natural gas imports.

Figure 26. Sample chart. Summary of natural gas exports.
(Source: U.S. Energy Information Administration, "Table 10. Summary of U.S. natural gas exports, 2013–2017," Natural Gas Annual: 2017, September 28, 2018.)

Methodology

Figure 27 outlines the FAF4 methodology for estimating natural gas commodity flows.[46] Domestic natural gas movements are disaggregated from the State- to the FAF4-zone level through the development of a gravity model and the application of the IPF process. The gravity model is developed to estimate the initial natural gas O-D matrix. Once the initial matrix is produced, the IPF procedure is applied to generate the final natural gas flow matrix for the FAF4. The remainder of this section provides greater detail on the specific steps implemented in the methodology.

[46] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 53–56, September 2016.

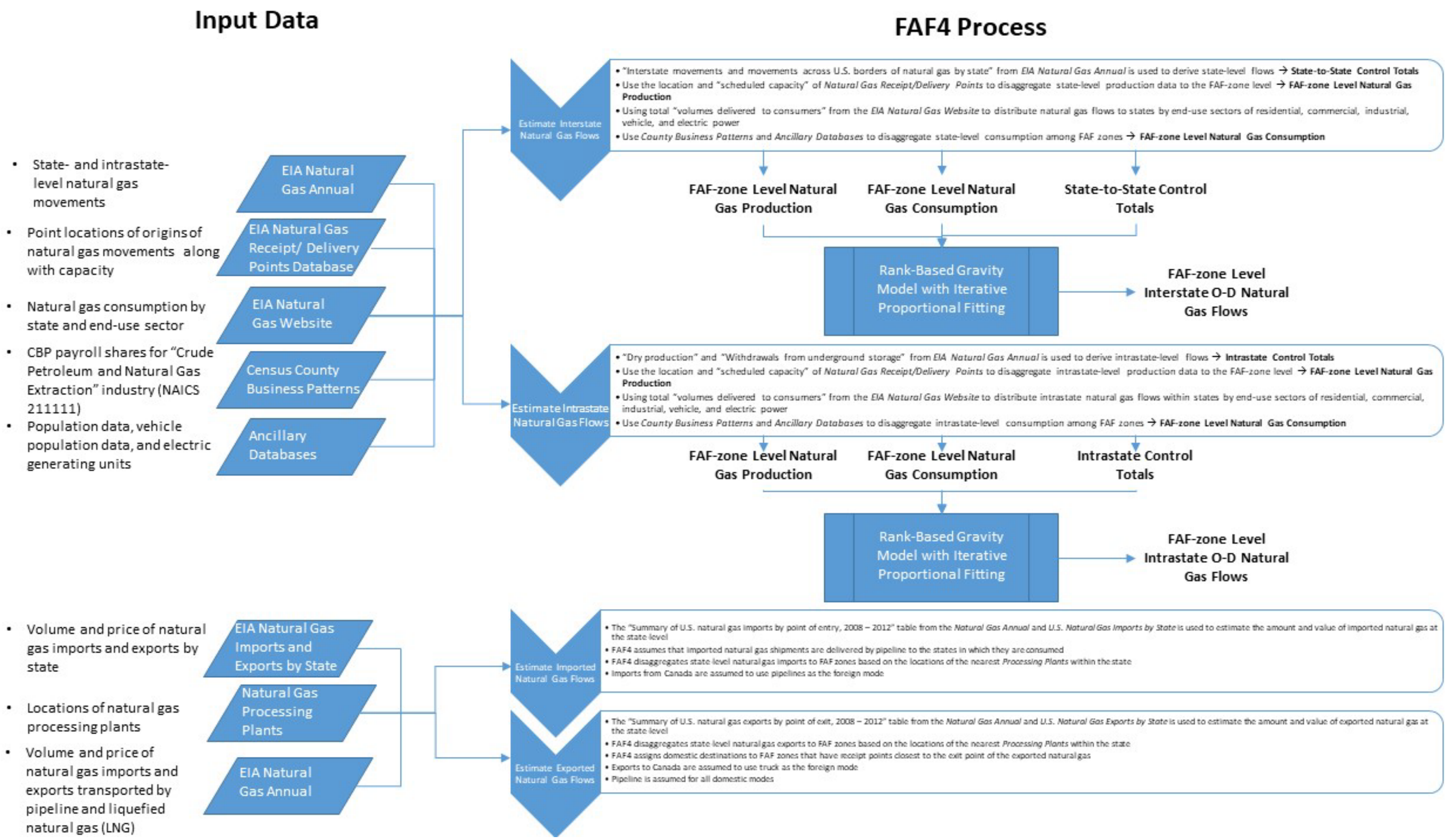


Figure 27. Flow chart. Summary of natural gas exports.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

Estimate Interstate Natural Gas Flows

Interstate movements of natural gas are estimated by first extracting the State-to-State movements (which serve as control totals) from table 12 of the *2012 Natural Gas Annual*. The production of natural gas at the FAF4-zone level is estimated by aggregating the scheduled capacity of receipt points into FAF4 zones. The attraction (i.e., consumption) of natural gas at the FAF4-zone level is first estimated by end-use consumption sector at the county level and then aggregated to the FAF4-zone level using one of the following methods which are specific to consumption type:

- Residential—Assuming that consumption is proportional to population, consumption by State is disaggregated to the county level.
- Industrial and Commercial—Assuming that consumption is correlated to payroll in each industry, CBP data is used to disaggregate consumption to the county level.
- Vehicle—Vehicle natural gas use is assumed to be proportional to the number of natural gas vehicles. The FAF4 uses natural gas vehicle population data from Polk to disaggregate vehicle consumption data to the county level.
- Electric Power—The FAF4 uses natural gas cost information for electric generating units to disaggregate natural gas consumption by electric power to the county level.

The total consumption by FAF4 zone is obtained by adding the end-use consumption sector estimates for counties within each FAF4 region. A rank matrix of distance is used in this process. The initial assignment uses a gravity model by utilizing the production and attraction estimates applied to the spatial interaction procedure. Then, with the State-level control totals from the EIA data, the assignment and iterative proportional fitting are repeated for all State-to-State records until the predetermined level of convergence is met.

Estimate Intrastate Natural Gas Flows

The FAF4 follows a similar process for estimating intrastate natural gas flows as it does for interstate movements. The primary difference is the preparation of the State-level data. Because this information is not directly available from the EIA, the FAF4 derives it using data from tables S1—S52 in the *2012 Natural Gas Annual*.

Data on “dry production” and “withdrawals from underground storage” from the *Natural Gas Annual* is used to derive intrastate-level flows that serve as control totals for the gravity model. The FAF4 then uses the location and “scheduled capacity” data on natural gas receipt/delivery points to disaggregate intrastate-level production data to the FAF-zone level. Using total “volumes delivered to consumers” from the *Natural Gas* website, the FAF4 distributes intrastate natural gas flows within States by the end-use sectors of residential, commercial, industrial, vehicle, and electric power. It then uses payroll share data for the NAICS 211111 industry sector (Crude Petroleum and Natural Gas Extraction) from the *County Business Patterns* database as well as information on population data, vehicle population data, and electric generating units from ancillary databases to disaggregate intrastate-level consumption among FAF zones.

Estimate Imported Natural Gas Flows

To estimate imported natural gas flows, the FAF4 first obtains data on the amount and value of imported natural gas at the State level from the "Summary of U.S. natural gas imports by point of entry, 2008–2012" table from the *Natural Gas Annual* as well as "U.S. Natural Gas Imports by State" from the EIA. Using Geographic Information System (GIS), the FAF4 assigns natural gas points of entry to FAF4 zones. The FAF4 then obtains data on the locations of "natural gas processing plants" and again uses GIS to assign these facilities to FAF4 zones.

The FAF4 assumes that imported natural gas shipments are delivered by pipeline to the States in which they are consumed. For each import record, a domestic FAF4 zone is assigned by identifying the FAF4 zone with a processing plant that is closest to the entry point of imported natural gas. In this manner, FAF4 disaggregates State-level natural gas imports to FAF4 zones within the State.

Natural gas imports from Canada are assumed to use truck as the foreign mode. For other countries, the foreign mode as provided in the EIA data is retained. Pipeline is the assumed domestic mode for all shipments.

Lastly, natural gas volumes are converted to tons and values of shipments are estimated.

Estimate Exported Natural Gas Flow

The FAF4 procedure for estimating exported natural gas flows follows a similar logic as the process for imported natural gas flows. The FAF4 first obtains data on the amount and value of exported natural gas at the State level from the "Summary of U.S. natural gas exports by point of exit, 2008–2012" table from the *Natural Gas Annual* as well as "U.S. Natural Gas Exports by State" from the EIA. Using GIS, the FAF4 assigns "natural gas processing plants" to FAF4 zones based on their location data. The FAF4 again uses GIS and location data to assigns natural gas points of exit to FAF4 zones.

For each export record, a domestic FAF4 zone is assigned by identifying the FAF4 zone with a processing plant that is closest to the exit point of exported natural gas. In this manner, FAF4 disaggregates State-level natural gas exports to FAF4 zones within the State.

Natural gas exports to Canada are assumed to use truck as the foreign mode. For other countries, the foreign mode as provided in the Energy Information Agency data is retained. Pipeline is the assumed domestic mode for all shipments.

Lastly, natural gas volumes are converted to tons and values of shipments are estimated.

Results

The FAF4 estimated a total of $827 billion weighing 2.42 billion tons of natural gas shipments were transported in 2012.

FOREIGN TRADE

Though there are highly developed datasets on which to base FAF4 estimates of import and export flows, there is a lack of geographic detail for inland movements. This creates significant gaps in the regional commodity flow picture.

The FAF4 defines imports as shipments originating in one of eight foreign zones and terminating inside the U.S. in one of the 132 domestic FAF4 zones. Upon entering the U.S., these imports pass through a port of entry. Imports from Canada and Mexico are generally assumed to enter at U.S. border crossings with no change in mode, unless an unreasonable domestic mode was encountered. Imports from other countries are assumed to enter via U.S. ports or airports. Similarly, the FAF4 defines exports as shipments that originate from one of the FAF4 zones, pass through a U.S. port of exit, and end in a foreign country. As in the imports, domestic modes of exported shipments terminating in Canada or Mexico are assumed the same as their foreign modes, except for unreasonable modes.

There is a significant gap in knowledge of freight movements of imports after they enter the country and of freight movements of exports before they exit the country. There is no readily available dataset on which the FAF4 can rely that covers these movements in terms of geographic details or mode of transportation. For trade with Canada and Mexico, there is some State-level origination and destination data available with which to estimate the domestic leg of their movements. However, for seaborne and airborne shipments from other nations this is not the case.

While the CFS does not capture imports, it may include movements of imported goods that change ownership once they arrive in the U.S. The FAF4 assumes that most of the imports that remain within a port region are moved internally with that region by truck.

Data

The FAF4 relies on five primary data sources. Four of those five datasets are provided by the U.S. Census Bureau with the remaining dataset provided by IHS Markit, Inc.

1. Census Special Tabulation of 2012 Foreign Trade Public Data.
2. Transborder Surface Freight Data.
3. County Business Patterns.
4. Port Import/Export Reporting Service (PIERS) Dataset.[47]

Census Foreign Trade Public Data is produced by the Foreign Trade Division of the U.S. Census Bureau. The dataset provides information on all air and vessels engaged in U.S. foreign trade only as other modes are not included. It includes cargo data by type of service, U.S. and foreign ports involved, country of origin or destination, commodity, value and tonnage, for both

[47] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 58–60, September 2016.

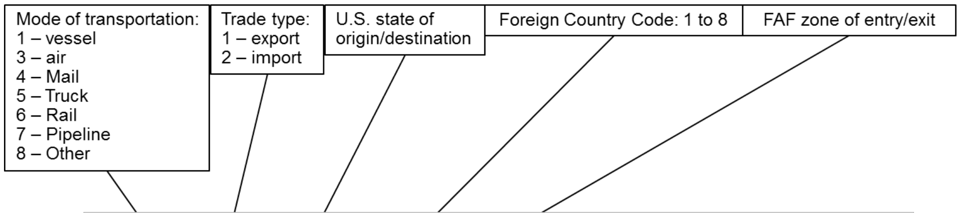
bulk and containerized cargo. For waterborne trade, the *Census Foreign Trade Public Data* covers both seaborne and Great Lakes international commodity movements. In the publicly available version of the *Census Foreign Trade Public Data*, no specific location information on U.S. origins or destinations on shipments is provided. In addition, commodity information is provided according to the Harmonized System codes (HS) classification as opposed to SCTG which the FAF4 uses to report commodity flows.

In order to overcome the limitations of the public version of the *Census Foreign Trade Public Data*, the Census made available to the Bureau of Transportation Statistics (BTS) special tabulations of the foreign trade data that provided more details on the domestic segments of foreign-trade shipments. Generally, the special tabulations provide the State-level origin/destination, commodity, and port of entry/exit at the FAF4-zone level. The data also provided commodity information using SCTG codes as opposed to Harmonized System (HS) codes as is done in the publicly available version.

In addition to the data on “direct” trade (i.e., shipments moved between the U.S. and a foreign country with no interim stops), the Census also provided data on “indirect” trade (i.e., shipments moved between the U.S. and a foreign country via Canada or Mexico). For example, a shipment that begins in Europe, moves across a portion of Canada, and terminated in Boston would be considered in this portion of the data. The FAF4 considers these shipments as origin-destination commodity mode (ODCM) flows between the U.S. and Canada or Mexico regardless of the endpoint in another foreign country. However, since the foreign trade data only records the mode of travel between Canada/Mexico and the other foreign country, the FAF4 assigns all of these shipments to the “multiple mode” for their foreign segments as opposed to water or air.

Figure 28 shows an example of the data elements contained within the Census-provided U.S.A. Trade Online special table, along with example records illustrating the information it contains. These data elements are:

- *Mode of transportation (DISAGMOT)*—these Census codes are different from what are used in FAF; thus a simple lookup table was used to recode them into FAF-defined mode codes in the FAF process.
- *Trade type (TRDTYPE)*—where Census defines exports with ‘1’ and imports with ‘2’.
- *State (USASTATE)*—contains 2-character State abbreviation for State of destination for imports, or State of origin for exports.
- *Foreign country (FAF_ZONE)*—same as FAF foreign zone, except using only the last digit (without the ‘80’ up front).
- *Port of Entry/Exit (FAF_AREA)*—this is the FAF zone where the port is located.
- *Commodity code (SCTG)*—2-digit SCTG that Census provided based on HS conversion.
- *YEAR*—data year.
- *VALUE*—shipment values in dollar ($).
- *SHIPWT*—shipment weights in kilograms.



DISAGMOT	TRDTYPE	USASTATE	FAF_ZONE	FAF_AREA	SCTG	YEAR	VALUE	SHIPWT
1	1	AK	1	020	5	2012	10309712	3679366
1	1	AK	1	020	14	2012	238744477	136192394
1	1	AK	1	020	17	2012	40459	32182
1	1	AK	1	020	25	2012	1669259	2085809
1	1	AK	1	261	25	2012	13958	4568

Figure 28. Sample chart. Example tabulation of foreign trade data.
(Source: Federal Highway Administration.)

The *Transborder Surface Freight Data* provides more detail on trade involving Canada and Mexico than is available from the *Census Foreign Trade Public Data*. It provides more information on the mode used in the border crossing—truck, rail, vessel, air, pipeline, mail, and other as opposed to only air and vessel as is provided in the *Census Foreign Trade Public Data*. Furthermore, the Transborder data specifies the domestic origin/destination of a shipment at the State level. However, like the Foreign Trade data, commodity information is provided according to the HS classification as opposed to SCTG. Also, the Transborder data provides only two of three key pieces of information for determining a complete commodity flow: (1) domestic origin or destination at the State level, (2) port of entry or exit, and (3) commodity shipped. Traditionally, the FAF has relied on modeling approaches to "fill in the gap" and develop a complete State-port-commodity matrix as the first step in estimating ODCM flows.

Like other OOS commodities, payroll information from the 2012 CBP database is used to disaggregate State-level estimates to their corresponding FAF4 regions. The CBP data was previously discussed in the section on retail commodity flows.

The PIERS dataset, available from IHS Markit, Inc., contains detailed information from the Bills of Lading records of the cargoes on- and off-loaded at U.S. ports from ships facilitating foreign trade. The PIERS database records information on the port (by custom district), tons, dollar value, commodity (6-digit HS codes), container count (if it is a container ship), foreign country of origin or destination, and the shipper. The PIERS data allows for an accurate and straightforward determination of the value and tonnage for a given port region, foreign country, and commodity. However, the Port of New York and New Jersey is contained in a single custom district whereas FAF4 zones do not extend across State lines. For simplicity, the FAF4 assumes all activities involving this custom district occur within the New Jersey FAF4 zone in which a portion of the port is contained (FAF4 zone 341).

Methodology

As shown in figure 29, the FAF4 estimates foreign trade flows by first disaggregating commodity groups from 1-digit groupings (as they are provided by the Census) to 2-digit SCTG groups. The FAF4 then imputes flows for foreign trade shipments with unknown States. For trade involving unknown States of origin or destination, the FAF4 allocates these volumes proportionally based on trade records that share the same shipment characteristics. Next, the FAF4 estimates flows with unspecified port zones. These are Census-designated special codes for ports that do not correspond to FAF4 figure 29 zones for shipments that meet certain conditions. Next, using value-to-weight ratios derived from data on imports using information on the country of origin, transportation mode, and commodity type, the FAF4 estimates missing shipment weights and values. After that, the FAF4 assigns a domestic mode and disaggregates State-level flows to the zone level. Lastly, the FAF4 makes assumptions on the domestic legs of foreign waterborne shipments as the PIERS and Census data do not explicitly define these movements. [48]

[48] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* pages 60–64, September 2016.

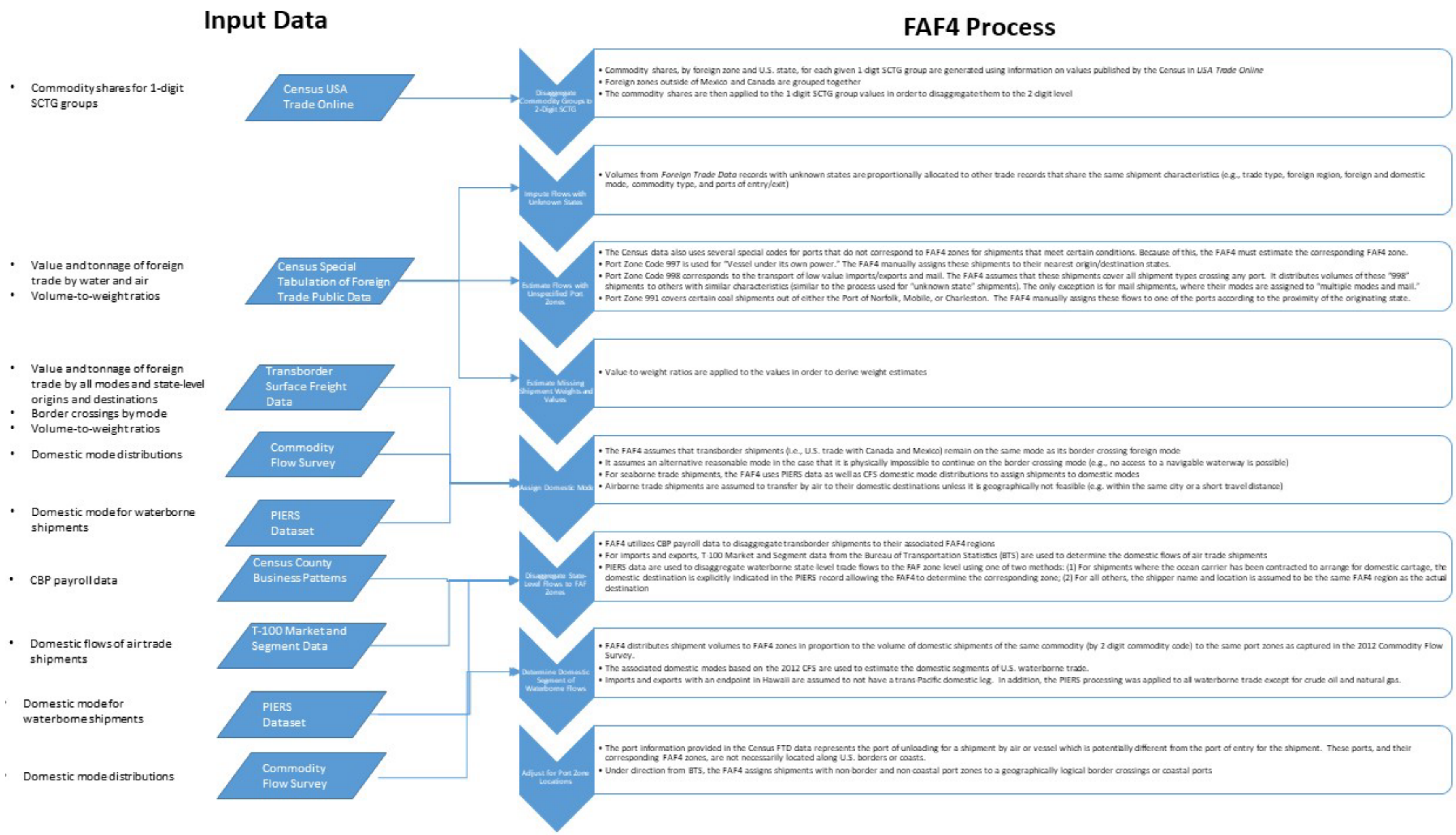


Figure 29. Flow chart. Methodology for foreign trade shipments.
(Source: Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.)

Disaggregate Commodity Groups to 2-Digit Standard Classification of Transported Goods

In order to maintain privacy, the Census aggregates commodities into less detailed 1-digit commodity groups instead of the 2-digit SCTG groups as done in the FAF4. Therefore, the first step in the process for estimating freight flows from the Foreign Trade data is to disaggregate these 1-digit SCTG groups into their associated 2-digit codes. First, commodity shares for each given SCTG group are generated using information on the value of trade for those commodities published on the Census' USA Trade Online website.[49] Those 1-digit commodity value shares (i.e., percentages) are then multiplied by their associated tonnages to develop an estimate of tonnage by 2-digit commodity code. To account for regional variations in commodities being shipped, commodity shares are summarized by both foreign zone and the U.S. State involved. However, foreign zones outside of Canada and Mexico are grouped together assuming that commodity shares are the same within these zones. In this manner, both import and export trade tonnages were estimated.

Impute Flows with Unknown States

In addition to the Census data aggregating trade shipments to the 1-digit SCTG code level, it also reports trade data with an "unknown State" as the origin or destination. For trade involving unknown States of origin or destination, the FAF4 allocates these volumes proportionally based on trade records that share the same shipment characteristics (i.e., import or export, foreign region, transportation mode to enter or exit the U.S., commodity type, and port of entry or exit).

Estimate Flows with Unspecified Port Zones

The Census data also uses several special codes for ports that do not correspond to FAF4 zones for shipments that meet certain conditions. Because of this, the FAF4 must estimate the corresponding FAF4 zone. The special port codes for which the FAF4 must estimate corresponding zones includes:

- Port Zone Code 997—This code is used for "Vessel under its own power." The FAF4 manually assigns these shipments to their nearest origin/destination States.
- Port Zone Code 998—This code corresponds to the transport of low-value imports/exports and mail. The FAF4 assumes that these shipments cover all shipment types crossing any port. It distributes volumes of these "998" shipments to others with similar characteristics (similar to the process used for "unknown State" shipments). The only exception is for mail shipments, where their modes are assigned to "multiple modes and mail."
- Port Zone 991—This code covers certain coal shipments out of either the Port of Norfolk, Mobile, or Charleston—though the Census does not specify which one. The FAF4 manually assigns these flows to one of the ports according to the proximity of the originating State. For example, Mobile is assigned all exported coal shipments originating in Alabama or Texas and for coal shipments originating in Missouri and destined for Mexico or the Rest of America.

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[49] United States Census Bureau , USA Trade Online, https://usatrade.census.gov/.

Estimate Missing Shipment Weights and Values

The Census data do not include information on weight for many export shipments. In addition, some records do not contain data on values, which must also be estimated. For these records, the FAF4 applies value-to-weight ratios derived from data on imports using information on the country of origin, transportation mode, and commodity type.

Assign Domestic Mode

In assigning a domestic mode for foreign trade shipments, the FAF4 assumes that transborder shipments (i.e., U.S. trade with Canada and Mexico) remain on the same mode as its border-crossing foreign mode. In the case that it is physically impossible to continue the border-crossing mode (e.g., no access to a navigable waterway is possible), the FAF4 assigns another reasonable mode (e.g., truck, rail, or multiple mode). For seaborne trade shipments, the FAF4 uses PIERS data as well as CFS domestic mode distributions to assign shipments to domestic modes. Airborne trade shipments are assumed to transfer by air to their domestic destinations unless it is geographically not feasible (e.g., within the same city or a short travel distance).

Disaggregate State-Level Flows to Freight Analysis Framework Zones

The FAF4 then disaggregates State-level flows to FAF4 regions. As in the processing of other OOS commodities, the FAF4 utilizes CBP payroll data to disaggregate transborder shipments to their associated FAF4 regions. For imports and exports, T-100 Market and Segment data from the BTS are used to determine the domestic flows of air trade shipments.[50] For waterborne trade, the PIERS data are utilized.

Determine Domestic Segment of Waterborne Flows

Though the PIERS data is used to disaggregate waterborne shipments to the FAF4 level, it does not explicitly provide this information. Instead, it must be inferred from one of two components of the data:

- For some shipments, the ocean carrier has been contracted to arrange for domestic cartage. For those shipments, the domestic destination is explicitly indicated in the PIERS record allowing the FAF4 to determine the corresponding zone.
- PIERS provides a shipper name and location for each record which the FAF4 assumes is in the same FAF4 region as the actual destination.

When the domestic destination of a shipment is unknown, the FAF4 distributes the volume of this shipment to FAF4 zones in proportion to the volume of domestic shipments of the same commodity (by 2-digit commodity code) to the same port zones as captured in the 2012 Commodity Flow Survey. Similarly, the associated domestic modes based on the 2012 CFS are used to estimate the domestic segments of U.S. waterborne trade. Furthermore, imports and

[50] https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/?sect=collection.

exports with an endpoint in Hawaii are assumed to not have a trans-Pacific domestic leg. In addition, the PIERS processing was applied to all waterborne trade except for crude oil and natural gas.

Adjust for Port Zone Locations

Lastly, the port information provided in the Census Foreign Trade Division data represents the port of unloading for a shipment by air or vessel which is potentially different from the port of entry for the shipment. These ports, and their corresponding FAF4 zones, are not necessarily located along U.S. borders or coasts. Under direction from the BTS, the FAF4 assigns shipments with nonborder and noncoastal port zones to a geographically logical border crossings or coastal ports.

Results

The FAF4 estimated a total of $1.4 billion weighing 3,410 billion tons of foreign trade shipments were transported in 2012.

SUMMARY

As shown in table 8, the FAF4 relies on several different types of data gathered from various sources. However, the majority of data come from other Federal agencies, namely the U.S. Census Bureau, National Agricultural Statistics Service, National Oceanic Atmospheric Administration, U.S. Forest Service, BTS, U.S. Bureau of Economic Analysis, and the U.S. Energy Information Agency. Just as the majority of data for the FAF4 comes from a relatively small number of Federal agencies, it also uses data from relatively few sources within those agencies. The primary data sources are the Commodity Flow Survey, Economic Census, Census of Agriculture, Vehicle Inventory and Use Survey, County Business Patterns, and the American Community Survey. These data sources are broadly used across OOS commodity methodologies.

The FAF4 data acquired from the various public-sector and industry sources are also updated according to different schedules. For example, the Economic Census (including the Commodity Flow Survey) and the Census of Agriculture are updated every 5 years in years ending in “2” and “7.” Data from the County Business Patterns, American Community Survey, Retail Trade Survey, Service Annual Survey, and the various tables published by the U.S. Energy Information Agency, among others, are updated annually.

Other data sources on which the FAF4 relies have less consistent updates. Most notably, the VIUS is discontinued. The *State of Garbage in America Survey* in recent years transitioned from the BioCycle Journal to Columbia University, so it is unclear if this data source will continue to exist or the frequency with which it will be updated. Though reports on municipal solid waste and C&D debris production and movements are typically produced annually by States, this is not always the case. Furthermore, not all States produce these reports requiring the FAF4 to supplement with data from the *State of Garbage in America Survey*.

Table 8. Summary of out-of-scope data sources.

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Farm-Based Shipments	Value of agricultural production at the statewide level	Census of Agriculture	National Agricultural Statistics Service, U.S. Department of Agriculture	Every 5 years
	Volume and weight of agricultural production at the statewide level	Census of Agriculture	National Agricultural Statistics Service, U.S. Department of Agriculture	Every 5 years
	Value of agricultural production at the county level	Census of Agriculture	National Agricultural Statistics Service, U.S. Department of Agriculture	Every 5 years
	Volume and weight of agricultural production at the county level	Census of Agriculture	National Agricultural Statistics Service, U.S. Department of Agriculture	Every 5 years
	Volume-to-weight conversion factors	*Agricultural Statistics*	National Agricultural Statistics Service, U.S. Department of Agriculture	Annual
	Commodity Flow Survey zones originating agricultural shipments	Commodity Flow Survey	U.S. Census Bureau; Bureau of Transportation Statistics, U.S. Department of Transportation	Every 5 years
	Distribution of average shipment distances by truck and commodity type	Vehicle Inventory and Use Survey	U.S. Census Bureau	Discontinued
Fishery Shipments	Value and tonnage of fishery landings at the statewide level	*Fisheries of the United States*	National Oceanic and Atmospheric Administration, U.S. Department of Commerce	Annual
	Value and tonnage of fishery landings at the top 104 ports	*Fisheries of the United States*	National Oceanic and Atmospheric Administration, U.S. Department of Commerce	Annual

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Logging Shipments	Board feet of timber produced at the county level	Various State reports from the Forest Inventory Data Online database	U.S. Forest Service, U.S. Department of Agriculture	Unclear
	Board feet of timber produced at the county level in the States of California and Nevada	Timber Product Output	U.S. Forest Service, U.S. Department of Agriculture	Unclear
	Board feet-to-tons conversion factors	Various State and Region Price Reports	Various universities and State agricultural agencies	Varies
Municipal Solid Waste (MSW) Shipments	Tonnage of MSW produced at the county and statewide levels for reporting States	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Tonnage of MSW moved across State borders	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Destinations of MSW moved across State borders	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Tonnage of MSW produced at the county and statewide levels for nonreporting States	*BioCycle State of Garbage in America Survey*	Earth Engineering Center, Columbia University	Bi-annual, though current status is unclear
	Population growth factors	American Community Survey	U.S. Census Bureau	Annual
	County-level population shares	American Community Survey	U.S. Census Bureau	Annual

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Construction and Demolition (C&D) Debris Shipments	Tonnage of C&D debris produced at the county and statewide levels for reporting States	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Tonnage of C&D debris moved across State borders	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Destinations of C&D debris moved across State borders	Various State Annual MSW Reports	Various State environmental agencies	Varies, typically annual
	Tonnage of C&D debris produced at the county and statewide levels for nonreporting States	*BioCycle State of Garbage in America Survey*	Earth Engineering Center, Columbia University	Bi-annual, though current status is unclear
	Population growth factors	American Community Survey	U.S. Census Bureau	Annual
	County-level population shares	American Community Survey	U.S. Census Bureau	Annual
Retail Shipments	Total retail trade sales	Annual Retail Trade Survey	U.S. Census Bureau	Annual
	Sales receipts by retail-related NAICS industry sector	Economic Census	U.S. Census Bureau	Every 5 years
	Commodity value-to-weight ratios	Commodity Flow Survey Public Use Microdata	U.S. Census Bureau; Bureau of Transportation Statistics, U.S. Department of Transportation	Every 5 years
	Payroll shares by retail-related NAICS industry sector	County Business Patterns	U.S. Census Bureau	Annual

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Service Shipments	Total service sales	Service Annual Survey	U.S. Census Bureau	Annual
	Sales receipts by service-related NAICS industry sector	Economic Census	U.S. Census Bureau	Every 5 years
	Commodity value-to-weight ratios	Commodity Flow Survey Public Use Microdata	U.S. Census Bureau; Bureau of Transportation Statistics, U.S. Department of Transportation	Every 5 years
	Payroll shares by service-related NAICS industry sector	County Business Patterns	U.S. Census Bureau	Annual
	Distribution of average shipment distances by truck and commodity type	Vehicle Inventory and Use Survey	U.S. Census Bureau	Discontinued
Household and Business Moves (HH&B)	County-level migration flows	County-to-County Migration Flows, American Community Survey	U.S. Census Bureau	Annual
	Average household size by county	American Community Survey	U.S. Census Bureau	Annual
	Percentage of total moves that are business or self-moves	American Moving and Storage Association website	American Moving and Storage Association	Unclear
	Consumer durable goods involved in HH&B moves and their per-move average value	Consumer Durable Goods Current-Cost Net Stock	U.S. Bureau of Economic Analysis	Annual
	Value-to-weight ratios	Commodity Flow Survey Public Use Microdata	U.S. Census Bureau; Bureau of Transportation Statistics, U.S. Department of Transportation	Every 5 years

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Crude Petroleum Shipments	PADD-to-PADD movements	PADD Movements	U.S. Energy Information Agency	Annual
	Locations, operating capacities, and crude petroleum input to refineries	Refinery Net Input	U.S. Energy Information Agency	Annual
	Payroll shares for NAICS 211111 (Crude Petroleum and Natural Gas Extraction) industry sector	County Business Patterns	U.S. Census Bureau	Annual
	Origins and destinations of transborder rail crude petroleum shipments	Carload Waybill Sample	Surface Transportation Board, U.S. Department of Transportation	Annual
	Total amount of crude petroleum imported by U.S. companies	Company-Level Imports	U.S. Energy Information Agency	Annual
	Locations, operating capacities, and crude petroleum input to refineries	Refinery Net Input	U.S. Energy Information Agency	Annual
	Locations, operating capacities, and crude petroleum input to refineries	Refinery Net Input	U.S. Energy Information Agency	Annual
	Payroll shares for NAICS 211111 (Crude Petroleum and Natural Gas Extraction) industry sector	County Business Patterns	U.S. Census Bureau	Annual
	Origins and destinations of transborder rail crude petroleum shipments	Carload Waybill Sample	Surface Transportation Board, U.S. Department of Transportation	Annual
	Total amount of crude petroleum imported by U.S. companies	Company-Level Imports	U.S. Energy Information Agency	Annual
	Barrels of exported crude petroleum by destination country	Exports by Destination Country	U.S. Energy Information Agency	Annual
	Barrels of exported crude petroleum by PADD	Exports by PADD	U.S. Energy Information Agency	Annual

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Natural Gas Shipments	Interstate and intrastate natural gas movements	*Natural Gas Annual*	U.S. Energy Information Agency	Annual
	Locations and operating capacities natural gas receipt/delivery points	Natural Gas Receipt/Delivery Points Database	U.S. Energy Information Agency	Unclear
	Payroll shares for NAICS 211111 (Crude Petroleum and Natural Gas Extraction) industry sector	County Business Patterns	U.S. Census Bureau	Annual
	Natural gas consumption by State and end-use sector	Natural Gas website	U.S. Energy Information Agency	Annual
	Volume and value of natural gas imports by State	*Natural Gas Annual*	U.S. Energy Information Agency	Annual
	Volume and value of natural gas exports by State	*Natural Gas Annual*	U.S. Energy Information Agency	Annual
	Locations of natural gas processing plants	Natural Gas Processing Plants Database	U.S. Energy Information Agency	Unclear
	Population data, vehicle population data, and electric generating units	Ancillary Databases	Unclear	Unclear
Foreign Trade Shipments	Commodity shares for 1-Digit SCTG groups	USA Trade Online	U.S. Census Bureau	Annual
	Value and weight of foreign trade by water and air	Special Tabulation of Foreign Trade Public Data	U.S. Census Bureau	As requested
	Volume-to-weight conversion factors	Special Tabulation of Foreign Trade Public Data	U.S. Census Bureau	As requested
	Value and weight of foreign trade by all modes and State-level origins and destinations	Transborder Surface Freight Data	Bureau of Transportation Statistics, U.S. Department of Transportation	Annual

Table 8. Summary of out-of-scope data sources (continuation).

OOS Commodity	Data Type	Data Source	Responsible Entity	Update Frequency
Foreign Trade Shipments (continuation)	Border crossings by mode	Transborder Surface Freight Data	Bureau of Transportation Statistics, U.S. Department of Transportation	Annual
	Volume-to-weight conversion factors	Transborder Surface Freight Data	Bureau of Transportation Statistics, U.S. Department of Transportation	Annual
	Domestic mode distributions of freight shipments	Commodity Flow Survey	U.S. Census Bureau	Every 5 years
	Domestic mode for waterborne foreign shipments	PIERS: Bill of Lading Data for U.S. Imports and Exports	IHS Markit, Inc.	Annual
	Payroll shares by NAICS industry sector	County Business Patterns	U.S. Census Bureau	Annual
	Domestic destinations for foreign airborne shipments	T-100 Market and Segment Data	Bureau of Transportation Statistics, U.S. Department of Transportation	Annual

(Source: Federal Highway Administration.)

In general, the FAF4 uses the results of the Commodity Flow Survey (CFS) to develop an origin-destination-commodity-mode (ODCM) matrix of freight shipments. Because the CFS suppresses some shipment information either due to shipper privacy concerns or statistical reliability, the FAF4 estimates a log-linear effects model using iterative proportional fitting procedure to develop a complete ODCM matrix. The FAF4 deploys a similar methodology for estimating O-D flows for OOS commodities with data sources that do not provide complete information on where those commodities are ultimately consumed, namely crude petroleum and natural gas shipments. For crude petroleum and natural gas shipments, the FAF4 estimates gravity models via iterative proportional fitting in order to distribute productions of crude petroleum and natural gas to destination FAF4 zones.

From the assessment of the data sources and methodologies supporting the estimation of the OOS commodity flows, a number of limitations/opportunities for improvement are identified. These are summarized in table 9. The identified limitations/potential opportunities for improvement are in the areas of improved data and methodological changes.

Table 10 contains estimates of the total weight and value of out-of-scope commodity flows. While some of these estimates were provided directly by FAF4 documentation,[51] others were estimated from the FAF4 Data Tabulation Tool. The purpose of the analysis is to determine which commodities comprise the largest shares of the 30 percent of total FAF4 commodity flows that constitute out-of-scope shipments. The results of the analysis indicate that Foreign Trade, Crude Petroleum, Natural Gas, and Farm-Based Shipments are the largest out-of-scope commodity groups by total tonnage and value. These commodities are estimated to comprise over 81 percent of OOS commodity flows by tonnage and nearly 94 percent by value. Therefore, improvements to the data and methodologies supporting these commodities would potentially result in relatively large improvements to the FAF4 overall.

Table 9. Summary of out-of-scope commodity methodologies.

OOS Commodity	Models Utilized	Limitations/Opportunities for Improvement
Farm-Based Shipments	None	This process relies on the VIUS, which is discontinued, and the CFS to distribute farm-based productions to FAF zones. For each farm-based commodity, the FAF4 assumes that the destination regions for a commodity are those that originate a product derived from that farm-based commodity. The FAF4 further assumes that the distance farm-based commodities are shipped follow the distance thresholds found in the VIUS field “areas of operation.” The midpoint of the VIUS distance ranges are assumed in the analysis. Potentially, the “areas of operation” on which the distance thresholds have changed over time to reflect changes in the industry. For instance, the FAF4 assumes that farm-based shipments do not travel distances greater than 501 miles. Also, the midpoint of the distance ranges may not reflect actual distribution patterns. For States with multiple FAF zones or near State borders, it could result in some flows being improperly attributed to the incorrect zone.
Fishery Shipments	None	The OOS estimation process assumes that O-D flows are local (i.e., within a FAF zone), which may under- or over-estimate flows associated with ports located on State borders.
Logging Shipments	None	The OOS estimation process assumes that O-D flows are local (i.e., within a FAF zone), which may under- or over-estimate flows. Examples include timber producing regions in South Georgia-north Florida, southeast Texas and the western portions of Louisiana and Arkansas, and the Upper Peninsula of Michigan and Wisconsin.

[51] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.

Table 9. Summary of out-of-scope commodity methodologies (continuation).

OOS Commodity	Models Utilized	Limitations/Opportunities for Improvement
Municipal Solid Waste (MSW) Shipments	None	Not all States produce MSW Reports, which forces the FAF4 to use an alternative data source—namely the *State of Garbage in America* Survey. However, the current status of that survey and its continuation is unclear. The FAF4 documentation is unclear on how value is assigned to MSW shipments.
Construction and Demolition (C&D) Debris Shipments	None	Not all States produce MSW Reports, which forces the FAF4 to use an alternative data source—namely the *State of Garbage in America* Survey. However, the current status of that survey and its continuation is unclear. Relies on third-party data on C&D recycling rates from the Construction and Demolition Recycling Association. The frequency and consistency of updates to this data source is unclear. The FAF4 documentation is unclear on how value is assigned to C&D debris shipments.
Retail Shipments	None	The OOS estimation process relies on a set of assumed shares (i.e., proportions) of retail sales involving a truck shipment. From the documentation, it is unclear how the estimate of these shares is developed. The estimation process also requires that 2-digit NAICS data on retail sales be disaggregated to the 3-digit level. Currently, in cases where more than one commodity could be involved within a specific 3-digit retail subsector, commodities are assumed to represent equal shares for that sector in that State. Potentially, this disaggregation process could be altered to reflect the actual proportion of related industries for a State.
Service Shipments	None	The OOS estimation process relies on a set of assumed shares (i.e., proportions) of retail sales involving a truck shipment. From the documentation, it is unclear how the estimate of these shares is developed. The estimation process also requires that 2-digit NAICS data on retail sales be disaggregated to the 3-digit level. Currently, in cases where more than one commodity could be involved within a specific 3-digit retail subsector, commodities are assumed to represent equal shares for that sector in that State. Potentially, this disaggregation process could be altered to reflect the actual proportion of related industries for a State. For the NAICS 7111, 7112, and 71211 subsectors, shipments are assumed to be destined for nearby major metropolitan areas only. A potential improvement is to investigate the validity of this assumption and make revisions as necessary to improve the accuracy of this OOS estimation process.

Table 9. Summary of out-of-scope commodity methodologies (continuation).

OOS Commodity	Models Utilized	Limitations/Opportunities for Improvement
Household and Business Moves (HH&B)	None	This OOS estimation process assumes that all intra-county moves are self-moves that do not involve trucks. A potential improvement is to investigate the validity of this assumption and make revisions as necessary. This process also estimates an average value per household move at the national level and applies it to all household moves. A potential improvement is to investigate if there are regional variations in the average value of a household move. If so, then regional-level averages could be developed and applied for a more accurate estimate. The average value per household move is adjusted to remove items not likely to be transported by trucks, but the documentation is unclear on what these items are. A potential improvement is to verify the actual commodities included in this group and further investigate if other commodities could be included or if included commodities could be removed.
Crude Petroleum Shipments	Gravity model	Refinery capacity is a proxy for actual county-level data on consumption, which requires that production-to-consumption flows be estimated via a gravity model.
Natural Gas Shipments	Gravity model	Utilizes several ancillary data sources that are not well documented, including the locations and capacities of natural gas receipt/delivery points, vehicle population data, and electric generating units. Assumes LNG shipments from Canada are by pipeline or water, though there may be some truck LNG movements.
Foreign Trade Shipments	None	Generally, foreign trade flow data on the domestic leg of shipments is lacking, requiring numerous assumptions and the use of professional judgment.

(Source: Federal Highway Administration.)

Table 10. Total tonnage and value of out-of-scope shipments.

Commodity	Weight (thousand ton)	Percent of Total	Value (million $)	Percent of Total
Farm-Based Shipments	959,422	13.7%	$385,378	7.0%
Fisheries	4,800	0.1%	$5,100	0.1%
Logging	239,000	3.4%	$6,400	0.1%
Municipal Solid Waste [1]	309,000	4.4%	$0	0.0%
Construction and Demolition Debris	448,000	6.4%	$0	0.0%
Retail	224,000	3.2%	$206,000	3.7%
Services	71,000	1.0%	$119,000	2.2%
Household and Business Moves	29,000	0.4%	$128	0.002%

Table 10. Total tonnage and value of out-of-scope shipments (continuation).

Commodity	Weight (thousand ton)	Percent of Total	Value (million $)	Percent of Total
Crude Petroleum [2]	868,907	12.4%	$553,139	10.0%
Natural Gas [3]	2,419,972	34.6%	$827,060	15.0%
Foreign Trade [4]	1,423,956	20.4%	$3,410,698	61.9%
Total	6,997,057	100.0%	$5,512,903	100.0%

(Source: Oak Ridge National Laboratory, "Table 5-1. National Total for Farm-Based Agricultural Shipments in 2012," *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies;* FAF4 Data Tabulation Tool.)

Note: [1] The FAF4 documentation indicates that municipal solid waste and construction and demolition debris have no value associated with those flows. [2] From the FAF4 Data Tabulation Tool, total flows of Crude Petroleum (SCTG 16) accounted for nearly 869 million tons valued at over $553 billion. [3] From the FAF4 Data Tabulation Tool, total flows of Coal-n.e.c. (SCTG 19), which includes natural gas, accounted for nearly 2.42 billion tons valued at over $827 billion. However, this estimate includes petroleum products other than natural gas (e.g., propane, butane, petroleum asphalt, etc.). [4] From the FAF4 Data Tabulation, the total tonnage and value of all imports and exports was calculated. Foreign trade tonnage and value for Crude Petroleum (SCTG 16) and Coal-n.e.c. (SCTG 19) were omitted from this estimate since the FAF4 OOS methodology estimates those values separately for those commodities.

CHAPTER 3. REVIEW OF ALTERNATIVE COMMODITY FLOW SURVEY OUT-OF-SCOPE METHODS

Chapter 3 reviews efforts made by academic institutions, State departments of transportation (DOT), metropolitan planning organizations (MPO), and other Federal agencies to model the movements of out-of-scope commodities. Since the development of the Freight Analysis Framework (FAF), there have been numerous efforts across agencies and academic institutions to capture these flows. In many cases, these efforts were motivated by the economic importance of a particular commodity to local industries or the impact of its transport on local transportation operations.

Similar to chapter 2, chapter 3 is organized by out-of-scope (OOS) commodity. For each OOS commodity, relevant case studies related to modeling OOS commodity movements and flows are summarized. These summaries provide background information for the OOS commodity initiative (such as the motivation for the study, its geographic scale, etc.), discuss its data sources, and describe the methodological approach.

In order to identify case studies, the project team performed searches in scholarly databases such as Google Scholar, the Transportation Research Board's Transportation Research International Documentation database, and the Bureau of Transportation Statistic's National Transportation Library. Search terms included the names of the out-of-scope commodities (e.g., 'Logging' and 'Municipal Solid Waste'). The search also used the terms 'commodity flows', 'commodity flow database', 'out-of-scope', and variations of these terms.

While the search focused on research efforts whose primary goal was the development of a commodity flow database for the out-of-scope commodities, it also included those efforts that attempted to capture the movements of out-of-scope commodities for other purposes. Though these studies did not explicitly attempt to model commodity flows, the insights gained from the modeling of vehicle movements is potentially useful to the Freight Analysis Framework (FAF) 4. This is especially true considering the Freight Analysis Framework Version 4 (FAF4)'s reliance on the discontinued Vehicle Inventory and Use Survey (VIUS) for similar information.

FARM-BASED SHIPMENTS

Developing a Potato Commodity Flow Database

Background

National Cooperative Freight Research Program (NCFRP) Report 26: Guidebook for Developing Subnational Commodity Flow Data provided guidance for developing subnational commodity flow databases to meet transportation planning needs at the regional level.[52] Among other items, the Guidebook describes methods to develop primary commodity flow data using local data

[52] Transportation Research Board, NCFRP Report 26: Guidebook for Developing Subnational Commodity Flow Data, National Cooperative Freight Research Program, 2013.

collection along with how to augment local data collection efforts with information from published data sets and commodity flow disaggregation techniques. In developing a sub-national commodity flow database, the Guidebook argues that it is important to understand the supply chain associated with a commodity, including facilities involved in the processing of a commodity and the modes used in transporting a commodity across the supply chain. Though the Guidebook proposes a supply chain-based approach as a method to developing a subnational commodity flow database, it is applicable to OOS commodity flows at the national level as well.

One example in the Guidebook, described in detail in this section of the report, is the development of a commodity flow database for potatoes in Washington State. In this example, the Guidebook's insistence on a supply chain-approach to modeling commodity flows is evident.

Data Sources

With guidance from the Washington State Potato Commission, the NCFRP Report 26 team assembled data from several sources including:

- United States Department of Agriculture (USDA) field production data from the USDA Economic Research Service. These data include national and State data on potato acreage, production, value, and use.
- Export data (Origin of Movement) from the U.S. Census Bureau Foreign Trade Statistics.
- Origin-destination truck surveys from Washington State University.
- Agricultural surveys from the Washington State Department of Agriculture that contain data on acreage and production.
- Washington State Potato Commission Survey on potato commodity destinations and routes.
- Washington State Potato Commission member activity data on shipments of potatoes by variety, product, and destination.
- U.S. Census Bureau Population and Housing Unit Estimates.

Methodology

Using data from the Washington State Department of Agriculture and the Washington State Potato Commission, the methodology first estimates the amount of potatoes produced in Washington State. The magnitude of potato production is done at the regional level (i.e., multiple counties). While the Washington State Department of Agriculture estimates production totals for fresh potatoes, the Washington State Potato Commission estimates production totals for both fresh and processed potatoes. The total amount of potatoes produced by region is then adjusted to account for harvested crops that were loss or otherwise discarded. Based on data from the Washington State Potato Commission, the loss rate was set at 6 percent.

Next, the methodology uses data from the Washington State Potato Commission on the locations of potato processing facilities to estimate the destinations of farm-based potato shipments. It also uses data from the Washington State Potato Commission on the ratios of fresh potatoes to processed potatoes (i.e., frozen, potato chips, and dehydrated) to link the production of farm-based potatoes to in-State destinations. For example, the ratio of fresh potatoes to dehydrated potatoes is 6:1. This implies that every ton of dehydrated potatoes requires as input 6 tons of fresh potatoes.

The NCFRP 26 methodology then makes assumptions on the modes used by potato commodities. Based on stakeholder interviews, it was estimated that 25 percent of frozen and 11 percent of all other potato commodities are shipped out of Washington State via rail. The remainder are assumed to be either shipped out to domestic destinations via truck, consumed in Washington State, or exported primarily to Mexico and Canada via truck.

Main Takeaways

The methodology utilizes several of the same data sources and techniques employed in the estimation of farm-based shipments. In particular, both methods rely on data produced by the Agricultural Census. The methods diverge in the use of local data from industry trade groups. In order to shed more light on the movement of potatoes from farms to processing facilities, the NCFRP methodology uses additional data from the Washington State Potato Commission as well as their professional judgment.

Given the large number of agricultural products that are included in farm-based shipments (see appendix A), reproducing this type of analysis at the national level on a product-by-product basis is challenging. However, the current FAF4 methodology contains some elements of the NCFRP process in that the productions of farm-based commodities are linked to FAF zones that the Commodity Flow Survey (CFS) recorded a shipment of a product derived from that commodity. Therefore, the NCFRP methodology, or similar, may be appropriate to apply to select farm-based commodities in order to improve their accuracy.

Developing a Cattle Commodity Flow Database

Background

In December 2017, the Center for Transportation Research (CTR) at the University of Texas at Austin (UT Austin), in cooperation with the Texas Department of Transportation and Federal Highway Administration (FHWA), published a study entitled “Commodity-based Approach for Evaluating the Value of Freight Moving on the Texas’ Roadway Network.” The major objective of the study was to develop a commodity-based approach for evaluating the value of a select group of commodities moved on the Texas freight network. The research team obtained unique data sources for the select commodities through online investigations and communication with industry representatives. From that data, the project team estimated the quantity of commodities moved from their origins to their destinations, as well as the routes, transportation modes, and vehicle types used. The selected commodities included: cattle, grain sorghum and corn, chickens, and timber, among others. This section of the report describes the data and methodology used by the study to develop cattle commodity flows.

Data Sources

The following data sources were used by the CTR to develop cattle commodity flow estimates:

- USDA National Agricultural Statistics Service (NASS)—The USDA NASS reports the number of cattle in each county by type: all cattle and calves, beef cows, and milk cows. This data provides a good estimate of cattle supply, or production.
- Texas Workforce Commission (TWC) and Texas Livestock Marketing Association (TLMA)—Upon leaving the ranch, cattle may be sent directly to feedyards or sent to auction houses, cattle dealerships, or order-buyers. The TWC and TLMA provide location data on cattle auction houses.
- Texas Animal Health Commission (TAHC)—The TAHC provides market reports on all cattle sold at livestock markets. In addition, it maintains data on permits to ship cattle into or out of Texas.
- Texas Commission on Environmental Quality (TCEQ)—The TCEQ maintains data on concentrated animal feeding operation (CAFO) permits. CAFO permits provide the location and maximum capacity of cattle feedyards.
- USDA Grain Inspection, Packers, and Stockyards Administration (GISPA)—The USDA GISPA maintains data on the location of slaughterhouses and their bond amount ($). The bond amount gives an indication of the capacity of the slaughterhouse (i.e., higher bond amounts indicate higher capacity).

Methodology

The methodology developed by the CTR for estimating the commodity flows consists of three distinct movements:

- Cattle Ranch to Auction House, Order-Buyer, or Feedyard.
- Feedyard to Slaughterhouse.
- Movement across State Boundaries.

Based on information from cattle industry representatives, the CTR research team determined that ranchers typically send cattle to auction houses within 30 to 40 miles of the ranch. However, there is uncertainty in the proportion of cattle that go down each potential route of the supply chain—auction hose, order-buyer, or feedyard. Though unclear from their description of the methodology, the CTR seems to assume that all cattle are assumed to travel to an auction house before being shipped to a feedyard.

To estimate the movement of cattle from the feedyard to the slaughterhouse, the number of cattle at each feedyard (assumed to be the capacity reported on the TCEQ CAFO permits) is summed for each county. If a feedyard was dedicated to a particular slaughterhouse, the number of cattle from that feedyard were removed from the county total and set aside for the Origin-Destination (O-D) flow to the county that contains its dedicated slaughterhouse. For the remainder, it is assumed that the feedyard cattle are shipped to the nearest slaughterhouse.

Lastly, the CTR methodology estimates out-of-State movements. The TAHC maintains data from permits issued for cattle shipped into and out of Texas. Though not all cattle that enter or leave the State get permits, the data provides a good approximation of the flow to each State. For international flows, the TAHC monitors the import of cattle from Mexico (by number of head and not by type of cattle).

Main Takeaways

The main takeaway of this case study is that the CTR methodology for modeling flows of cattle (a farm-based commodity) primarily relies on location data of processing facilities as opposed to the FAF4 which relies on shipment distance distribution data from the VIUS. The published VIUS shipment distance distribution data are not disaggregated by industry type (e.g., Agriculture, Mining, Construction, etc.), but rather by State, vehicle size, and truck type. As a result, the published shipment distance distributions indicate average distance ranges for all freight-intensive industries and not farm-based commodities specifically.

The advantage of the CTR methodology is that it is based on observed physical components of the commodity's, in this case cattle, supply chain. Furthermore, the methodology is tailored to a specific farm-based commodity as opposed to a general process for all farm-based shipments. Like the case study for potatoes from Washington State, scaling this methodology to the national level is a challenge because it would require a conceptual model of the supply chain for every farm-based shipment and location data on the relevant processing facilities up until the point the commodity becomes in-scope for the CFS. However, there are third-party sources of location data that could be utilized. Furthermore, once cattle reach a processing facility, it becomes an in-scope commodity captured by the Commodity Flow Survey.

Developing a Grain Sorghum and Corn Commodity Flow Database

Background

The Center for Transportation Research (CTR) at the University of Texas at Austin report, "Commodity-based Approach for Evaluating the Value of Freight Moving on the Texas' Roadway Network," also developed commodity flows for grain sorghum and corn. Corn and grain sorghum are an integral part of the cattle supply chain. The CTR study models grain sorghum and corn commodity flows from farms to grain elevators and them from grain elevators to cattle feedyards. This section of the report describes the data and methodology used in that estimation process.

Data Sources

The following data sources were used by the CTR to develop grain sorghum and corn commodity flow estimates:

- USDA National Agricultural Statistics Service (NASS)—The USDA NASS County Production Estimates data include acreage planted, acreage harvested, yield per harvested acre, and production (in bushels) for sorghum and corn.

- Texas Workforce Commission (TWC)—The TWC maintains data on the location of grain elevators.
- BNSF Elevator Directory and Map—The locations of rail-served grain elevators in Texas.
- USDA Census of Agriculture—Inventory of hogs and pigs, as well as change in inventory data and maps.
- USDA Meat Animals Production, Disposition, and Income: 2014 Summary—The total number of hogs marketed in Texas is used to determine the amount of grain traveling to hog farms.
- Texas Commission on Environmental Quality (TCEQ)—The TCEQ maintains data on permits for cattle feedyards.

Methodology

There are three distinct components of the CTR methodology to model corn and grain sorghum commodity flows:

- County Productions to Grain Elevators.
- Grain Flow from Elevators to Hog Feedyards.
- Grain Elevators to Cattle Feedyards.

County Productions to Grain Elevators

The total productions of sorghum and corn by county were taken directly from the USDA NASS County production estimates and aggregated together after allocation to grain elevators. The methodology then determines the total number of elevators accepting this grain from the TWC data. In order to account for the elevators identified by the BNSF data as accepting grain from railroad shipments, the elevators identified by both datasets were removed from the TWC list. The methodology assumes that all grain produced in Texas was not shipped to any of the elevators identified by the BNSF dataset, but instead was shipped to the nearest non-BNSF elevator. As a result, the methodology implies that a large proportion of grain will only travel within the county where it was produced.

Once the number of elevators in each county was determined using the abridged TWC data, an estimate of the size of each elevator was made using the number of employees at that elevator. The methodology assumes that every 10 employees at an elevator implies a capacity of 1 million bushels.

Upon determining the productions and attractions (elevator capacity) for each county, the methodology uses an algorithm to allocate county-level grain productions to its closest elevator. The algorithm allocated county-level attractions to their closest elevators until reaching capacity. Once capacity at the nearest elevator was reached, the algorithm then allocated the remaining production to the next closest elevator.

Grain Flow from Elevators to Hog Feedyards

Once the amount of grain flowing to each county's elevators was determined, the amount of grain continuing on to hog feedyards was estimated. The methodology noted that a previous survey of grain elevator operators determined that elevators in certain regions of Texas, as defined in the survey, sent only a small proportion of their grain to Texas feedyards.[53] The CTR methodology determined to which survey-based region each county in Texas belonged. For each county, the amount of sorghum and corn was separately multiplied by their proportions proceeding from elevators to feedyards by truck. From this point forward, the methodology aggregates the amount of sorghum and corn for further analysis.

Next, the methodology estimated the capacity of BNSF elevators in order to determine the amount of grain flowing from those elevators to hog farms. An ad hoc methodology was used to estimated capacity based on factors, including track capacity, number of employees, the railroad serving that elevator, any elevators of similar size and any elevators of the same company. These elevators were assigned to counties by overlaying a Geographic Information System (GIS) shapefile of Texas counties onto the shapefile of BNSF-identified grain elevators. Then the total capacities for all elevators within a county were aggregated.

The CTR methodology then considers the amount of grain flowing from each of the BNSF-identified elevators to hog farms. In order to estimate the amount of grain diverted from these elevators for this purpose, the total sale of hogs in Texas was identified using USDA data. The total amount of grain consumed (in bushels) was calculated based on proportions of grain consumption per hog identified in the *Texas Grain Transportation Study*.

In order to determine the elevators from which this grain was diverted, the CTR methodology identifies the locations of hog farms was determined using data from the *Texas Grain Transportation Study* and USDA NASS maps. The CTR methodology determined that hog farms are primarily within three regions as defined in the *Texas Grain Transportation Study*. The proportions of hog farms in those regions were applied to the grain flow totals to determine the total amount of grain diverted from each elevator by region and based on elevator capacity.

Grain Elevators to Cattle Feedyards

The CTR methodology then identified cattle feedyards in Texas using TCEQ permit data for CAFOs. The data also included the size of each feedyard (in head of cattle). Based on the total amount of grain identified in the previous step as flowing to cattle feedyards, an estimate of the amount of grain flowing to each feedyard was determined. The CTR methodology assigned counties to feedyards by overlaying a GIS shapefile of Texas counties onto the shapefile of TCEQ-identified feedyards. The total consumption of grain was aggregated to a county level for further analysis.

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53 Fuller, S., The Texas Grain Transportation Study, 2011.

Then, the methodology ran a gravity model to allocate the productions for each county (i.e., the amount of grain at county elevators transported by truck to cattle feedyards) to attractions for each county (the amount of grain consumed at each county's cattle feedyards). Road distance between each county was used as a friction factor in the model.

Main Takeaways

Like the case study on the CTR methodology for modeling cattle commodity flows, the main takeaway of this case study is that the methodology relies on location data of processing facilities as opposed to data on shipment distance distributions. This is an advantage since the published VIUS shipment distance distribution data are not disaggregated by industry type, which indicates that the average distance ranges are for all freight-intensive industries as opposed to farm-based commodities specifically. In addition, the CTR methodology focuses on grain sorghum and corn and the physical components of its supply chain which is another advantage. However, only the farm to grain elevator component is relevant for the FAF4 since shipments departing grain elevators are an in-scope commodity movement.[54]

Developing a Broiler Commodity Flow Database

Background

The Center for Transportation Research (CTR) at the University of Texas at Austin report, "Commodity-based Approach for Evaluating the Value of Freight Moving on the Texas' Roadway Network," also developed commodity flows for broilers—chickens that are bred and raised specifically for meat. Broilers are an economically important agricultural commodity for Texas. This section of the report describes the data and methodology used in that estimation process.

Data Sources

The following data sources were used by the CTR to develop broiler commodity flow estimates:

- Texas Workforce Commission (TWC) Socrates Database—The Socrates database consists of business location data by North American Industry Classification System (NAICS) code. It was used, in part, to identify broiler processing plants.
- WATT Global Media Poultry Report—This was used to validate information on the number of broilers processed by top companies.
- USDA State Production Data—This data set provided information on the total number, total weight, and total value of broilers produced in Texas.
- USA Trade Data—This data set provided import and export data by port and by commodity type.

[54] Bureau of Transportation Statistics (BTS), "2017 Commodity Flow Survey Overview and Methodology," https://www.bts.dot.gov/archive/publications/commodity_flow_survey/methodology_2012, Accessed February 5, 2019.

Methodology

The commodity flow estimation process is defined by the seven steps in the broiler supply chain identified by the CTR researchers:

1. *Pullet breeding farms:* These farms provide parent breeding stock that are solely responsible for laying eggs to create pullets (i.e., young hens).
2. *Pullet farms:* After hatching, the young chicks will be transported to a pullet farm where they are raised until they can lay eggs.
3. *Breeder farms:* The pullets are later transferred to breeder farms where they will start laying eggs.
4. *Hatcheries:* The eggs are transferred to a hatchery where they remain until they hatch.
5. *Broiler farms:* Once the eggs are hatched, the chicks are transported to broiler farms.
6. *Processing plants:* Upon maturity, the broilers are transferred to processing plants where they are prepared so that they are ready to cook or to be used in a secondary processing facility for more specific products.
7. *Distribution:* After processing, the broilers are either transferred to a secondary facility for further processing or distributed to retailers, wholesalers, or restaurants.

Working with the production data by State (from the USDA) and export and import data by State (from USA Trade), the CTR methodology estimates the per capita number of broilers available for each American per year. This value, 97.2 pounds per capita, is not representative of how much broiler meat an average American actually eats each year, but rather the weight of the carcass. The CTR methodology then goes on to calculate the demand for broilers in each State using the per capita number of broilers available (i.e., 97.2 pounds per capita), State population, and State exports. State-level supply is calculated as the sum of broiler production (from the USDA data) and imports. The difference between total supply and total demand yields the net supply of broilers for each State, where a positive value indicates a surplus and a negative value indicates a deficit.

Using the supply and demand for broilers for each State, the CTR methodology then develops a State-to-State O-D Matrix using a gravity model, where the impedance is based on the distances between each State's most populous cities. Next, the CTR methodology develops an O-D Matrix of chicken products within Texas. In order to do this, the production and consumption of each zone is required. Production zones are the following:

1. The 11 broiler processing facilities in Texas.
2. Three international ports in Texas.
3. Interstate border points that are used in the chicken product supply chain.

Consumption zones are the following:

1. Each of the 254 counties with a known population. The demand for each county is the product of the county's population and consumption per capita from Equation (5.1).
2. 14 International ports in Texas.
3. Intrastate border points that are used in the chicken product supply chain.

Using this approach, the CTR researchers developed a 254x254 O-D matrix representing broiler commodity flows in Texas. After estimation, the O-D matrix was further adjusted to account for sparsely populated counties without access to a moderate-sized grocery store (i.e., at least 50 employees) and for larger and/or border counties that import broilers (i.e., Dallas, Harris, and Webb).

Main Takeaways

The primary takeaway from this case study is the methodology utility of processing facility location data on modeling farm-based shipments. This is an advantage given the potential of farm-to-farm movements in the early stages of the broiler supply chain that may not be captured as an in-scope commodity move by the CFS. Once broilers reach a processing plant, they become an in-scope commodity movement.

LOGGING

Developing a Timber Commodity Flow Database

Background

The Center for Transportation Research (CTR) at the University of Texas at Austin report, "Commodity-based Approach for Evaluating the Value of Freight Moving on the Texas' Roadway Network," also developed commodity flows for timber. Timber is essential to the Texas economy as an input to paper production plants and as a construction material. The CTR study models commodity flows of logs from harvest sites to mills where they are further processed. This section of the report describes the data and methodology used in the timber commodity flow estimation process.

Data Sources

The following data sources were used by the CTR to develop log commodity flow estimates:

- Forest Inventory Data Online (FIDO)—The U.S. Forest Service's FIDO tool provides spatial (at the State and county levels) and temporal (at the annual level) data on timber production. At the county level, on those counties in East Texas were included in the FIDO tool since that is the primary timber-producing region of the State.
- Texas A&M Directory of Forest Product Industries, Texas A&M Harvest Trends, Primary Forest Products Network, and USDA—From these databases, the locations of mills by type (i.e., sawmills and pole mills) in East Texas and neighboring States were determined.
- Texas Workforce Commission (TWS) Socrates Database—The TWC Socrates database was used to gather revenue data for mills.
- USDA Forest Service Southern Research Station—Data on timber shipments between Texas and other States was gathered from reports published by the USDA Forest Service Southern Research Station.

Methodology

The CTR methodology began by extracting from the FIDO tool the annual average harvest removals for trees greater than 5 inches in diameter for all counties in Texas, six southwest Arkansas counties, nine western Louisiana counties, and three southeast Oklahoma counties. Once this data was obtained, the methodology estimates the amount of saw timber and pole timber was calculated. Similar county-level data for saw timber was extracted from FIDO for all counties in question. Since this data was in board feet, the CTR researchers converted it to cubic feet using the International ¼-Inch Rule which adjusts for losses that occur during the conversion of logs to lumber.

The percentage of saw timber and pole timber transported to each type of mill was determined using timber product output reports from the USDA Forest Service. The methodology assumes that the proportion of timber traveling to each type of mill was constant for each county in Texas.

The CTR methodology then estimates that amount of timber shipped into and out of Texas using data from the *Texas A&M Harvest Trends* report. The report revealed that the flow of timber was limited to the three States surrounding East Texas—Arkansas, Louisiana, and Oklahoma. For each of these States, the counties in close proximity to Texas with significant timber harvests were considered.

Production data was obtained from FIDO for the out-of-State counties and again converted to saw timber and pole timber estimates using the International ¼-Inch Rule methodology. The amount of timber shipped into Texas from each State was estimated using published data from the USDA Forest Service Southern Research Station. Reports were obtained for Arkansas, Louisiana, and Oklahoma that indicated the amount of timber shipped to each type of mill mentioned above.

Using data from the reports published by the Texas A&M Forest Service and USDA Forest Service Southern Research Station, the CTR methodology estimates the amount of timber shipped from Texas to out-of-State mills. The researchers only considered the out-of-State mills published in the Texas A&M Harvest Trends 2014 document since those mills are relatively large and they assumed that timber would not be shipped to relatively small mills. For the in-State mills, the CTR methodology used revenue data from the TWC Socrates database as a proxy for the capacity of each mill. Mills with larger revenues were assumed to process more timber than mills with smaller revenues.

At this point, the total timber productions for each in-State county, broken down by mill type—sawmill; pulp or paper mill; and, veneer, plywood, or oriented-strand-board mill—had been determined. In addition, the amount of timber shipped into Texas from Arkansas, Louisiana and Oklahoma had been determined. The total timber attractions also were completed, using the mill revenue for each in-State mill and calculated exports.

In order to allocate the harvested timber to mills, the CTR methodology estimated three separate gravity models, one for each mill type. Road distance between each county, calculated using an algorithm in Python that used the optimal Google Maps route, was used for the friction factor in the gravity model. Importantly, because Texas State law prohibits the transport of timber more than 125 miles from the point of origin to the point of primary processing (the destination), the gravity model was further adjusted to assign an extremely high impedance factor to O-D combinations more than 125 miles apart. This would prevent the majority of these prohibited trips from taking place. This was done for all three O-D matrix types: 1) sawmills; 2) veneer, plywood, and oriented-strand-board mills; and 3) pulp/paper mills.

Main Takeaways

One of the main takeaways from this case study is that the FAF4 assumption on the typical shipment distance range of logging commodity flows is still relevant based on more recent observations of the timber industry. The CTR study indicated that logs are largely transported a short distance from where they are harvested. However, it also revealed that shipments to processing facilities are not limited to those facilities within State boundaries. Again, the use of processing facility location data because it provides more accurate information on the forest-to-facility move that occurs before logs become an in-scope commodity movement. This could be important for timber-producing regions that straddle State lines.

Analyzing Log and Chip Truck Performance in the Upper Peninsula of Michigan with Global Positioning System Tracking Devices

Background

While this study does not develop a commodity flow database for logging shipments, it does offer some insights that could be useful to improving current FAF4 methodologies for OOS logging shipments.[55] This study collected data on the movements of log and chip trucks in the Upper Peninsula region of Michigan using global positioning systems (GPS) data. Its primary purpose was to identify opportunities to increase the efficiency of these movements in order to lower the overall transportation costs to shippers. Though most forest products companies collect data on origins and destinations of truck trips, less data is collected on the actual routing decisions of the drivers. This study combines GPS data with trip diaries.

Data Sources

The primary data sources for this study are GPS data on log truck movements and trip diaries completed by truck drivers.

Methodology

Using GPS data and trip diaries, this study tracked the movement of logging trucks from active timber-harvesting sites to processing facilities located throughout the Upper Peninsula region of

[55] Lautala, P., Pouryousef, H., Stewart, R., Ogard, L., Vartiainen, 2012. “Analyzing Log and Chip Truck Performance in the Upper Peninsula of Michigan with GPS Tracking Devices,” National Center for Freight and Infrastructure Research and Education, University of Wisconsin—Superior.

Michigan. An important observation of the study was that though the timber-harvesting sites were centered in the State of Michigan, there was overlap into the northeast portion of Wisconsin. This overlap includes the processing facilities to which the harvested timber was delivered. This has implications for the assumption in the FAF4 that movements of harvested timber occur within a FAF4 zone, which by design do not overlap State boundaries.

Main Takeaways

Though this study does not offer an alternative methodology for OOS logging shipments, it does provide additional insight into origins (i.e., areas of production) and destinations (i.e., areas of processing). While the study implies that the FAF4 assumption that logging shipments are primarily local is well-founded, it also implies that in many cases local movements are not limited to FAF4 zones that end at State borders. In the case of timber producing regions such as Upper Peninsula of Michigan/North Wisconsin and South Georgia/North Florida, logging shipments may cross State lines into neighboring FAF4 zones to access processing facilities and/or rail spurs. A targeted improvement would be to identify timber producing regions that straddle State lines and determine if processing facilities are located in multiple States. In this scenario, logging shipments produced in that region could be divided across the constituent States. Though it is possible the magnitude of tonnage and value of cross-border shipments is relatively small at the national level, it could be important for State and regional partner-agencies that utilize the FAF4 for statewide and regional freight planning.

MUNICIPAL SOLID WASTE

New York Metropolitan Transportation Council Regional Freight Plan Update 2015–2040 Interim Plan

Background

Due to limitations in the availability of data on municipal solid waste (MSW) flows from public sources (such as the Freight Analysis Framework) as well as private sources (such as IHS Markit's TRANSEARCH database) as part of their 2013 Regional Freight Plan Update, the New York Metropolitan Transportation Council (NYMTC) developed their own origin-destination database of MSW flows.[56] In order to account for these flows, NYMTC collected data on facility-level volumes of received materials from the New York State Department of Environmental Conservation's (NYSDEC) 2010 report, *Beyond Waste: A Sustainable Materials Management Strategy for New York State.*[57]

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[56] New York Metropolitan Transportation Council, https://www.nymtc.org/portals/0/pdf/Fright%20planning/TM2-2-2_NYMTC_Solid%20Waste%20Flows_FINAL.pdf.

[57] New York State Department of Environmental Conservation, *Beyond Waste: A Sustainable Materials Management Strategy for New York State,* https://www.dec.ny.gov/docs/materials_minerals_pdf/frptbeyondwaste.pdf.

Data Sources

The primary source of data for the NYMTC process are facility-level volumes of received materials from the New York State Department of Environmental Conservation's (NYSDEC) 2010 report, *Beyond Waste: A Sustainable Materials Management Strategy for New York State*. This report also contains information on the locations and functions of waste handling facilities in the NYMTC region as well as the locations from which they receive and ship MSW.

Methodology

The first step in NYMTC's estimation process was to calculate the sum total of facility-level waste volumes in each NYSDEC planning unit. Planning units are a collection of municipalities and/or counties from which MSW is collected and processed at various facilities. At the time of the report, there were 333 waste handling and processing facilities in the NYMTC region: 125 transfer stations, 198 construction and demolition processing facilities, 5 combustor or resource recovery facilities, and 5 landfills. Because transfer stations are the point at which MSW are consolidated for disposal at facilities in other locations, the NYMTC estimation process treats these points as origins of MSW flows. The MSW volumes received by these facilities were aggregated to the planning unit level.

Next, the NYMTC estimation processed apportioned these outbound volumes to various destination States and counties. The apportionment was based on the destination distribution shares reported in the NYSDEC Planning Unit Profiles. In the event that out-of-State county detail was not provided in the Planning Unit Profiles, the county containing the centroid of the destination State was used as a proxy. For example, for a Planning Unit Profile that indicates that a specified amount of MSW is destined for Pennsylvania with no information on the specific destination county, that flow would be assigned to Centre County, Pennsylvania.

Planning unit flows were then aggregated at their origins from the planning unit level to the county level. Thus, the entire MSW flow is represented at the county level. The result is a county-to-county origin-destination database of MSW flows for the NYMTC region that can be appended to a broader commodity flow database that represents the full breadth of commodity movements, such as the FAF or TRANSEARCH.

Main Takeaways

The methodology utilizes several of the same data sources and techniques employed in the FAF4 estimation of MSW and construction and demolition (C&D) debris flows. Like the FAF4 process, it relies on data provided by a State environmental agency, in this case the New York State Department of Environmental Conservation. Given its similarities to current FAF4 OOS processes, it does not offer an alternative.

CRUDE PETROLEUM

Diesel Fuel

Background

As discussed in the case study of Potato commodity flows, NCFRP Report 26: Guidebook for Developing Subnational Commodity Flow Data provided guidance for developing subnational commodity flow databases to meet transportation planning needs at the regional level.[58] It describes methods to develop primary commodity flow data using local data collection along with how to augment local data collection efforts with information from published data sets and commodity flow disaggregation techniques. The supply chain-based approach to developing a subnational commodity flow database proposed in the Guidebook is applicable to OOS commodity flows at the national level as well.

One example in the Guidebook, described in detail in this section of the report, is the development of a commodity flow database for diesel fuel in Washington State. Though diesel fuel is an in-scope CFS commodity, the development of an origin-destination database for this commodity at the State level provides insight into strategies to improve current OOS methods.

Data Sources

- Cardlock facility locations, which are the primary distribution locations for diesel trucks. These data were obtained from private-sector companies.
- Data on the location and capacity of underground storage tanks from the Washington State Department of Ecology, which regulates active underground storage tanks.
- Data on the location and capacity of above-ground storage tanks from the U.S. Environmental Protection Agency.
- Data on the location of active terminals (where fuel is distributed to trucks from refineries, barges, or pipelines) from the Washington State Department of Revenue.

Methodology

The terminals define the origins of diesel fuel shipments. These are the locations from which fuel is distributed to trucks.

Next, the locations of cardlock facilities were compared to the locations of under- and above-ground storage tanks. This was done in order to determine which cardlock facilities are valid destinations of diesel fuel shipments since a storage tank is required to make a delivery. Cardlock facilities colocated with a storage tank serve as diesel fuel destinations in the methodological approach.

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[58] Transportation Research Board, NCFRP Report 26: Guidebook for Developing Subnational Commodity Flow Data, National Cooperative Freight Research Program, 2013.

The researchers observed that data on the actual movements of diesel fuel shipments is difficult to obtain as these movements vary quickly over time and space. In addition, national-level commodity flow databases (such as the FAF) were determined to be too aggregate to be useful for estimating diesel flows within the State. To address this challenge, the researchers contacted the Washington Oil Marketers Association who provided information on the Washington State diesel distribution network.

Despite the information on the diesel distribution network obtained from the Washington Oil Marketers Association, the researchers still did not have information on commodity flows which was needed to estimate diesel flow volume between terminals and cardlock facilities. The researchers used two sources to fill in this missing data. First, they identified the closest terminal by travel time to each cardlock facility. They then assumed that the closest terminal was the one that was used as the origin of diesel fuel destined for each cardlock facility.

Information also was missing on the number and routing of truck trips between terminals and cardlock facilities. To fill in this missing information, the research team used vehicle count data from nearby stations to estimate diesel flows. They determined that the number of origin-destination pairs using each link in the roadway network would be a sufficient proxy for volumes.

In addition, the researchers also determined that the annual average daily traffic (AADT) could be used to estimate the amount of diesel consumed at each cardlock. Thus, the AADT at the nearest count station to the cardlock facility was used to distribute known volume of diesel produced by terminals. Each cardlock received a portion of the total diesel dispensed equal to its AADT relative to total AADT. This implies that cardlocks on roadways with more traffic distribute more fuel.

Main Takeaways

The NCFRP Report 26 methodology for estimating diesel fuel flows in Washington State follows many of the same principles as those observed in the FAF4 OOS process. For instance, both approaches utilize data on the locations of facilities where petroleum products are gathered and distributed to estimate State-level flows. Overall, this case study provides further confirmation of the current processes for modeling crude petroleum flows but does not offer an alternative method that may be applied.

NATURAL GAS

Risk Assessment of Surface Transport of Liquid Natural Gas

Background

In 2018, the Pipeline and Hazardous Materials Safety Administration (PHMSA) Office of Hazardous Materials Safety conducted their *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)* with an emphasis on rail. The report outlines LNG supply and demand in the context of overall energy market, including new trends for using LNG for propulsion in the motor carrier, maritime, and rail industries. Importantly, it also explored how natural gas and LNG are transported throughout the United States, and the relationship between peak shaving facilities, merchant plants, and export facilities. The results of this investigation formed the foundation for a commodity flow framework for LNG, which may be useful for informing the FAF4 estimates on nonpipeline natural gas flows.

Data Sources

The PHMSA LNG Commodity Flow Framework relies on data produced by the U.S. Energy Information Agency on LNG processing and storage facilities, inter- and intrastate flows of natural gas, international and domestic demand for LNG, and information on the transportation networks (e.g., pipelines, rail, etc.) over which LNG is transported.

Methodology

The PHMSA LNG Commodity Flow Framework contains four major elements: 1) LNG Networks; 2) LNG Facilities; 3) LNG Transportation; and 4) LNG Economics. The LNG Networks component considers the primary networks over which LNG is transported, including natural gas pipelines, railroads, and highways. Though maritime LNG operations for import/ export and fueling is referenced, the focus of the framework is on surface transport modes, with an emphasis on rail. Often referred to as the "midstream" portion of the energy supply chain, pipelines, railroads, and highways move natural gas, natural gas liquids, other fuels in bulk quantities from "upstream" production and processing facilities to distant "downstream" locations, where the shipments are refined, stored, and/or delivered to end customers by barge, truck, or pipeline.

Table 11. Elements of the Pipeline and Hazardous Materials Safety Administration liquefied natural gas commodity flow framework.

LNG Networks	LNG Facilities	LNG Transportation	LNG Economics
Base load facility supply and demand.	LNG liquefaction facility locations.	Interstate LNG Flows (State to State).	LNG projected import supply.
LNG rail network analysis.	LNG facility storage capacities.	Intrastate LNG Flows (within a State).	LNG projected export demand.
LNG maritime network analysis.	LNG liquefaction capabilities.	Truck trips serving liquefaction facilities.	LNG projected domestic LNG demand.
Projected rail network for LNG transport.		LNG fuel operations and demand.	Peak shaver supply and demand.
Natural gas pipeline network.			
LNG truck network analysis.			

(Source: Pipeline and Hazardous Materials Safety Administration, "Table 3.1 Elements of Commodity Flow Framework by Category," *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

LNG Facilities encompass those locations that liquefy, transport, store, or gasify LNG. There currently are 153 LNG facilities operating in the U.S. performing a variety of services as shown in figure 30. LNG peak shavers are identified in green, and satellite peak shavers (no liquefaction) in purple. The import/export facilities are identified by red squares and emerging LNG facilities as blue stars. These “emerging” LNG facilities are mostly merchant plants that have been constructed but do not yet appear in the PHMSA and Energy Information Administration (EIA) databases. They include facilities built in Florida, Louisiana, Pennsylvania, Texas, and Vermont.

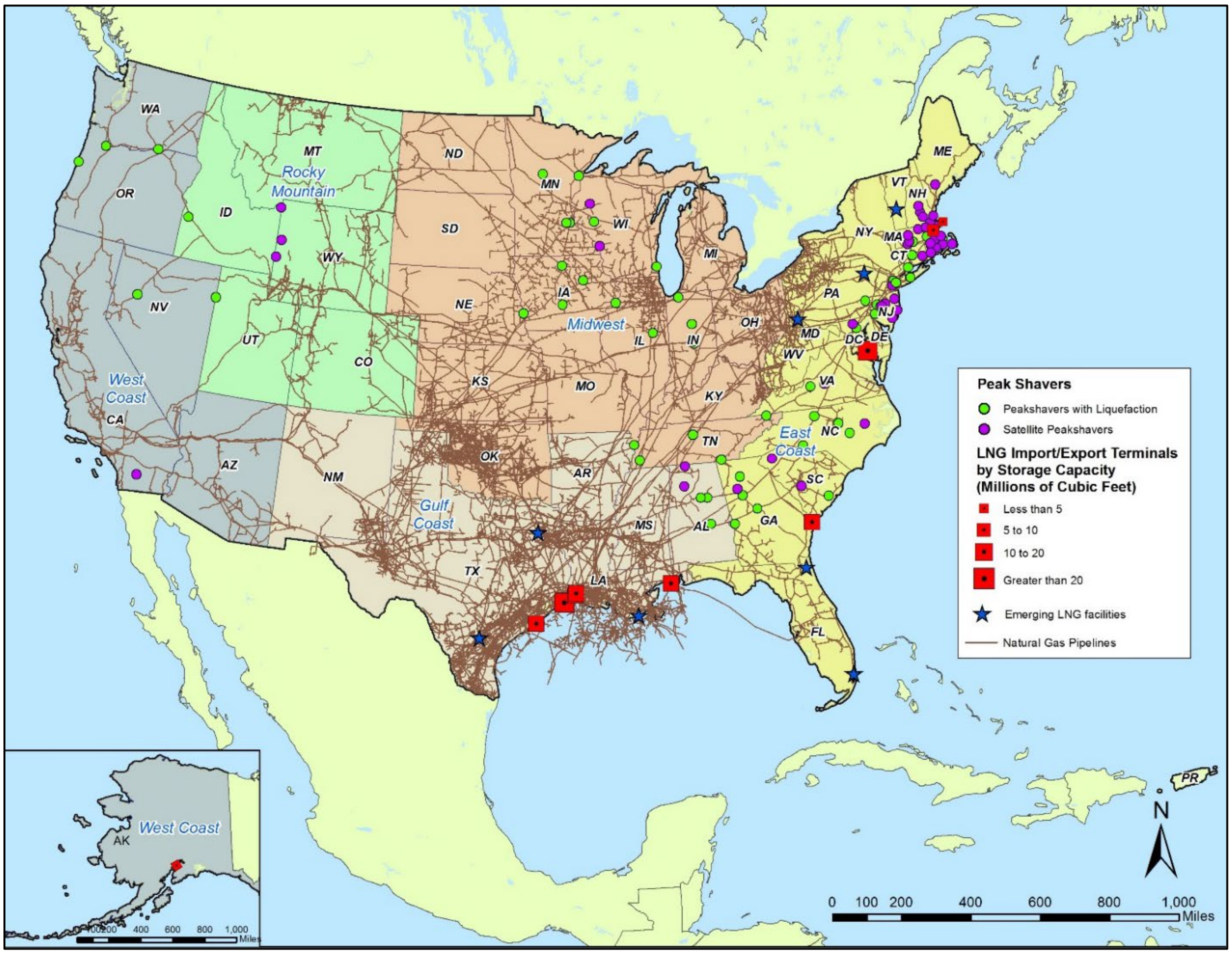

Figure 30. Map. U.S. liquefied natural gas facilities with natural gas pipeline network. (Source: U.S. Energy Information Agency; Pipeline and Hazardous Materials Safety Administration, “Figure 3.6 U.S. LNG Facilities with Natural Gas Pipeline Network,” *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

The third component of the PHMSA framework, LNG Transportation, describes how LNG is physically conveyed over the LNG Network. The vast majority of natural gas is moved by pipeline and when natural gas is moved by truck and vessel, it is assumed that it is moved in liquefied form. In their 2018 report, PHMSA reported that a preliminary analysis of the U.S. EIA. Survey 176 data, which is published as part of the U.S. EIA Annual Report, shows that

roughly 65.1 million cubic feet (MMCF) of natural gas were moved across the U.S. in 2016—99.574 percent by pipeline, 0.421 percent by vessel, and 0.004 percent by truck.
Figure 31 shows movements of natural gas that are captured by the EIA Survey 176. Net Interstate movements, imports, and exports of natural gas are represented by the mode of transportation: pipeline, truck, and vessel. Imports and exports are shown in red, while domestic movements are shown in blue. These movements are the net result of movements that may occur in either directions, showing the dominating direction of flow.

Though pipelines are the most efficient for moving natural gas over short distances, truck movements of natural gas in its liquefied form do occur with truck transport being the main alternative to pipeline delivery. Figure 32 shows gross Interstate movements of LNG by truck. A single truck carries 10,943 gallons of LNG, which is equivalent to 0.9 million cubic feet of natural gas. Therefore, the movement of one million cubic feet of natural gas between Texas and Delaware can be estimated to represent one truck.

Figure 31. Map. Net interstate natural gas movements.
(Source: U.S. Energy Information Agency, "2016 Annual Report"; Pipeline and Hazardous Materials Safety Administration, "Figure 3.13 Net Interstate Natural Gas Movements 2016 Annual Report," *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

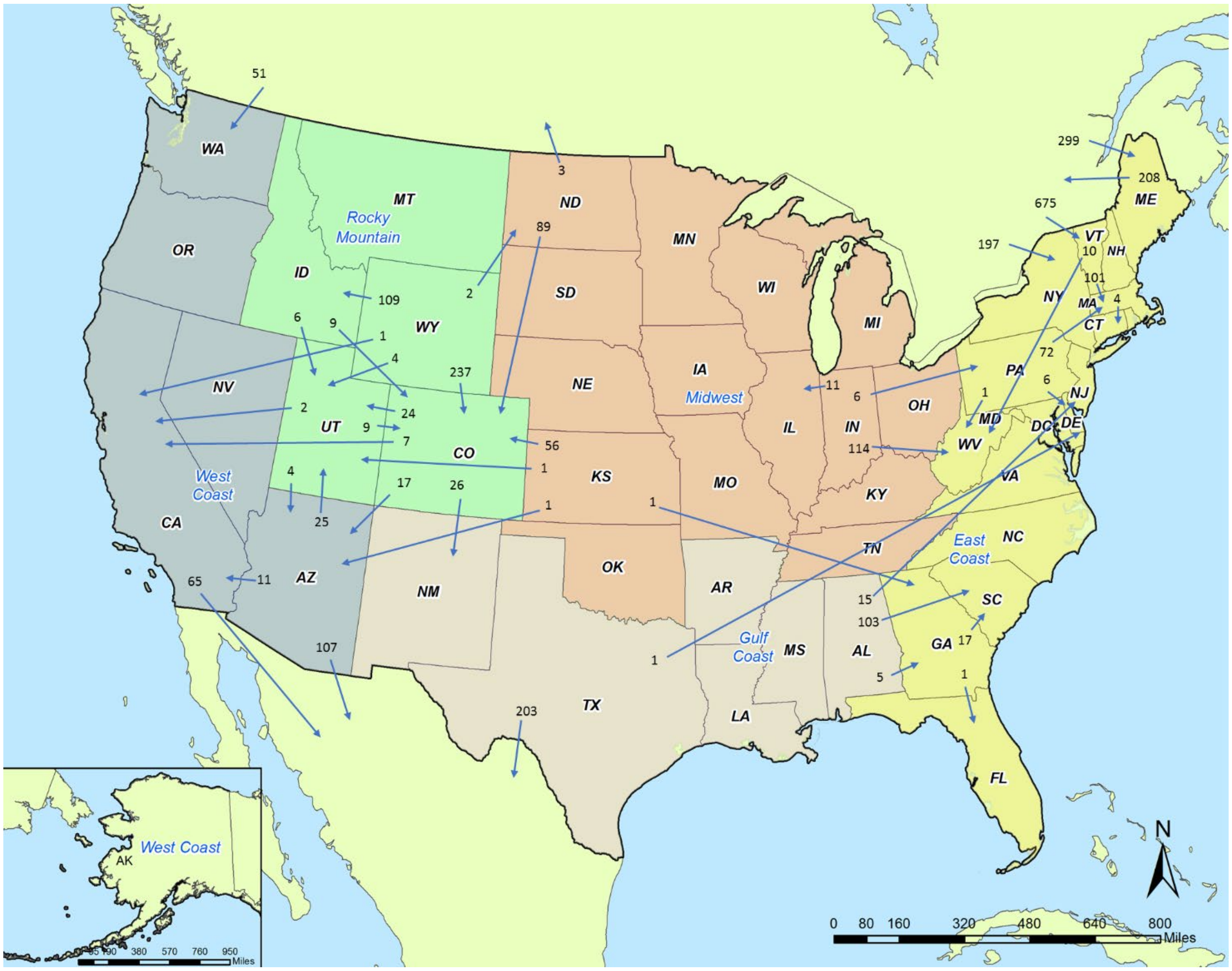

Figure 32. Map. Gross interstate natural gas movements by truck in 2016.
(Source: U.S. Energy Information Agency, "2016 Annual Report"; Pipeline and Hazardous Materials Safety Administration, "Figure 3.14 Gross Interstate Natural Gas Movements by Truck in 2016," *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

Figure 33 and figure 34 give additional perspective on truck movements by showing gross LNG movements and the truck movements solely between production and consumption natural gas regions, respectively. In particular, figure 34 illustrates that the majority of the movements are within the natural gas regions, but some of the LNG movements do move more than 1,000 miles. Observing current movements of LNG by truck reveals how the market handled the inability of the pipeline network to serve certain consumer demands. This provides insight on the origins that have liquefied LNG supply and the destinations that demand natural gas from off the pipeline grid.

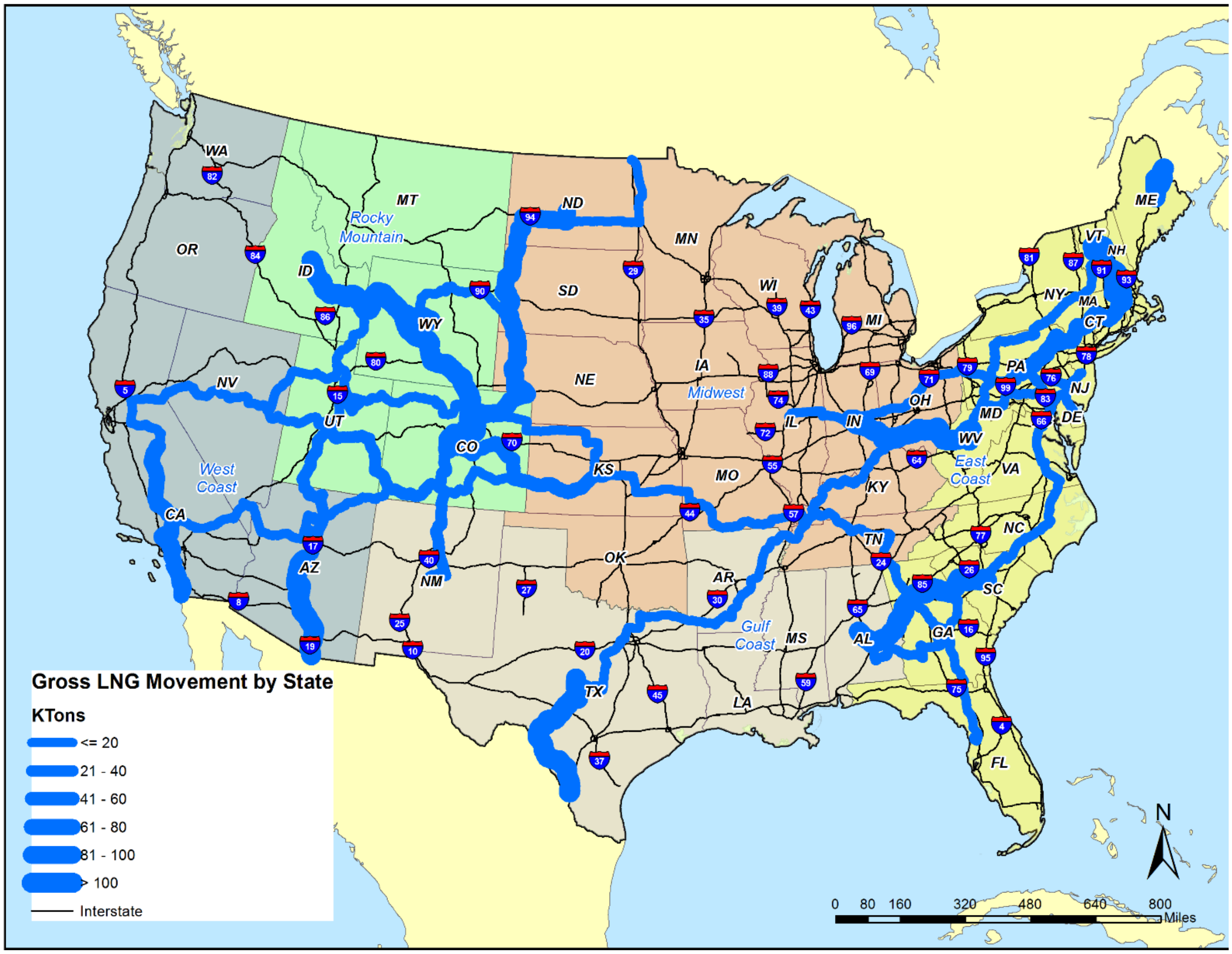

Figure 33. Map. Gross liquefied natural gas movements by State (truck, 2016).
(Source: U.S. Energy Information Agency, "2016 Annual Report"; Pipeline and Hazardous Materials Safety Administration, "Figure 3.16 Gross Interstate Natural Gas Movements by State—Truck, 2016," *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

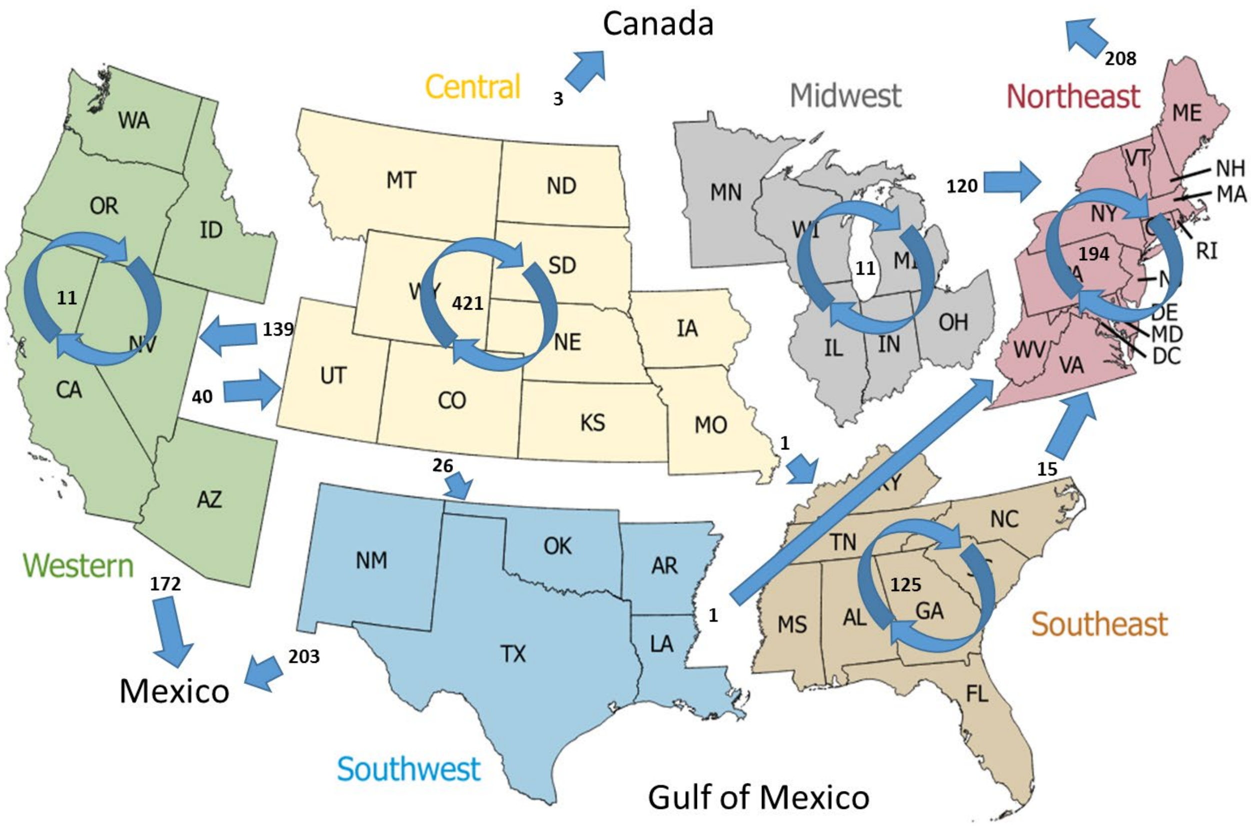

Figure 34. Map. Liquefied natural gas truck movements between regions in 2016. (Source: U.S. Energy Information Agency, "2016 Annual Report"; Pipeline and Hazardous Materials Safety Administration, "Figure 3.17 LNG Truck Movements between Regions in 2016," *Risk Assessment Study of Surface Transport of Liquid Natural Gas (LNG)*, 2018.)

The final component of the PHMSA LNG framework is LNG Economics. The price of natural gas and the cost of transportation play a large role in where it is sourced. LNG competes with other fuel sources (such as pipeline gas, propane, and diesel) and is sourced when it is cost-competitive with those alternatives. In the case of pipeline gas, LNG is typically cost-competitive when a region does not contain an extensive pipeline network or the network is oriented in the opposite direction of travel than what is needed (i.e., the network was designed to supply gas to other areas as opposed to receiving gas). If another fuel source were more economical to procure, the users could switch products. As long as a supply source is close enough that the cost to transport it and supply it is cheaper than other energy products, the LNG will move. In conjunction with the other components of the PHMSA LNG framework, the LNG Economic component is used to develop alternative scenarios by which LNG will be demanded by certain regions, supplied by others, and transported over the LNG network.

Main Takeaways

As its name implies, the PHMSA LNG Commodity Flow Framework focuses on the movement of a specific type of natural gas—LNG. While the vast majority of natural gas is moved by pipeline, a small percentage is moved by truck and vessel in liquefied form. PHMSA estimated that the breakdown of natural gas movement by mode is 99.574 percent by pipeline, 0.421 percent by vessel, and 0.004 percent by truck. The differences in how natural gas may be transported domestically based on its form (i.e., liquid, compressed, or gas) do not appear to be explicitly considered in the FAF4 OOS methodology. The framework developed by PHMSA offers some insights for better incorporating those into the FAF4. However, as the PHMSA estimates indicate, this is a small portion of overall flows.

SUMMARY OF ALTERNATIVE COMMODITY FLOW SURVEY OUT-OF-SCOPE METHODS

The literature search for alternative methodologies for estimating CFS out-of-scope commodity movements revealed that there are relatively few efforts on which to draw comparisons. The most applicable efforts were those conducted as part of the National Cooperative Freight Research Program and the University of Texas at Austin (UT Austin) Center for Transportation Research (CTR). These efforts estimated movements of farm-based shipments, municipal solid waste, and timber, among others.

Both the NCFRP Report 26 and the UT Austin CTR methodologies can be viewed as supply chain-based processes for modeling commodity flows. Both methods relied on knowledge of commodity supply chains gathered from industry trade groups or academic literature. While the NCFRP Report 26 employed an origin-destination survey, the UT Austin CTR methodology primarily relied on third-party data sources. Both methodologies demonstrated how data collected at the local level and knowledge of commodity supply chains can be used to augment national data sources for the purpose of developing sub-national commodity flows.

The challenge with applying these methodologies at the national scale are the number of distinct farm-based commodities. There are 117 farm-based commodities included in the FAF4. Applying the NCFRP and UT Austin CTR methodologies of augmenting national data with local and supply chain data would require that the process be extended to all 117 of these commodities. Thus, recreating this type of analysis at the national level for all farm-based commodities would require an extensive new data collection given the vast number of crops that are included in farm-based shipments. While this may be a worthwhile effort over the long-term, a more feasible short-term alternative would be to apply a similar supply chain-based methodology to a smaller number of farm-based commodities that are large in magnitude relative to the scale of OOS flows, or that are deemed economically important from a national perspective.

The literature review revealed additional insight into the distribution patterns of freshly harvested logs. The results of the research conducted by the UT Austin CTR and the National Center for Freight and Infrastructure Research and Education (CFIRE) implied that though logging shipments from timber-producing sites are primarily local, in many cases they are not limited to FAF4 zones that end at State borders. In the case of timber producing regions such as Upper Peninsula of Michigan/North Wisconsin, southeastern Texas and western Louisiana and Arkansas, and South Georgia/North Florida, logging shipments may cross State lines into neighboring FAF4 zones to access processing facilities and/or rail spurs. Though the magnitude of these movements relative to other OOS commodity flows is relatively small as indicated by table 10 in chapter 2, they are important for State and regional partner-agencies that utilize the FAF4 for statewide and regional freight planning.

Table 12. Alternative out-of-scope methodologies.

Commodity	Source	Data Source(s)	Strengths	Weaknesses
Farm-Based Commodities (Potatoes)	National Cooperative Freight Research Program (NCFRP) Report 26	• Origin-destination truck surveys. • Agricultural surveys on acreage and production from the Washington State Department of Agriculture. • Industry feedback from the Washington State Potato Commission on the potato supply chain including destinations and routes. • U.S. Census Bureau Population and Housing Unit Estimates.	The approach models commodity flows based on their associated supply chains, potentially resulting in a more accurate picture of the OOS commodity flow.	Because the approach focuses on only a single farm-based commodity, it is not easily scaled up to the national level. Furthermore, because this method relies on an origin-destination survey, direct application at the national scale would require multiple origin-destination surveys specific to each farm-based commodity.
Farm-Based Commodities (Cattle, Grain Sorghum and Corn, and Chickens)	University of Texas at Austin Center for Transportation Research	• USDA Census of Agriculture. • USDA National Agricultural Statistics Service (NASS) Reports. • USDA Grain Inspection, Packers, and Stockyards Administration Data. • USDA Meat Animals Production, Disposition, and Income Data. • Various state agricultural databases. • Various industry group reports.	The approach models commodity flows based on their associated supply chains, potentially resulting in a more accurate picture of the OOS commodity flow.	Because the approach focuses on only a single farm-based commodity, it is not easily scaled up to the national level. Applying this method at the national scale would require extensive data collection for numerous commodities.

Table 12. Alternative out-of-scope methodologies (continuation).

Commodity	Source	Data Source(s)	Strengths	Weaknesses
Logs	National Center for Freight & Infrastructure Research & Education	• GPS data on logging truck movements. • Logging truck trip diaries.	The approach tracks the movements of logging shipments from a timber-producing region that is based on firsthand data.	The approach does not actually develop an origin-destination matrix of log commodity flows.
Logs	University of Texas at Austin Center for Transportation Research	• Data on timber production from Forest Inventory Data Online (FIDO). • Sawmill location data from the Texas A&M Directory of Forest Product Industries, Texas A&M Harvest Trends, Primary Forest Products Network, and USDA. • Revenue data on mills from the Texas Workforce Commission (TWS) Socrates Database. • Data on timber shipments between States from the USDA Forest Service Southern Research Station.	The approach models log commodity flows based on their associated supply chains, potentially resulting in a more accurate picture of the out-of-scope portion of the commodity flow. In addition, it can be scaled to the national level.	This approach requires the collection of more data than is currently gathered to model log commodity flows.
Municipal Solid Waste	New York Metropolitan Transportation Council (NYMTC)	• Facility-level volumes on received materials and information on the locations and functions of waste handling facilities from the New York State Department of Environmental Conservation 2010 Beyond Waste: A Sustainable Materials Management Strategy for New York State Report.	The NYMTC approach produces an origin-destination matrix of MSW flows for the metropolitan region, similar to what is desired and ultimately produced for the FAF4. Thus, it is directly applicable to the FAF4.	Despite its applicability, the NYMTC approach does not offer many new techniques or data sources beyond what already is employed by the FAF4.

Table 12. Alternative out-of-scope methodologies (continuation).

Commodity	Source	Data Source(s)	Strengths	Weaknesses
Diesel Fuel	National Cooperative Freight Research Program (NCFRP) Report 26	• Cardlock facility location information from private-sector companies. • Data on the location and capacity of underground storage tanks from the Washington State Department of Ecology. • U.S. Environmental Protection Agency on above-ground storage tanks. • Washington State Department of Revenue data on the location of active terminals.	The methodology employs many of the same techniques observed in the FAF4 and results in a detailed origin-destination matrix for diesel fuel flows at the State level.	The NCFRP approach does not provide many new techniques or data sources that could potentially aid the development of out-of-scope crude petroleum shipments in the FAF4.
Natural Gas		• U.S. Energy Information Agency (EIA) data on LNG processing and storage facilities. • U.S. EIA data on inter- and intrastate flows of natural gas. • U.S. EIA data on international and domestic demand for LNG. • U.S. EIA data on pipelines.	The PHMSA framework focuses on LNG movements, which do not appear to be explicitly considered in the FAF4 OOS methodology beyond LNG imports from Canada and Mexico.	The framework focuses only on LNG and no other form of natural gas. Also, it focuses on domestic surface transportation modes, namely truck and rail, as opposed to pipelines which transport the bulk of natural gas.

(Source: Federal Highway Administration.)

CHAPTER 4. SUMMARY OF FINDINGS AND APPROACHES FOR IMPROVEMENT

The Freight Analysis Framework Version 4 (FAF4) relies on several different types of data gathered from various sources. However, the majority of data come from other Federal agencies, namely the U.S. Census Bureau, National Agricultural Statistics Service, National Oceanic Atmospheric Administration, U.S. Forest Service, Bureau of Transportation Statistics, U.S. Bureau of Economic Analysis, and the U.S. Energy Information Agency. Just as the majority of data for the FAF4 comes from a relatively small number of Federal agencies, it also uses data from relatively few sources within those agencies. The primary data sources are the Commodity Flow Survey, Economic Census, Census of Agriculture, Vehicle Inventory and Use Survey (VIUS), County Business Patterns, and the American Community Survey. These data sources are broadly used across out-of-scope (OOS) commodity methodologies.

In reviewing the data and methodologies used to develop the out-of-scope commodity flows, the project team identified limitations/opportunities for improvement as presented in table 13. Largely, these insights can be summarized into one of three categories: 1) Sufficiency of Current Data; 2) Availability of Data in the Future; and 3) Appropriateness of Methodological Approach. The first category, Sufficiency of Current Data, addresses the challenges that U.S. Department of Transportation (USDOT) faces in obtaining data that is of sufficient quality (in terms of accuracy, spatial resolution, and frequency of updates, among others). One of the most significant issues related to data quality is that the estimation processes for farm-based and service commodities rely on the VIUS. Given that the 2002 version represents the most recent VIUS, it is possible that the underlying industry-specific logistics patterns regarding vehicle types and operating distances that are captured in the VIUS have changed. The potential impact of this is large given that farm-based shipments represent a considerable amount of commodity flows in terms of tonnage and value as shown in table 10.

Regarding the second challenge, Availability of Data in the Future, some out-of-scope commodities rely on data inputs from sources with unclear plans for future data collection efforts. For instance, both municipal solid waste (MSW) and construction and demolition (C&D) commodity flows utilize data from the biannual *BioCycle State of Garbage in America Survey* conducted by the Earth Engineering Center at Columbia University. Prior to Columbia University, the survey was conducted by the BioCycle Journal. Given the transition and that some survey years were missed prior to the transition, the future status of the survey and its update frequency are unclear. The VIUS similarly represents an availability challenge as it is not feasible to use the 2002 results in perpetuity.

The last challenge to estimating out-of-scope commodity flows is the Appropriateness of Methodological Approach. These are fewer pressing challenges than those associated with data and primarily relate to assumptions made about the magnitude of retail and service commodity flows by truck and the shipment distances of logging and fishery commodities. For retail and service commodity flows, the FAF4 assumes that a portion of brick-and-mortar sales and services results in a truck shipment in an amount that varies by the specific type of good (e.g., furniture, clothing, etc.). However, no supporting information is provided to justify this assumption and the exact assumed shares by commodity group are given. Regarding fishery and logging shipments, the FAF4 assumes that all shipments occur within the FAF4 zone that the port or timber-producing site is located. Based on the case studies, though these commodities are likely to be transported over relatively short distances (as assumed in the FAF4), they may cross State lines as the political boundaries do not affect the supply chain decisions for these commodities.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods.

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Farm-Based Shipments	• Value of agricultural production at the statewide and county levels. • Volume-to-weight conversion factors. • Commodity Flow Survey zones originating agricultural shipments. • Distribution of average shipment distances by truck and commodity type.	• Census of Agriculture. • Agricultural Statistics. • Vehicle Inventory and Use Survey.	• Among other data sources, the estimation of farm-based Origin-Destination (O-D) flows rely on the Vehicle Inventory and Use Survey (VIUS), which is discontinued. This creates the possibility that while the overall analytical estimation process may be sound, the underlying industry logistics practices (in terms of the average distances farm-based shipments are transported) that are reflected in the VIUS may have changed. If those patterns have changed, then the FAF4 does not estimate for these O-D flows that are as accurate as would be given more recent data. • For each farm-based commodity, the FAF4 assumes that the destination regions for a commodity are those that originate a product derived from that farm-based commodity. An alternative methodology may be to base the destinations of farm-based commodities on the locations of out-of-scope facilities within the supply chain.
Fishery Shipments	• Value and tonnage of fishery landings at the statewide level. • Value and tonnage of fishery landings at the top 104 ports.	• Fisheries of the United States.	• The FAF4 assumes that all fishery shipments are local (i.e., within a FAF4 zone) as processing facilities tend to be proximate to ports. While this is likely an accurate assumption, there may be port areas that straddle State boundaries and contain local processing facilities in two or more States. An alternative methodology is to allow fishery shipments to cross state lines.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Logging Shipments	• Board feet of timber produced at the county level. • Board feet of timber produced at the county level in the States of California and Nevada. • Board feet-to-tons conversion factors.	• Various State reports from the Forest Inventory Data Online database. • Timber Product Output. • Various State and Region Price Reports.	• The FAF4 assumes that all logging shipments are local (i.e., within a FAF4 zone) as processing facilities tend to be proximate to timber producing sites. While the literature confirms this assumption, it also revealed that there are timber-producing areas that straddle State boundaries and contain processing facilities in two or more States. In those areas, freshly harvested logs may be transported over state lines. • An alternative methodology is to base the destinations of freshly harvested logs on the locations of mills in the timber-producing region and to allow logging shipments to cross state lines.
Municipal Solid Waste (MSW) Shipments	• Tonnage of MSW produced at the county and statewide levels for reporting States. • Tonnage of MSW moved across State borders. • Destinations of MSW moved across State borders. • Tonnage of MSW produced at the county and statewide levels for nonreporting States. • Population growth. • County-level population.	• Various State Annual MSW Reports. • *BioCycle State of Garbage in America Survey.* • U.S. Census American Community Survey.	• Not all States produce municipal solid waste reports. Furthermore, the current status of the State of Garbage in America Survey is unclear. Determining if this data source will continue to be available in future years is important for modeling MSW commodity flows.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Construction and Demolition (C&D) Debris Shipments	• Tonnage of C&D produced at the county and statewide levels for reporting States. • Tonnage of C&D moved across State borders. • Destinations of C&D moved across State borders. • Tonnage of C&D produced at the county and statewide levels for nonreporting States. • Population growth. • County-level population. • C&D recycling rates.	• Various State Annual MSW Reports • *BioCycle State of Garbage in America Survey* • U.S. Census American Community Survey. • *The Benefits of Construction and Demolition Materials Recycling in the United States.*	• Not all States produce municipal solid waste reports. Furthermore, the current status of the State of Garbage in America Survey is unclear. Determining if this data source will continue to be available in future years is important for modeling C&D debris commodity flows. • Census data on new housing construction is potentially a new source of data on the locations of productions of C&D debris. Currently, the methodology for estimating these flows relies on a factor applied to the magnitude of MSW flows and assumes the same distribution patterns as MSW flows.
Retail Shipments	• Total retail sales. • Sales receipts by retail-related North American Industry Classification System (NAICS) industry sector. • Commodity value-to-weight ratios. • Payroll shares by retail-related NAICS industry sector.	• Annual Retail Trade Survey. • Economic Census. • Commodity Flow Survey Public Use Microdata. • County Business Patterns.	• The FAF4 methodology for estimating out-of-scope retail shipments assumes that a share of retail sales by commodity result in a truck delivery. The method by which these assumed shares and the data supporting them are unclear. Industry outreach to retail sectors that historically generate home deliveries, such as furniture and home appliances, could provide more information on the magnitude of retail home deliveries.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Service Shipments	• Total service sales. • Sales receipts by service-related NAICS industry sector. • Commodity value-to-weight ratios. • Payroll shares by service-related NAICS industry sector. • Distribution of average shipment distances by truck and commodity type.	• Service Annual Survey • Economic Census • Commodity Flow Survey Public Use Microdata • County Business Patterns. • Vehicle Inventory and Use Survey.	• The FAF4 methodology for estimating out-of-scope service shipments assumes that a share of service sales by commodity result in a truck delivery. The method by which these assumed shares and the data supporting them are unclear. • The FAF4 approach also assumes that service shipments associated with NAICS industry subsectors 7111, 7112, and 71211, are destined for nearby major metropolitan areas only.
Household and Business Moves (HH&B)	• County-level migration flows. • Average household size by county. • Percentage of total moves that are business or self-moves. • Consumer durable goods involved in HH&B moves and their per-move average value.	• County-to-County Migration Flows, American Community Survey. • American Community Survey. • American Moving and Storage Association website. • Consumer Durable Goods Current Cost Net Stock. • Commodity Flow Survey Public Use Microdata.	• In the FAF4 methodology, all intracounty moves are assumed to be self-moves that do not involve trucks. This assumption could be investigated further to determine if it is accurate. Data from the American Community Survey or Current Population Survey could be used to estimate the household size of movers which may help to verify this assumption. • The average shipment value is based on national, as opposed to regional, averages. • Furthermore, the average value per household and business move is adjusted to remove items that are not likely to be transported by truck. However, the FAF4 documentation is unclear on what these items are.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Crude Petroleum Shipments	• Petroleum Administration for Defense District (PADD)-to-PADD movements. • Locations, operating capacities, and crude petroleum input to refineries. • Payroll shares for NAICS 211111 (Crude Petroleum and Natural Gas Extraction) industry sector. • Origins and destinations of transborder crude petroleum shipments. • Total amount of crude petroleum imported by U.S. companies. • Barrels of exported crude petroleum by destination country. • Barrels of exported crude petroleum by PADD.	• PADD Movements. • Refinery Net Input. • County Business Patterns. • Carload Waybill Sample. • Company-Level Imports. • Exports by Destination Country. • Exports by PADD.	• Refinery capacity is a proxy for actual county-level data on consumption, which requires that production-to-consumption flows be estimated via a gravity model.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Natural Gas Shipments	• Interstate and intrastate natural gas movements. • Locations and operating capacities natural gas receipt/delivery points. • Payroll shares for NAICS 211111 (Crude Petroleum and Natural Gas Extraction) industry sector. • Natural gas consumption by State and end-use sector. • Volume and value of natural gas imports and exports by State. • Locations of natural gas processing plants. • Population data, vehicle population data, and electric generating units.	• Natural Gas Annual. • Natural Gas Receipt/Delivery Points Database. • County Business Patterns. • U.S. Energy Information Administration (EIA) Natural Gas website. • Natural Gas Processing Plants Database • Ancillary Databases.	• The FAF4 uses several ancillary data sources that are not well-documented, including the locations and capacities of natural gas receipt/delivery points, vehicle population data, and electric generating units. Furthermore, it is not detailed in how mode is assigned, especially for domestic movements. Generally, the FAF4 seems to assign most natural gas flows to pipeline.

Table 13. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Data	Data Source	Limitations/Opportunities for Improvement
Foreign Trade Shipments	• Commodity shares for 1-Digit Standard Classification of Transported Goods (SCTG) groups. • Volume and weight of foreign trade by water and air. • Value and weight of foreign trade by all modes and State-level origins and destinations. • Volume-to-weight conversion factors. • Border crossings by mode. • Domestic mode distributions of freight shipments • Domestic mode for waterborne foreign shipments. • Payroll shares by NAICS industry sector. • Domestic destinations for foreign airborne shipments.	• USA Trade Online. • Special Tabulation of Foreign Trade Public Data. • Transborder Surface Freight Data. • Commodity Flow Survey. • Port Import/Export Reporting Service (PIERS): Bill of Lading Data for U.S. Imports and Exports. • County Business Patterns. • T-100 Market and Segment Data.	• Generally, foreign trade flow data on the domestic leg of shipments is lacking, requiring numerous assumptions and the use of professional judgment.

(Source: Federal Highway Administration.)

APPROACHES FOR FURTHER TESTING AND IMPLEMENTATION

Table 14 identifies short- and long-term data improvement activities for further testing and implementation. Short-term activities are those efforts that can be started relatively quickly and whose results can be readily applied to the OOS commodity flows without an extensive data collection and/or modeling effort. Long-term activities are those that require a more substantial effort in terms of data collection and analysis. Short-term activities are candidates for implementation and are detailed in chapter 5.

Table 14. Limitations and opportunities for improvement in current out-of-scope methods.

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Farm-Based Shipments	• Among other data sources, the estimation of farm-based O-D flows rely on the Vehicle Inventory and Use Survey (VIUS), which is discontinued. This creates the possibility that while the overall analytical estimation process may be sound, the underlying industry logistics practices (in terms of the average distances farm-based shipments are transported) that are reflected in the VIUS may have changed. If those patterns have changed, then the FAF4 does not estimates for these O-D flows that are as accurate as would be given more recent data.	• Federal Highway Administration (FHWA) could consider using components of the National Cooperative Freight Research Program (NCFRP) Report 26 and the Center for Transportation Research approaches to modeling farm-based commodity flows. Both of these methodologies use a supply chain approach where acreage/yield data (i.e., productions) is combined with processing facility location data (i.e., attractions) to model the initial movement in the supply chain. Importantly, this initial movement is equivalent to the out-of-scope movement that the Commodity Flow Survey (CFS) does not capture. Due to the age of the VIUS, a short-term improvement effort is to apply this methodology to a few farm-based commodities at the national level in order to determine its feasibility at that geographic scope.	Short-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Fishery Shipments	• The FAF4 assumes that all fishery shipments are local (i.e., within a FAF4 zone) as processing facilities tend to be proximate to ports. While this is likely an accurate assumption, there may be port areas that straddle State boundaries and contain local processing facilities in two or more States.	• The supply chain approach taken by the Center for Transportation Research (CTR) and NCFRP Report 26 methodologies could also be applied to fishery shipments. The out-of-scope movement, ports to processing facilities, could be modeled using facility location data rather than shipment distance distributions. This may be especially useful for ports near State borders if the FAF4 methodology is revised to allow these shipments to travel between FAF4 zones in different States. A short-term improvement effort is to test this methodology at the national level to determine its feasibility and if it produces more accurate results than the current FAF4 approach.	Short-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Logging Shipments	• The FAF4 assumes that all logging shipments are local (i.e., within a FAF4 zone) as processing facilities tend to be proximate to timber producing sites. While the literature confirms this assumption, there may be timber-producing areas that straddle State boundaries and contain processing facilities in two or more States.	• Like the FAF4 methodology, the CTR approach relies heavily on U.S. Forest Service data, especially for determining total production for logs. Researchers at both the CTR and the National Center for Freight and Infrastructure Research and Education (CFIRE) observed that while freshly harvested logs traveled relatively shorts distances for processing, those facilities could be located in other States. This is especially important for timber-producing regions that straddle State borders. A short-term improvement effort is to employ a methodology that relies on processing facility location data at the national level to determine its feasibility and if it produces more accurate results than the current FAF4 approach. Importantly, this approach would allow log shipments to travel nearby FAF4 zones in other States, consistent with what was observed by the CTR and CFIRE researchers.	Short-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Municipal Solid Waste (MSW) Shipments	• Not all States produce municipal solid waste reports. Furthermore, the current status of the State of Garbage in America Survey is unclear. • Also, the FAF4 documentation states that MSW flows are assumed to have no value. However, in the FAF4 commodity flows corresponding to waste have an associated value.	• Confirm the future availability of the BioCycle State of Garbage in America Survey with the Earth Engineering Center at Columbia University. If it may no longer be available or be available inconsistently, then a suitable replacement is needed, or a new data collection effort begun. One possibility is to reach out to States that do not produce annual reports to determine if there are internal reports that could be made available for the Freight Analysis Framework (FAF).	Long-Term
Construction and Demolition (C&D) Debris Shipments	• Not all States produce municipal solid waste reports. Furthermore, the current status of the State of Garbage in America Survey is unclear.	• Confirm the future availability of the BioCycle State of Garbage in America Survey with the Earth Engineering Center at Columbia University. If it may no longer be available or be available inconsistently, then a suitable replacement is needed, or a new data collection effort begun. One possibility is to reach out to States that do not produce annual reports to determine if there are internal reports that could be made available for the FAF. • In addition, Census data on new housing construction is potentially a new source of data on the locations of productions of C&D debris. Currently, the methodology for estimating these flows relies on a factor applied to the magnitude of MSW flows and assumes the same distribution patterns as MSW flows.	Long-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Retail Shipments	• The FAF4 methodology for estimating out-of-scope retail shipments assumes that a share of retail sales by commodity result in a truck delivery. The method by which these assumed shares and the data supporting them are unclear.	• Include technical details about exact shares that are applied in the FAF4 in the FAF technical publications. It would be beneficial to determine the magnitude of the impact of the truck delivery share assumption on the estimate of retail commodity flows by performing a sensitivity analysis. Lastly, the accuracy of the estimated could be improved by performing outreach to industry representatives, especially in retail sectors that have historically generated home truck deliveries such as furniture and appliances.	Long-Term
Service Shipments	• The FAF4 methodology for estimating out-of-scope service shipments assumes that a share of service sales by commodity result in a truck delivery. The method by which these assumed shares and the data supporting them are unclear. • The FAF4 approach also assumes that service shipments associated with NAICS industry subsectors 7111, 7112, and 71211, are destined for nearby major metropolitan areas only.	• Include technical details about exact shares that are applied in the FAF4 in the FAF technical publications. It would be beneficial to determine the magnitude of the impact of the truck delivery share assumption on the estimate of retail commodity flows by performing a sensitivity analysis. Lastly, the accuracy of the estimate could be improved by performing outreach to industry representatives. • Determine the magnitude of the impact of the assumption of shipment distances for commodities associated with the 7111, 7112, and 71211 NAICS industry subsectors. Also, perform outreach to industry representatives to determine the accuracy of this assumption.	Long-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Household and Business Moves (HH&B)	• In the FAF4 methodology, all intracounty moves are assumed to be self-moves that do not involve trucks. This assumption could be investigated further to determine if it is accurate. • The average shipment value is based on national, as opposed to regional, averages. • Furthermore, the average value per household and business move is adjusted to remove items that are not likely to be transported by truck. However, the FAF4 documentation is unclear on what these items are.	• Investigate the assumption that all intracounty moves are self-moves. Perform outreach to industry associations to gain a better understanding of its accuracy. • Developing region-specific average values of household and business moves could increase the accuracy of the FAF4 estimates. The sensitivity of HH&B commodity flow to value may be further explored to determine if region-specific values are a worthwhile pursuit. • A potential improvement may also be to use American Community Survey or Current Population Survey data to cross-tabulate migration flows with household size. The assumption would be that intracounty moves of small households are self-moves while those of larger households involve a truck.	Long-Term
Crude Petroleum Shipments	• Refinery capacity is a proxy for actual county-level data on consumption, which requires that production-to-consumption flows be estimated via a gravity model.	• FHWA could consider coordinating with the U.S. EIA to determine if data on county-level consumption of crude petroleum is available through special tabulations that preserve confidentiality while providing greater information than what is currently available. This is similar to the existing collaborative effort that FHWA has with the U.S. Census Bureau Foreign Trade Division.	Long-Term

Table 14. Limitations and opportunities for improvement in current out-of-scope methods (continuation).

OOS Commodity	Limitations/Opportunities for Improvement	Approaches for Improvement	Timeframe
Natural Gas Shipments	• The FAF4 uses several ancillary data sources that are not well-documented, including the locations and capacities of natural gas receipt/delivery points, vehicle population data, and electric generating units. Furthermore, it is not detailed in how mode is assigned, especially for domestic movements. Generally, the FAF4 seems to assign most natural gas flows to pipeline.	• In light of recent work by Pipeline and Hazardous Materials Safety Administration (PHMSA) and ongoing interest in transporting liquefied natural gas (LNG) by rail, there may need to be refinements to the natural gas methodology. Furthermore, work by PHMSA indicates that there are domestic movements of LNG by truck that may not be captured by the FAF4, though these numbers are likely small. Collaboration with PHMSA on the methodology to estimate natural gas flows could help to improve its accuracy.	Long-Term
Foreign Trade Shipments	• Generally, foreign trade flow data on the domestic leg of shipments is lacking, requiring numerous assumptions and the use of professional judgment.	• Progress was made between Freight Analysis Framework Version 3 (FAF3) and FAF4 in the estimation of foreign trade shipments through collaboration with the U.S. Census Bureau Foreign Trade Division. However, there is still a gap in information on the domestic legs of foreign shipments. FHWA could consider a long-term investment in a new data collection as well as collaboration with the U.S. Census Bureau Foreign Trade Division to shed more light on these movements.	Long-Term

(Source: Federal Highway Administration.)

CHAPTER 5. IMPLEMENTATION OVERVIEW

The first four chapters of this report evaluated current Freight Analysis Framework Version 4 (FAF4) methods for integrating Commodity Flow Survey out-of-scope data and identified alternative methodological approaches and data modeling these flows. Using the results of the examination of alternative methodologies, this and subsequent chapters develop and test alternative methodologies that potentially offer short-term improvements for estimating out-of-scope (OOS) commodity flows.

BACKGROUND

The project team conducted a review of efforts made by other researchers to model the movements of out-of-scope commodities. This section of the report contains an overview of the findings of that review. While the search focused on research efforts whose primary goal was the development of a commodity flow database for the out-of-scope commodities, it also included those efforts that attempted to capture the movements of out-of-scope commodities for other purposes. Though these studies did not explicitly attempt to model commodity flows, the insights gained from the modeling of vehicle movements is potentially useful to the FAF4. This is especially true considering the FAF4's reliance on the discontinued Vehicle Inventory and Use Survey (VIUS) for similar information.

National Cooperative Freight Research Program (NCFRP) Report 26: Guidebook for Developing Subnational Commodity Flow Data provided guidance for developing subnational commodity flow databases to meet transportation planning needs at the regional level. In developing a sub-national commodity flow database, the Guidebook argues that it is important to understand the supply chain associated with a commodity, including facilities involved in the processing of a commodity and the modes used in transporting a commodity across the supply chain. One example in the Guidebook is the development of a commodity flow database for potatoes in Washington State where, among other data, the locations of potato processing facilities to estimate the destinations of farm-based potato shipments. Data from stakeholder interviews were used to estimate the share of potatoes shipped by each mode.

The Center for Transportation Research (CTR) at the University of Texas at Austin (UT Austin), in cooperation with the Texas Department of Transportation and Federal Highway Administration (FHWA), released a study that developed a commodity-based approach for evaluating the value of a select group of commodities moved on the Texas freight network. The UT Austin researchers obtained unique data sources for the select commodities through online investigations and communication with industry representatives. From that data, the researchers estimated the quantity of commodities moved from their origins to their destinations, as well as the routes, transportation modes, and vehicle types used. The selected commodities included: cattle, grain sorghum and corn, chickens, and timber, among others. Importantly, movements of cattle, grain sorghum and corn, chickens, and timber from farms (or forests in the case of timber) all represent out-of-scope commodity movements.

Overall, the various methodologies developed as part of the UT Austin CTR study can be described as taking a supply chain approach to estimating OOS commodity flows. With this approach, OOS movements are based on the locations of the facilities that represent the first step in supply chain upon leaving the farm or forest (in the case of timber). For example, The UT Austin CTR study modeled grain sorghum and corn commodity flows from farms to grain elevators and them from grain elevators to cattle feedyards. The OOS movement of grain sorghum and corn was estimated by first determining the number of elevators in each county and estimating their capacity based on the number of employees. Flows were then distributed to each county using an algorithm that allocated county-level grain productions to its closest elevator until capacity was reached. Once capacity at the nearest elevator was reached, the algorithm then allocated the remaining production to the next closest elevator.

Similar procedures were developed for estimating flows logs from forests to sawmills and of chickens from farms to processing facilities and from farms to farms. The latter movement of chickens is important because in the context of the FAF4, it represents two OOS movements. Also important, the UT Austin CTR study observed that the first point of processing for timber harvested in Texas was often in counties in Louisiana and Arkansas near those states borders with Texas. This has implications for the FAF4 assumption that movements of logging shipments are internal to FAF4 zones, which do not cross state boundaries.

The next relevant study was conducted by researchers at the National Center for Freight and Infrastructure Research Education at the University of Wisconsin-Superior. This study collected data on the movements of log and chip trucks in the Upper Peninsula region of Michigan using global positioning systems (GPS) data. Its primary purpose was to identify opportunities to increase the efficiency of these movements in order to lower the overall transportation costs to shippers. An important observation of the study was that though the timber-harvesting sites were centered in the State of Michigan, there was overlap into the northeast portion of Wisconsin. This overlap includes the processing facilities to which the harvested timber was delivered. As observed in the review of the UT Austin CTR study, this has implications for the assumption in the FAF4 that movements of harvested timber occur within a FAF4 zone.

OPPORTUNITIES FOR ALTERNATIVE APPROACHES

Of the literature reviewed, the NCFRP Report 26 and the UT Austin CTR methodologies were the most applicable for developing alternative methodologies for the FAF4. Both methodologies can be viewed as supply chain-based approaches for modeling commodity flows as both relied on knowledge of commodity supply chains gathered from industry trade groups or academic literature. While the NCFRP Report 26 employed an origin-destination survey, the UT Austin CTR methodology primarily relied on third-party data sources.

Based on these two studies in particular, there are opportunities for alternative approaches based on the limitations of the data used and certain assumptions taken by the FAF4. For farm-based shipments, one of the most significant issues related to data quality is that the estimation process relies on the VIUS, which has been discontinued since 2002. It is possible that the underlying industry-specific logistics patterns regarding vehicle types and operating distances that are captured in the VIUS have changed. Both the UT Austin CTR and the NCFRP Report 26 offer alternative methodologies for farm-based shipments as neither rely on the VIUS.

The challenge with applying these methodologies at the national scale are the number of distinct farm-based commodities. There are 117 farm-based commodities included in the FAF4. Applying the NCFRP and UT Austin CTR methodologies of augmenting national data with local and supply chain data would require that the process be extended to all 117 of these commodities. Thus, recreating this type of analysis at the national level for all farm-based commodities would require an extensive new data collection given the vast number of crops that are included in farm-based shipments. An alternative is to apply a similar supply chain-based methodology to a smaller number of farm-based commodities that are large in magnitude relative to the scale of OOS flows, or that are deemed economically important from a national perspective. This approach is demonstrated in this report as a potential short-term improvement for the FAF4.

The literature review also revealed additional insight into the distribution patterns of freshly harvested logs. The FAF4 assumes that all shipments occur within the FAF4 zone that the port or timber-producing site is located. However, the results of the research conducted by the UT Austin CTR and the National Center for Freight and Infrastructure Research and Education (CFIRE) implied that though logging shipments from timber-producing sites are primarily local, they are not limited to FAF4 zones that end at State borders. In the case of timber producing regions such as Upper Peninsula of Michigan/North Wisconsin, southeastern Texas and western Louisiana and Arkansas, and South Georgia/North Florida, logging shipments may cross State lines into neighboring FAF4 zones to access processing facilities and/or rail spurs. Though the magnitude of these movements relative to other OOS commodity flows is relatively small, they are important for State and regional partner-agencies that utilize the FAF4 for statewide and regional freight planning.

CHAPTER 6. FARM-BASED SHIPMENTS OF CORN

METHODOLOGICAL APPROACH

The process for modeling out-of-scope (OOS) farm-based corn commodity flows is based on the portion of the supply chain that constitutes the out-of-scope movement. Like the University of Texas at Austin (UT Austin) Center for Transportation Research (CTR) study, this study assumes that after corn is produced on the farm, it is then transported to a grain elevator or other agricultural storage facility where it then becomes an in-scope commodity movement that is captured by the Commodity Flow Survey. The process uses the following data sources:

- United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS)—The USDA NASS provides county-level production for corn.
- Grain Elevator Location Data—Data on the locations and sizes of grain elevators at the county level. Grain elevators are included under North American Industry Classification System (NAICS) 493130 and 424510. The U.S. Census Bureau's County Business Patterns database is used as the source of this information.

Key methodological steps are depicted in figure 37 and are described below:

- **Estimate County Level Corn Production—**Using the USDA NASS data on county level productions, the amount of corn produced at the county level was estimated, P_i in figure 35. Importantly, at this point in the approach the methodology defines a set of production-consumption zones that set the boundaries for where farm-based shipments of corn may be attracted. In this sense, production-consumption zones place a ceiling on how far farm-based shipments of corn may travel.

- **Estimate County Level Corn Attractions—**First, using U.S. Census Bureau County Business Pattern (CBP) data, the number of grain elevators in each county was counted and its share of all grain elevators was calculated using the NAICS 493130 and 424510 industry codes. Then, the same was done for each county using payroll data from the U.S. Census Bureau CBP. In this sense, payroll data served as a proxy for elevator capacity. The share of grain elevator facilities and payroll for each county were then added and normalized so that the total sums to 100 percent. The combined shares were then rebalanced so that when summed the county level attractions, A_j in figure 35, equal the total share of corn produced in each production-consumption zone. In this manner, the grain elevator capacity of each county was estimated and accounted for in the methodological approach.

- **Distribute Corn Between Counties—**Farm-based corn commodity flows were then distributed to counties based on the proxy for grain elevator capacity using a gravity model as shown in figure 35. The travel time factor between counties, F_{ij} in figure 35, is equivalent to the impedance function in figure 36 normalized so that it sums to 1 across a given production county and all its destination consumption counties. Network distances between origin and destination counties were obtained from the Oak Ridge National Laboratory's

County Distance Database. An iterative proportional fitting routine was run until the productions and attractions converge.

$$T_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_{j=1}^{n} A_j F_{ij} K_{ij}}$$

Figure 35. Equation. Gravity model.
(Meyer and Miller, 2001.)

where *i,j* = counties.
T_{ij} = tons of commodities between counties *i* and *j*.
P_i = tons produced in county *i*.
A_j = tons attracted to county *j*.
F_{ij} = travel time factor between counties *i* and *j*.
K_{ij} = adjustment factor for commodity flows between counties *i* and *j*.

$$I_{ij} = \frac{1}{d_{ij} + d_{ij}^2}$$

Figure 36. Equation. Impedance function.
(Federal Highway Administration.)

where I_{ij} = impedance between counties *i* and *j*.
d_{ij} = Great Circle distance between counties *i* and *j*.

- **Aggregate to the Freight Analysis Framework Version 4 (FAF4) Zone Level**—After distribution, the county-level productions and attractions were aggregated to the FAF4 zone level.

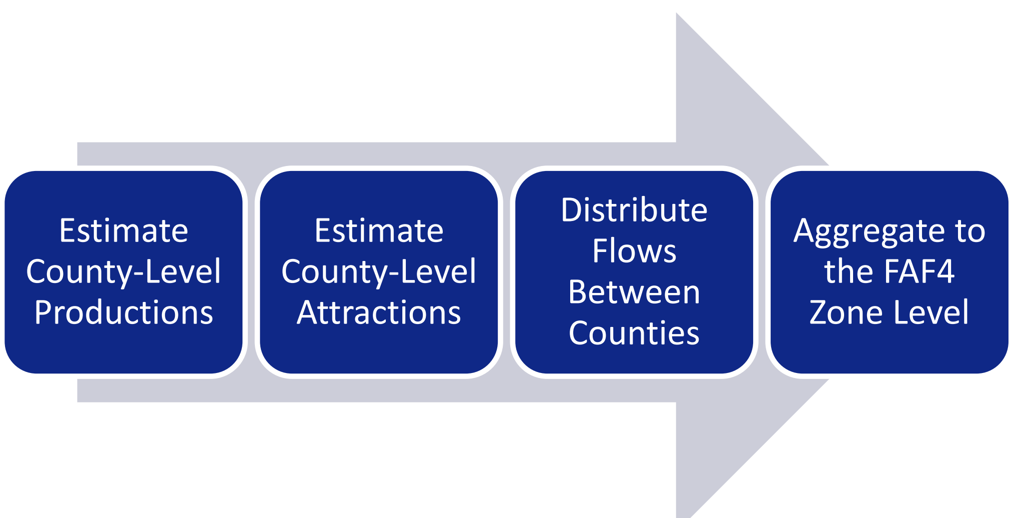

Figure 37. Flow chart. Framework for out-of-scope corn farm-based shipments.
(Source: Federal Highway Administration.)

RESULTS

Figure 38 depicts the assumed production-consumption zones for corn farm-based shipments. These zones were based on the clustering of counties that produce corn across states. Six production-consumption zones are defined for the contiguous U.S.: Northeast, Southeast, Heartland, Southwest, Mountain, and West Coast as shown in table 15. In keeping with the observation that farm-based shipments are primarily local, the methodology assumes that OOS movements of corn are distributed within these zones.

Table 15 States by zone for corn.

Zone	States	Zone	States
Northeast	• Connecticut. • Delaware. • District of Columbia. • Maine. • Maryland. • Massachusetts. • New Hampshire. • New Jersey. • New York. • Pennsylvania. • Rhode Island. • Vermont. • West Virginia.	Southwest	• Arizona. • Texas. • New Mexico. • Oklahoma.
Southeast	• Alabama. • Arkansas. • Florida. • Georgia. • Kentucky. • Louisiana. • Mississippi. • North Carolina • South Carolina. • Tennessee. • Virginia.	Mountain	• Idaho. • Nevada. • Utah. • Montana. • Wyoming.
Heartland	• Illinois. • Indiana. • Iowa. • Kansas. • Michigan. • Missouri. • Minnesota. • Nebraska. • North Dakota. • Ohio. • South Dakota. • Wisconsin.	West Coast	• California. • Oregon. • Washington.

(Source: Federal Highway Administration.)

Also depicted in figure 38 are the results of estimated corn production at the county level. For most counties, the 2017 USDA NASS data explicitly reports total production for each county. However, it aggregates data for other counties due to privacy concerns. For those counties, the amount of corn produced is apportioned equally among them. In total, over 413.6 million tons of shelled corn are estimated to have been produced in 2017. Of that total, the Heartland region produced the vast majority at 88 percent, followed by the Southeast at 6 percent, and the Southwest at over 2 percent. The Northeast, Mountain, and West Coast regions are estimated to have produced the remainder.

Figure 39 depicts the methodology's results for the estimation of corn farm-based attractions at the county level. In general, counties with higher numbers of farm product warehousing and storage establishments (NAICS 493130) and grain and field bean wholesalers (NAICS 424510) as indicated by U.S. Census Bureau County Business Pattern data attract higher amounts of corn farm-based shipments than others. By far the Heartland production-consumption zone has the highest share of these establishments in the U.S. at just under 60 percent. It is followed by the Southeast at just under 15 percent, the Southwest at approximately 9 percent, the West Coast at 8 percent, and the Northeast at 5 percent.

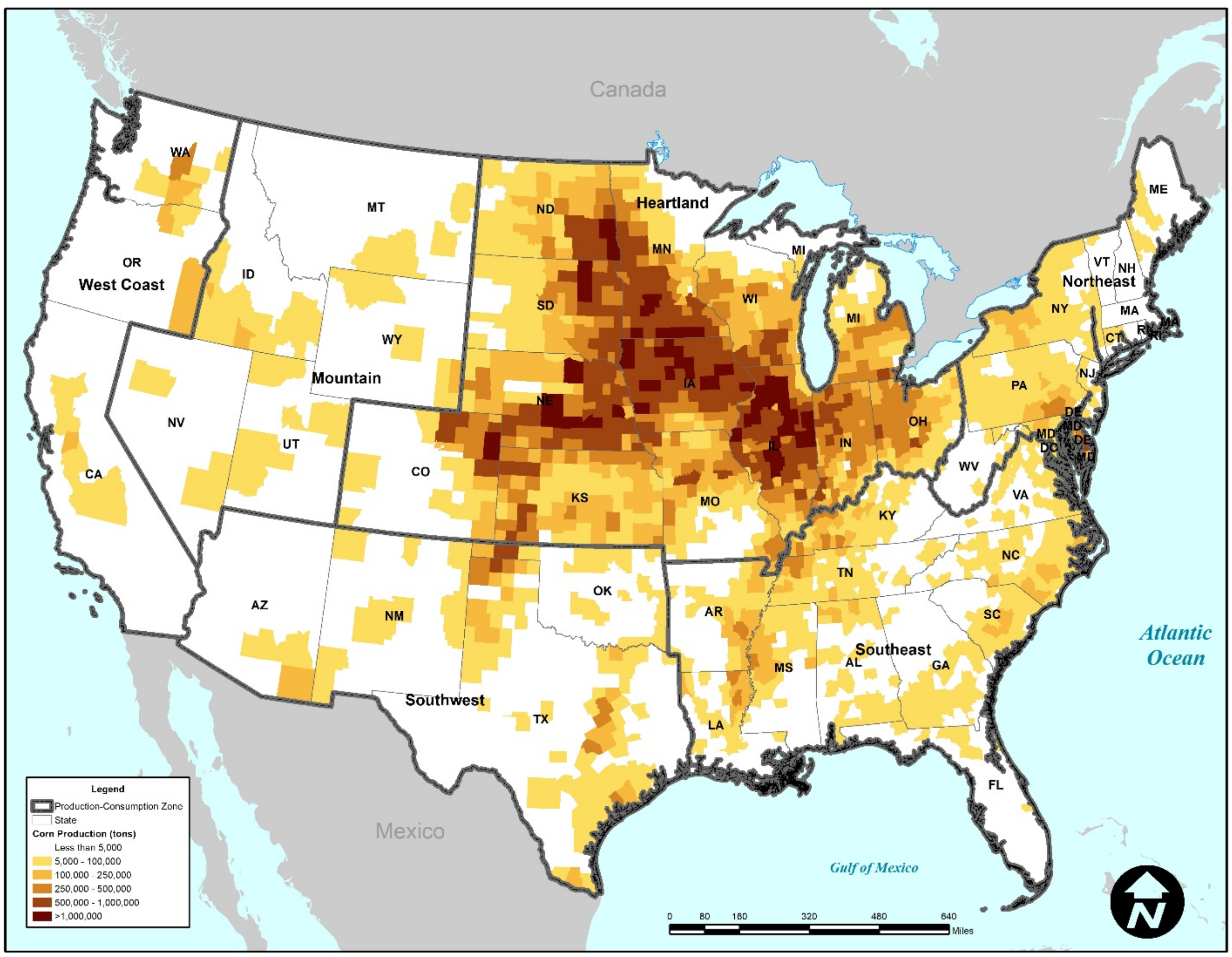

Figure 38. Map. Tons of shelled corn produced at the county level.
(Source: USDA NASS, 2017.)

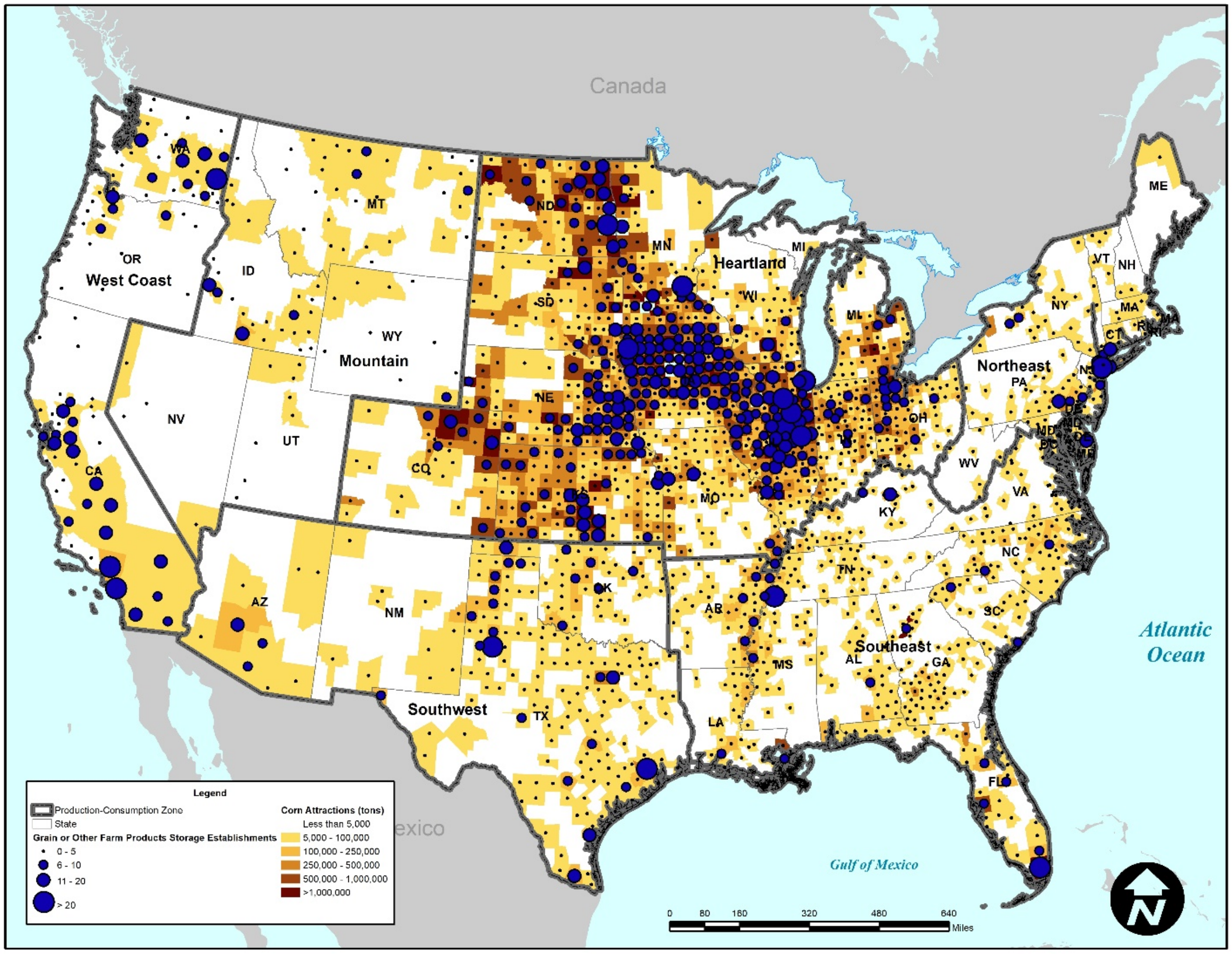

Figure 39. Map. Tons of shelled corn attracted at the county level.
(Source: USDA NASS, 2017; U.S. Census Bureau County Business Patterns, 2016.)

As an example, table 16 shows the results of the analysis of corn for the remainder of Illinois FAF4 zone. In total, over 69.8 million tons of corn are estimated to have an origin or destination within this zone. The results indicate that for the Remainder of Illinois zone nearly one-third (about 32 percent or over 22 million tons) of corn farm-based flows are internal. About 28 percent (19.7 million tons) of flows are inbound while the remainder (about 40 percent or over 28.1 million tons) is outbound. That the methodology estimates that nearly two-thirds of corn farm-based flows for this zone are either inbound or internal is reflective of its relatively large number of farm product warehousing and storage and grain and field bean wholesale establishments.

The results in table 16 also indicate that neighboring states with significant agricultural activity are relatively large receivers of corn farm-based shipments from the Remainder of Illinois zone. For example, the Remainder of Iowa zone is estimated to receive 20 percent of outbound corn farm-based flows from the Remainder of Illinois zone. The Remainder of Iowa FAF4 zone is estimated to be a similarly large shipper of corn farm-based shipments to the Remainder of Illinois zone at 22 percent.

Table 40 shows the distribution of tonnage by distance for all shipments in the Heartland production-consumption zone. The results indicate that about 26 percent of total tonnage travels 50 miles or less and over half (51 percent) travels 200 miles or less. About 81 percent of total tonnage for the Heartland zone is estimated to travel distances of 500 miles or less. The results are the same when viewed over the entire contiguous U.S. (see figure 41) since the Heartland zone produces the majority of U.S. corn. While this is largely consistent with the assumption in the current FAF4 process on distance thresholds for farm-based shipments, the draft methodology does result in about 12 percent of total tonnage traveling distances over 500 miles. In addition, the results indicate a sharp drop in the share of tonnage shipped over the 50–100 mile range. Most likely, this reflects the challenge of calibration as opposed to the underlying, real-world distribution pattern of the commodity.

Table 16. Results for the remainder of Illinois freight analysis framework version 4 zone.

	Outbound from Remainder of Illinois		**Inbound to Remainder of Illinois**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Denver-Aurora, CO Commodity Flow Survey (CFS) Area	191,678	1%	10,237	<1%
Remainder of Colorado	349,899	1%	119,980	1%
St. Louis-St. Charles-Farmington, MO-IL CFS Area (IL Part)	816,046	3%	625,614	3%
Chicago-Naperville, IL-IN-WI CFS Area (IL Part)	2,319,283	8%	1,117,586	6%
Fort Wayne-Huntington-Auburn, IN CFS Area	216,319	1%	228,798	1%
Indianapolis-Carmel-Muncie, IN CFS Area	591,049	2%	712,306	4%
Remainder of Indiana	1,114,599	4%	2,590,053	13%
Chicago-Naperville, IL-IN-WI CFS Area (IN Part)	126,202	<1%	341,222	2%
Remainder of Iowa	5,615,863	20%	4,282,971	22%
Remainder of Kansas	2,047,425	7%	587,918	3%
Kansas City-Overland Park-Kansas City, MO-KS CFS Area (KS Part)	981,701	3%	64,500	<1%
Wichita-Arkansas City-Winfield, KS CFS Area	276,035	1%	33,349	<1%
Remainder of Michigan	695,130	2%	506,316	3%
Grand Rapids-Wyoming-Muskegon, MI CFS Area	88,761	<1%	145,290	1%
Detroit-Warren-Ann Arbor, MI CFS Area	238,095	1%	102,037	1%
Remainder of Minnesota	1,416,596	5%	1,330,563	7%
Minneapolis-St. Paul, MN-WI CFS Area (MN Part)	918,170	3%	286,474	1%
Remainder of Missouri	1,330,794	5%	1,231,217	6%

Table 16. Results for the Remainder of Illinois freight analysis framework version 4 zone (continuation).

	Outbound from Remainder of Illinois		Inbound to Remainder of Illinois	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Kansas City-Overland Park-Kansas City, MO-KS CFS Area (MO Part)	578,320	2%	168,236	1%
St. Louis-St. Charles-Farmington, MO-IL CFS Area (MO Part)	473,298	2%	79,795	<1%
Remainder of Nebraska	1,404,717	5%	1,466,821	7%
Omaha-Council Bluffs-Fremont, NE-IA CFS Area (NE Part)	1,065,282	4%	98,675	1%
Remainder of North Dakota	1,771,256	6%	265,087	1%
Remainder of Ohio	1,102,734	4%	531,034	3%
Cleveland-Akron-Canton, OH CFS Area	99,805	<1%	69,081	<1%
Cincinnati-Wilmington-Maysville, OH-KY-IN CFS Area (OH Part)	189,391	1%	58,764	<1%
Dayton-Springfield-Sidney, OH CFS Area	217,517	1%	188,479	1%
Columbus-Marion-Zanesville, OH CFS Area	180,829	1%	315,529	2%
Remainder of South Dakota	835,542	3%	710,897	4%
Remainder of Wisconsin	763,551	3%	1,182,553	6%
Milwaukee-Racine-Waukesha, WI CFS Area	121,930	<1%	223,522	1%
Total	**8,137,818**	**100%**	**9,674,902**	**100%**

(Source: Federal Highway Administration.)

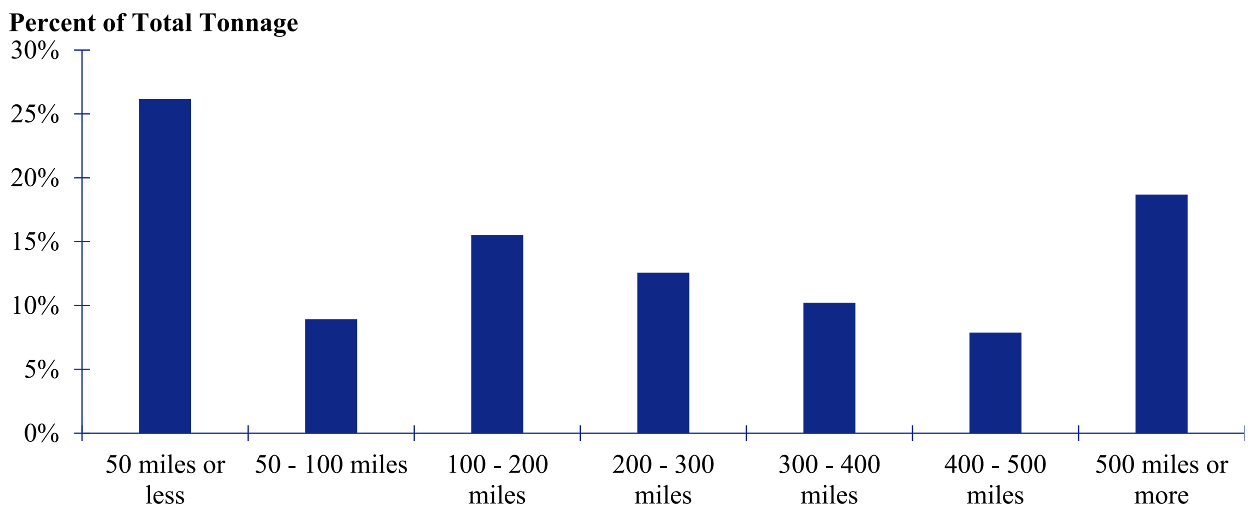

Figure 40. Bar chart. Distribution of shipment distances for farm-based shipments of corn in the Heartland zone.
(Source: Federal Highway Administration.)

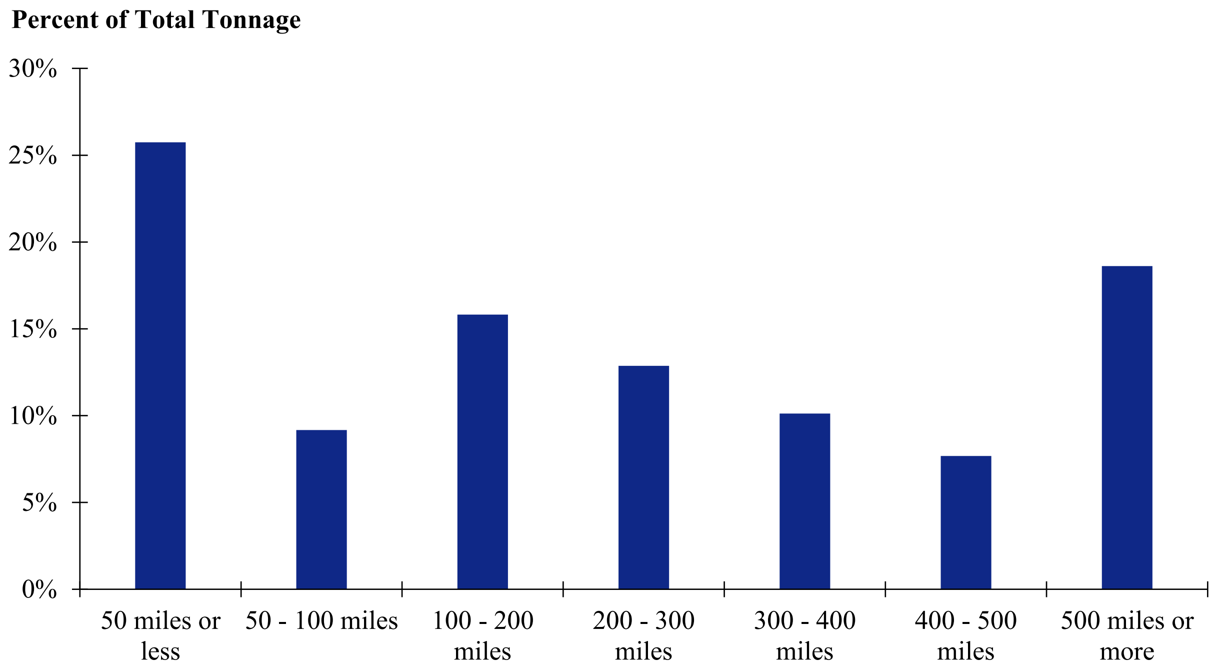

Figure 41. Bar chart. Distribution of shipment distances for farm-based shipments of corn in the contiguous U.S.
(Source: Federal Highway Administration.)

CHAPTER 7. FARM-BASED SHIPMENTS OF CHICKENS

METHODOLOGICAL APPROACH

The process for modeling chicken farm-based commodity flows is divided into two separate sub-processes—one for broilers and another for pullets. Broilers are raised for consumption while pullets are raised for breeding. After broilers are hatched in a hatchery, they are transported to broiler farms (where they continue to grow and develop) and then to processing facilities where they become an in-scope commodity. Similarly, after pullets are hatched they are then transported to either breeder farms (where they lay eggs that will eventually become broilers) or pullet breeder farms (where they lay eggs that will eventually become pullets). The sections that follow describe the data and the assumptions used to model this out-of-scope (OOS) commodity.

Broilers

The process for modeling OOS broiler farm-based commodity flows is based on the portion of the supply chain that constitutes the out-of-scope movement. Unlike other farm-based commodities examined as part of this study, broilers are assumed to feature two out-of-scope movements that must be captured: hatchery-to-farm and farm-to-processing. Once broilers reach a processing facility, it then becomes an in-scope commodity movement that is captured by the Commodity Flow Survey.

The process uses the following data sources:

- United States Department of Agriculture (USDA) National Agricultural Statistics Service—The USDA National Agricultural Statistics Service (NASS) provides county-level data on the amount of poultry hatched (measured in head) and state-level data on the number of broilers hatched (measured in chicks), and county-level data on the number of broilers inventoried.
- Poultry Processing Location Data—Data on the locations and sizes of poultry processing plants at the county level. Poultry processing plants are included under North American Industry Classification System (NAICS) 311615. The U.S. Census Bureau's County Business Patterns database is used as the source of this information.

Key methodological steps for hatchery-to-farm OOS movements are depicted in figure 37 and are described below:

- **Estimate County Level Broiler Production (Chicks Hatched)—**While data from USDA indicates the amount of poultry (i.e., chickens, turkeys, quails, etc.) hatched by county, it does not release that information for chicken broilers specifically at the county level. Instead, USDA publishes the number of chicken broilers hatched at the state level for the largest producing states. In this first step the methodology assumes that the share of broilers hatched by county is equal to the share of all poultry hatched by county. Furthermore, the number of broilers hatched is measured in chicks. In order to convert county level broiler productions to weight, the methodology assumes that a hatched broiler weighs approximately 0.25 pounds.

- **Estimate County Level Broiler Attractions**—Using USDA NASS data on county-level inventories of broilers, the number of hatched broilers attracted by county is estimated. With this step, the methodology is assuming that counties with inventories of broilers represent the locations of broiler farms. Though there is a NAICS code for establishments primarily engaged in raising broilers and other meat type chickens, this information is not publicly released due to privacy concerns. The analysis assumes that the number of broilers attracted to a county is proportional to its inventory. At this step in the process, production-consumption zones are defined which determine the physical extents that chicks may travel as shown in table 17.

- **Distribute Broilers Between Counties—**Farm-based broiler commodity flows were then distributed to counties based on their share of broiler inventories and the travel time factor between counties, F_{ij} in figure 35. Network distances between origin and destination counties were obtained from the Oak Ridge National Laboratory's County Distance Database. An iterative proportional fitting routine was run until the productions and attractions converge.

- **Aggregate to the Freight Analysis Framework Version 4 (FAF4) Zone Level—**After distribution, the county-level productions and attractions were aggregated to the FAF4 zone level.

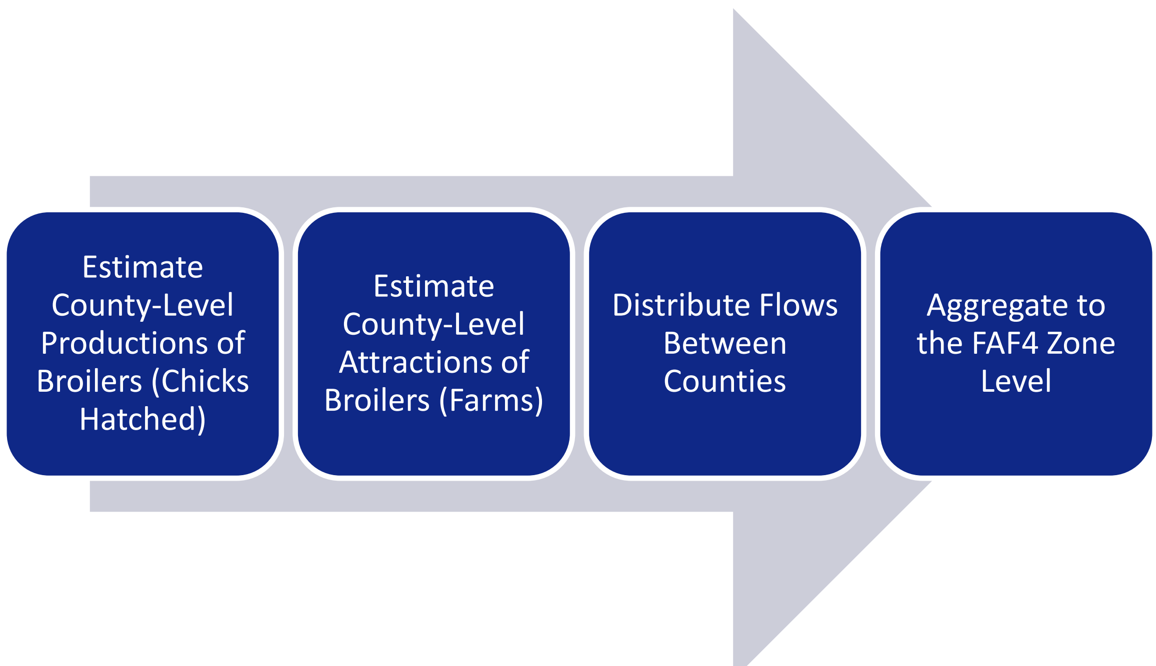

Figure 42. Flow chart. Framework for out-of-scope farm-based shipments of broilers—hatchery to farm.

(Source: Federal Highway Administration.)

Table 17. States by zone for chickens.

Zone	States
Northeast	• Connecticut. • Delaware. • District of Columbia. • Maine. • Maryland. • Massachusetts. • New Hampshire. • New Jersey. • New York. • Ohio. • Pennsylvania. • Rhode Island. • Vermont. • West Virginia.
Southeast	• Alabama. • Florida. • Georgia. • Kentucky. • North Carolina. • South Carolina. • Tennessee. • Virginia.
South Central	• Arkansas. • Louisiana. • Mississippi. • Oklahoma. • Texas.
Great Plains	• Kansas. • Nebraska. • North Dakota. • South Dakota.
North Central	• Illinois. • Indiana. • Iowa. • Michigan. • Missouri. • Minnesota. • Wisconsin.

Table 17. States by zone for chickens (continuation).

Zone	States
Intermountain	• Arizona. • Idaho. • Nevada. • New Mexico. • Utah. • Montana. • Wyoming.
California	• California.
Pacific Northwest	• Oregon. • Washington.

(Source: Federal Highway Administration.)

Key methodological steps for farm-to-processing OOS movements are depicted in figure 37 and are described below:

- **Estimate County Level Broiler Production—**For this movement, the number of broilers produced at the county level is estimated directly from the number of broilers attracted at the county level for hatchery-to-farm movements. Importantly, it is assumed that broilers increase in weight while awaiting processing. Broilers are assumed to increase in weight from an average of 0.25 pounds to 6 pounds before being shipped for processing.[59]

- **Estimate County Level Broiler Attractions—**Using U.S. Census Bureau County Business Pattern (CBP) data, the number of poultry processing establishments in each county was counted and its share of all establishments was calculated. Then, the same was done for each county using payroll data from the U.S. Census Bureau CBP. In this sense, payroll data served as a proxy for processing facility capacity. The share of poultry processing facilities and payroll for each county were then added and normalized so that the total sums to 100 percent. The combined shares were then rebalanced so that the when summed the county level attractions equal the total share of broilers produced in each production-consumption zone. In this manner, the poultry processing facility capacity of each county was estimated and accounted for in the methodological approach.

- **Distribute Broilers Between Counties—**Farm-based broiler commodity flows were then distributed to each county based on poultry processing facility capacity proxy and the travel time factor between counties. Great Circle distances between origin and destination counties were obtained from the National Bureau of Economic Research's County Distance Database. An iterative proportional fitting routine was run until the productions and attractions converge.

- **Aggregate to the FAF4 Zone Level—**After distribution, the county-level productions and attractions were aggregated to the FAF4 zone level.

[59] https://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-performance/.

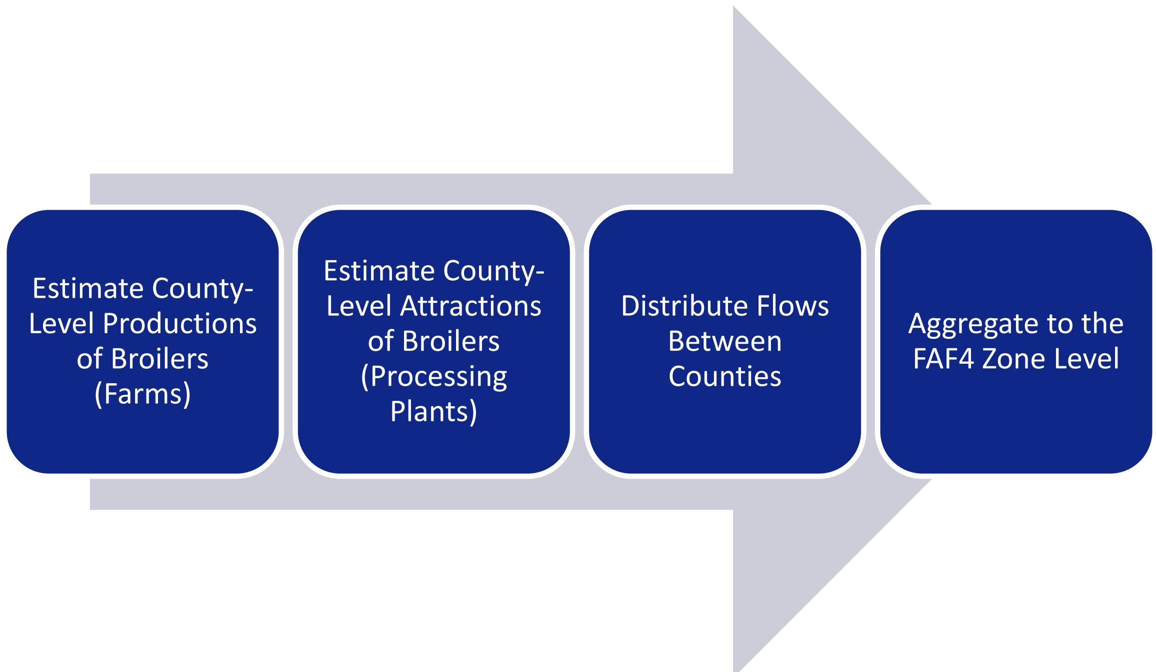

Figure 43. Flow chart. Framework for out-of-scope farm-based shipments of broilers—farm to processing.
(Source: Federal Highway Administration.)

Pullets

The process for modeling OOS pullet farm-based commodity flows is based on the portion of the supply chain that constitutes the out-of-scope movement. For pullets, the approach captures only the hatchery-to-farm movement though it is possible that pullets may also be subject to farm-to-farm movements. These farm-to-farm movements would not be captured in the Commodity Flow Survey, but eventually pullets are sent to a processing facility where it then becomes an in-scope commodity movement.

The process uses the following data sources:

- USDA National Agricultural Statistics Service—The USDA NASS provides county-level data on the amount of poultry hatched (measured in head) and state-level data on the number of broilers hatched (measured in chicks), and county-level data on the number of pullets sold (measured in head).

Key methodological steps for hatchery-to-farm OOS movements of pullets are depicted in figure 44 and are described below:

- **Estimate County Level Pullet Production (Chicks Hatched)**—As previously discussed for OOS movements of broilers, data from the USDA indicates the amount of poultry hatched by county but not for pullets specifically at the county or state levels. In this first step, the methodology assumes that counties hatch broilers and pullets at the same rate as they produced all other poultry. Additionally, the methodology assumes that the production-consumption zones for both broilers and pullets are the same.

- **Estimate County Level Pullet Attractions**—Using USDA NASS data on county-level sales of pullets (i.e., "Chickens, Pullets, Replacement – Sales Measured in Head"), the number of hatched pullets attracted by county is estimated.

- **Distribute Pullets Between Counties**—Farm-based broiler commodity flows were then distributed to counties based on their share of broiler inventories and the travel time factor between counties, F_{ij} in figure 35. Network distances between origin and destination counties were obtained from the Oak Ridge National Laboratory's County Distance Database. An iterative proportional fitting routine was run until the productions and attractions converge.

- **Aggregate to the FAF4 Zone Level**—After distribution, the county-level productions and attractions were aggregated to the FAF4 zone level.

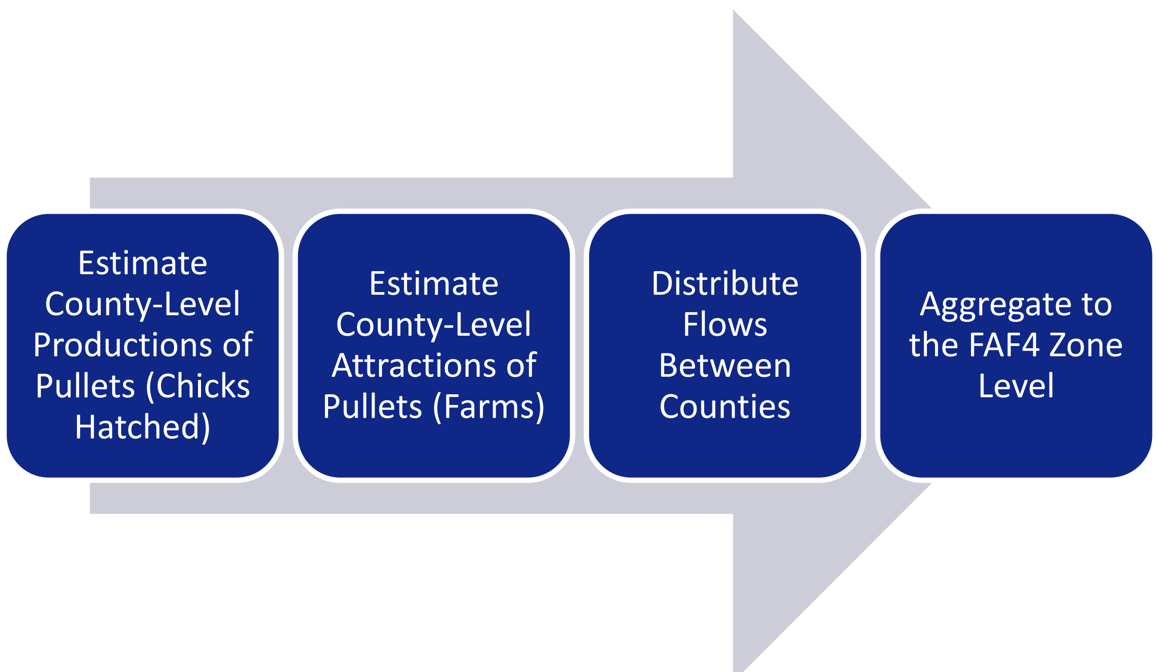

Figure 44. Flow chart. Framework for out-of-scope farm-based shipments of pullets—hatchery to farm.
(Source: Federal Highway Administration.)

RESULTS

Broilers

Figure 45 depicts the production-consumption zones for farm-based shipments of broilers which include for the contiguous U.S.: Northeast, North Central, Southeast, South Central, Intermountain, California, and Pacific Northwest. In keeping with the observation that farm-based shipments are primarily local, the methodology assumes that OOS movements of broilers are distributed within these zones. Also depicted in figure 45 are the results of estimated broiler production, in terms of tons of chicks hatched, at the county level. In total, over 1.2 million tons of broilers are estimated to have been produced (i.e., hatched) in 2017. Of that total, the Southeast region produced the most at 48 percent, followed by the South Central region at 31 percent, and the Northeast at 8 percent. While these data are reported at the state level, they are not reported at the county level which is the basis for the analysis methodology. In order to estimate the number of broilers hatched at the county level, the analysis assumes that counties hatch broilers in proportion to the amount of all poultry hatched.

As shown in table 18, nearly 56 percent of all broilers were hatched in the states of Georgia, Alabama, Arkansas, North Carolina, and Mississippi based on data from the USDA Chicken and Eggs Report. For hatchery-to-farm movements, the analysis assumes that broilers are transported from counties in which they are hatched to counties in which they are inventoried (i.e., "Chickens, Broilers—Inventory" in the USDA NASS database). It further assumes that the number of broilers attracted to a county is proportional to its inventory. As depicted in figure 46, these flows are broadly distributed across the Southeast and South Central zones.

Table 18. Broilers hatched in 2017.

State	Chicks (1,000 chicks)	Percent of Total
Georgia	1,487,111	15%
Alabama	1,286,677	13%
Arkansas	1,009,286	10%
North Carolina	943,885	10%
Mississippi	786,808	8%
Texas	694,855	7%
Missouri	357,703	4%
Maryland	353,891	4%
Oklahoma	321,195	3%
Kentucky	321,034	3%
Virginia	281,827	3%
South Carolina	240,727	3%
Delaware	210,622	2%
Pennsylvania	207,034	2%
Louisiana	152,788	2%
Florida	50,268	1%
California, Tennessee, & West Virginia	513,927	5%
Other States	392,946	4%
Total	**9,612,584**	**100%**

(Source: USDA, Chicken and Eggs Report, 2/28/2017–1/23/2018.)

As an example, table 19 shows the results of the analysis of hatchery-to-farm farm-based shipments for the Remainder of Georgia FAF4 zone. In total, over 200,000 tons of broilers are estimated to have an origin or destination within this zone. The results indicate that for the Remainder of Georgia zone nearly 35 percent, or about 71,000 tons, of hatchery-to-farm farm-based shipments of broilers are internal. About 40 percent (over 78,000 tons) of flows are outbound while the remainder (about 25 percent or over 51,000 tons) is inbound.

The results in table 19 also indicate that neighboring states with significant agricultural activity are relatively large receivers of hatchery-to-farm farm-based shipments of broilers from the Remainder of Georgia zone. For example, Remainder of Alabama is estimated to receive 39 percent of outbound hatchery-to-farm flows from Remainder of Georgia. The Remainder of Alabama FAF4 zone is estimated to be a similarly large shipper of hatchery-to-farm farm-based shipments of broilers to Remainder of Georgia at 46 percent.

Figure 47 shows the distribution of tonnage by distance for hatchery-to-farm farm-based shipments of broilers in the Remainder of Georgia zone. The results indicate that about 20 percent of total tonnage travels 50 miles or less and about 63 percent travels 200 miles or less. About 95 percent of total tonnage for the Southeast zone is estimated to travel distances of 500 miles or less.

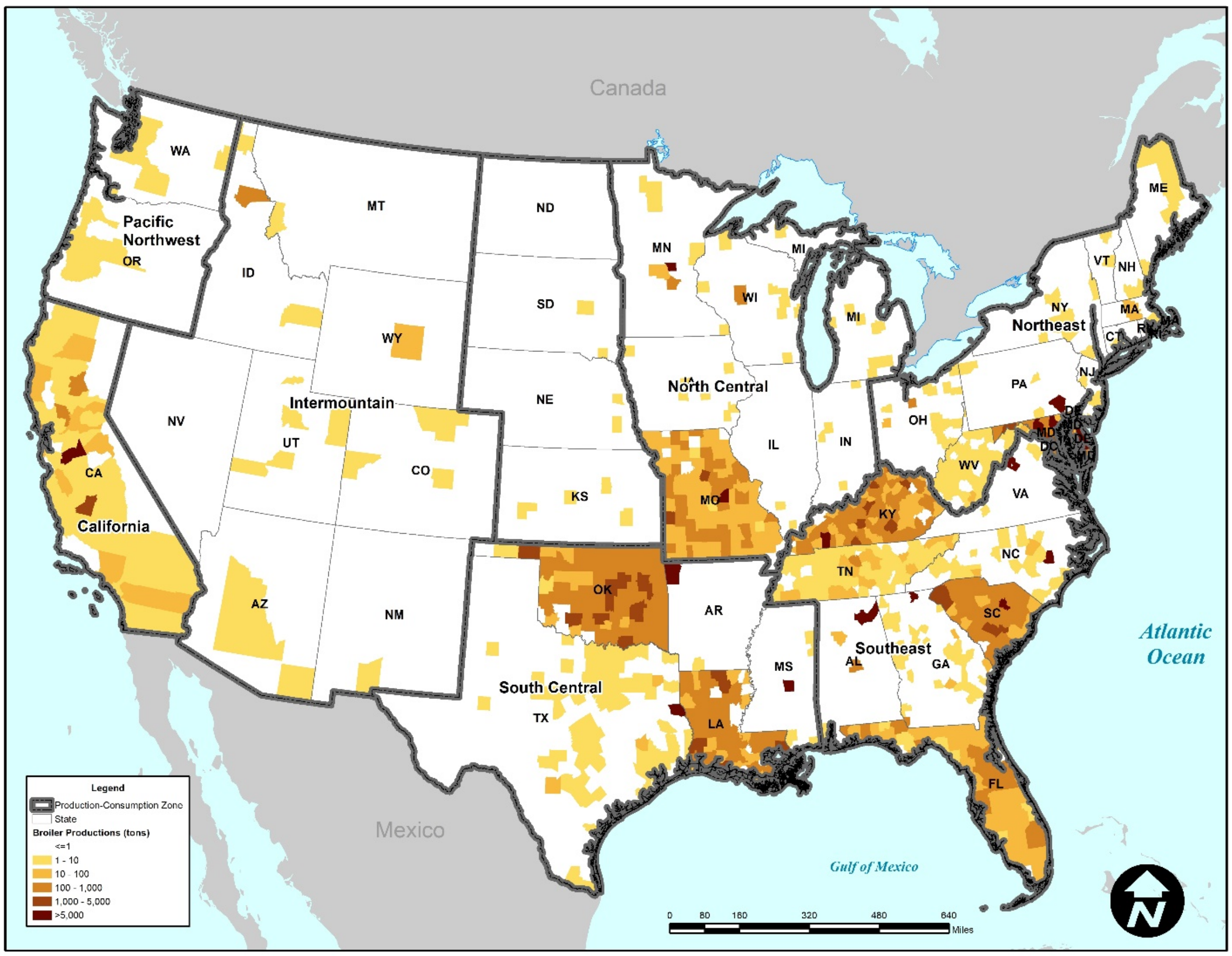

Figure 45. Map. Tons of broilers produced at the county level.
(Source: USDA NASS, 2017.)

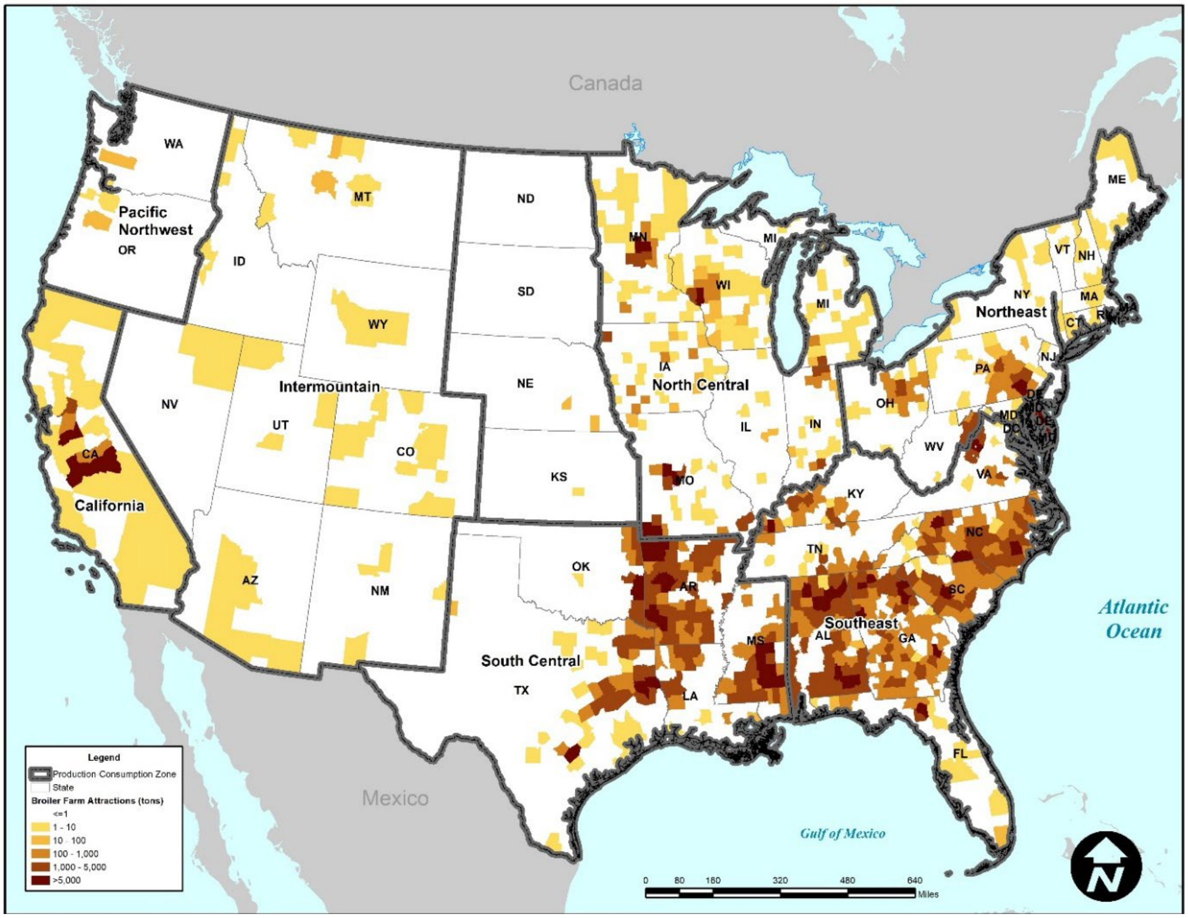

Figure 46. Map. Tons of broilers attracted at the county level for hatchery-to-farm movements. (Source: USDA NASS, 2017.)

Table 19. Hatchery-to-farm results for broilers for the remainder of Georgia freight analysis framework version 4 zone.

	Outbound from Remainder of Georgia		**Inbound to Remainder of Georgia**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Remainder of Alabama	30,517	39%	23,307	46%
Mobile-Daphne-Fairhope, AL Commodity Flow Survey (CFS) Area	602	1%	<1	<1%
Birmingham-Hoover-Talladega, AL CFS Area	3,190	4%	47	<1%
Remainder of Florida	2,681	3%	756	1%
Jacksonville-St. Mary's-Palatka, FL-GA CFS Area (FL Part)	<1	<1%	247	<1%
Miami-Fort Lauderdale-Port St. Lucie, FL CFS Area	2	<1%	244	<1%
Orlando-Deltona-Daytona Beach, FL CFS Area	1	<1%	685	1%
Tampa-St. Petersburg-Clearwater, FL CFS Area	<1	<1%	328	1%

Table 19. Hatchery-to-farm results for broilers for the remainder of Georgia freight analysis framework version 4 zone (continuation).

	Outbound from Remainder of Georgia		Inbound to Remainder of Georgia	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Atlanta-Athens-Clarke County-Sandy Springs, GA CFS Area	36,221	46%	13	<1%
Savannah-Hinesville-Statesboro, GA CFS Area	218	<1%	13	<1%
Remainder of Kentucky	4,829	6%	3,309	6%
Cincinnati-Wilmington-Maysville, OH-KY-IN CFS Area (KY Part)	<1	<1%	392	1%
Louisville/Jefferson County-Elizabethtown-Madison, KY-IN CFS Area (KY Part)	38	<1%	555	1%
Greensboro-Winston-Salem-High Point, NC CFS Area	–	0%	1	<1%
Remainder of North Carolina	–	0%	11,792	23%
Charlotte-Concord, NC-SC CFS Area (NC Part)	–	0%	2	<1%
Raleigh-Durham-Chapel Hill, NC CFS Area	–	0%	3	<1%
Greenville-Spartanburg-Anderson, SC CFS Area	–	0%	4,085	8%
Remainder of South Carolina	–	0%	2,744	5%
Charleston-North Charleston-Summerville, SC CFS Area	–	0%	167	<1%
Knoxville-Morristown-Sevierville, TN CFS Area	–	0%	21	<1%
Nashville-Davidson-Murfreesboro, TN CFS Area	–	0%	30	<1%
Remainder of Tennessee	–	0%	56	<1%
Memphis, TN-MS-AR CFS Area (TN Part)	–	0%	2	<1%
Remainder of Virginia	–	0%	2,410	5%
Richmond, VA CFS Area	–	0%	<1	<1%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (VA Part)	–	0%	1	<1%
Virginia Beach-Norfolk, VA-NC CFS Area (VA Part)	–	0%	<1	<1%
Total	**78,301**	**100%**	**51,211**	**100%**

(Source: Federal Highway Administration.)

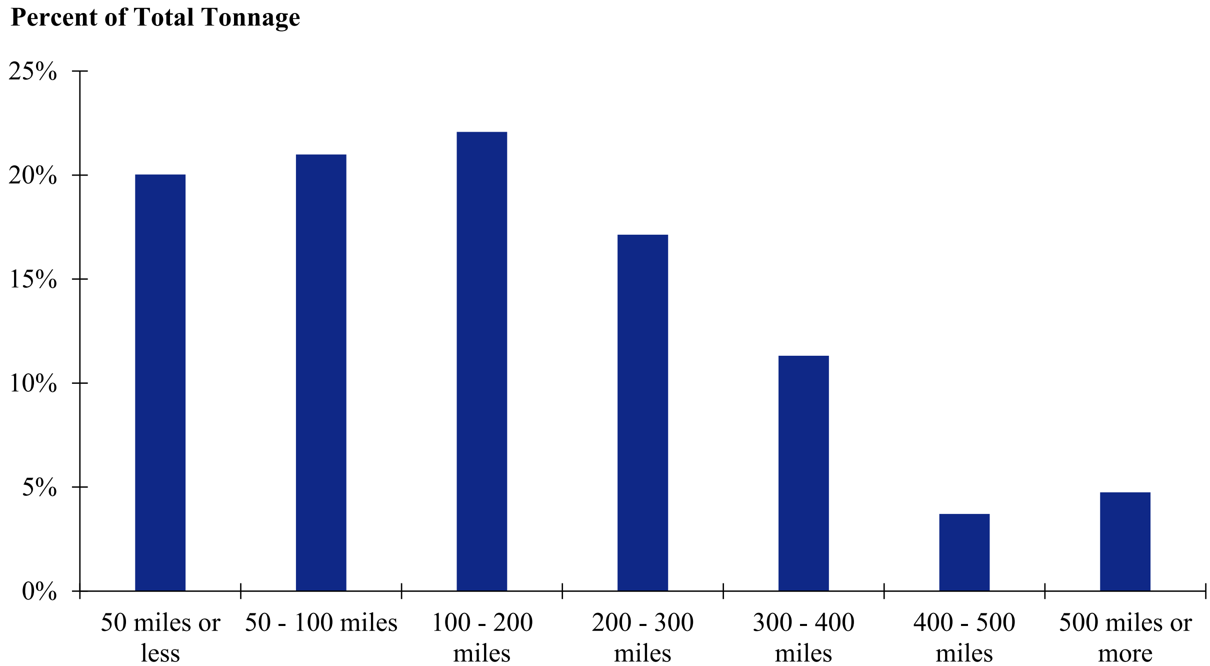

Figure 47. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the remainder of Georgia freight analysis framework version 4 zone. (Source: Federal Highway Administration.)

The estimation of farm-to-processing farm-based flows of broilers yielded results similar to hatchery-to-farm movements. In general, counties with higher numbers of poultry processing plants (NAICS 311615) as indicated by U.S. Census Bureau County Business Pattern data attract higher amounts of farm-to-processing farm-based shipments of broilers than others. As depicted in figure 48, poultry processing plants (and thus farm-to-processing flows) are concentrated in relatively few counties. Furthermore, these facilities also appear to be concentrated in FAF4 zones containing metropolitan regions as opposed to rural areas.

Table 20 shows the results of the analysis farm-to-processing farm-based shipments for the Remainder of Georgia FAF4 zone. In total, nearly 2.8 million tons of broilers are estimated to have an origin or destination within this zone. The reason for the growth in tonnage in between hatchery-to-farm and farm-to-processing movements is that broilers are assumed to increase in weight between these movements. The results indicate that for the Remainder of Georgia zone nearly 15 percent, or over 408,000 tons, of farm-to-processing farm-based shipments of broilers are internal. About 79 percent (over 2.1 million tons) of flows are outbound while the remainder (about 5 percent or over 153,000 tons) is inbound.

The results in table 20 also indicate that neighboring states with significant agricultural activity are relatively large receivers of hatchery-to-farm farm-based shipments of broilers from the Remainder of Georgia zone. For example, Remainder of Alabama is estimated to receive and ship 23 and 35 percent of farm-to-processing flows of broilers to and from Remainder of Georgia, respectively. Nearly three-quarters (or 74 percent) of outbound broiler shipments are estimated to be destined for the Atlanta-Athens-Clarke County-Sandy Springs, GA CFS Area

FAF4 zone which is estimated to contain a significant amount of poultry processing capacity in the Gainesville, GA area.

Figure 49 shows the distribution of tonnage by distance for farm-to-processing farm-based shipments of broilers in the Southeast production-consumption zone. The results indicate that about 33 percent of total tonnage travels 50 miles or less and about 68 percent travels 200 miles or less. About 96 percent of total tonnage for the Southeast zone is estimated to travel distances of 500 miles or less.

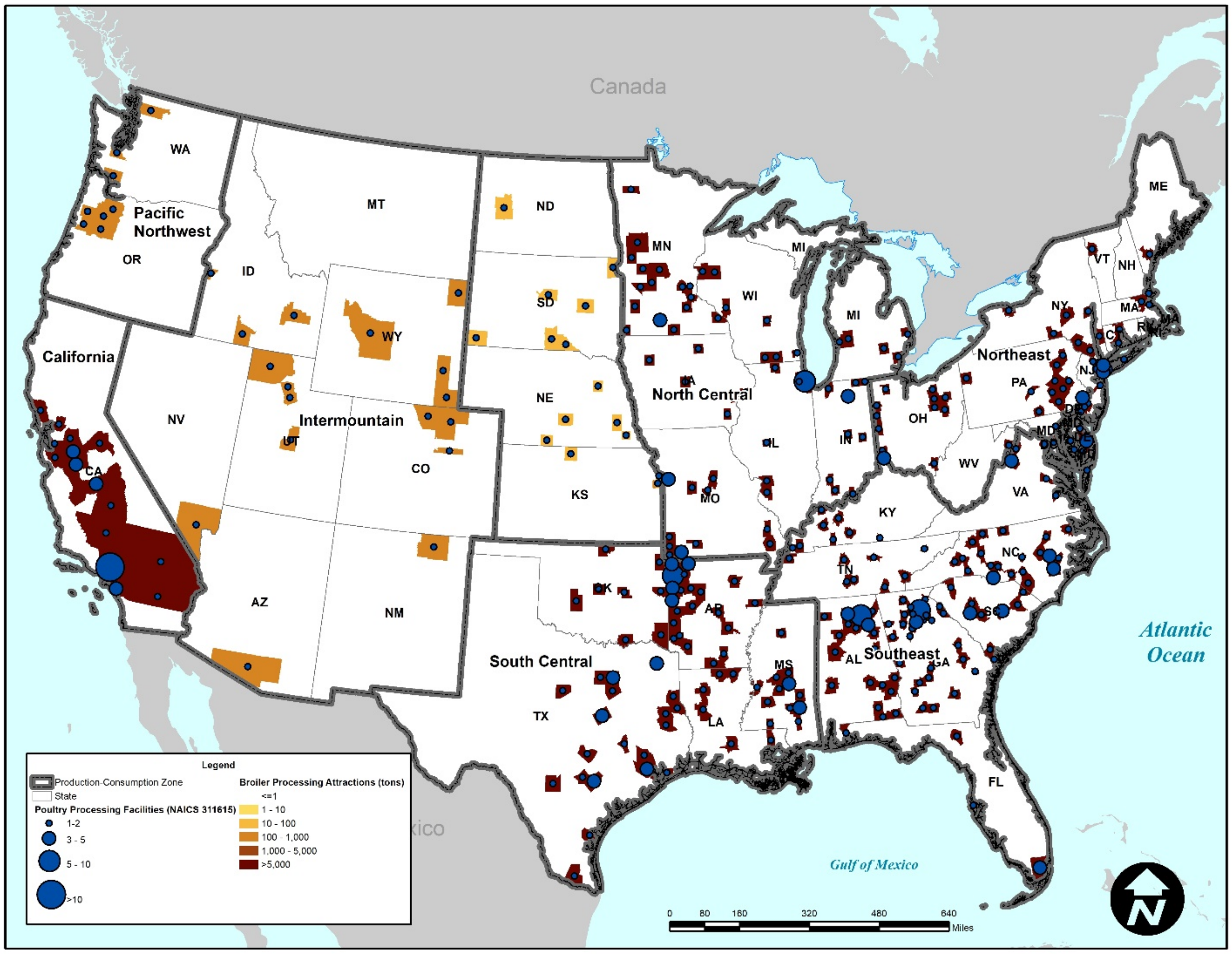

Figure 48. Map. Tons of broilers attracted at the county level for farm-to-processing movements. (Source: USDA NASS, 2017; U.S. Census Bureau County Business Patterns, 2016.)

Table 20. Farm-to-processing results for the remainder of Georgia freight analysis framework version 4 zone.

	Outbound from Remainder of Georgia		Inbound to Remainder of Georgia	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Remainder of Alabama	510,133	23%	53,047	35%
Mobile-Daphne-Fairhope, AL	–	0%	818	1%
Birmingham-Hoover-Talladega, AL	9,567	<1%	1,934	1%
Remainder of Florida	6,452	<1%	11,465	7%
Jacksonville-St. Mary’s-Palatka, FL-GA (FL Part)	–	0%	2	0%
Miami-Fort Lauderdale-Port St. Lucie	40,758	2%	1	<1%
Orlando-Deltona-Daytona Beach, FL	–	0%	4	<1%
Tampa-St. Petersburg-Clearwater, FL	12,612	1%	1	<1%
Atlanta-Athens-Clarke County-Sandy Springs, GA	1,633,467	74%	30,060	20%
Savannah-Hinesville-Statesboro, GA	–	0%	2,621	2%
Remainder of Kentucky	3,921	<1%	4,317	3%
Cincinnati-Wilmington-Maysville, OH-KY-IN (KY Part)	–	0%	3	<1%
Louisville/Jefferson County-Elizabethtown-Madison, KY-IN (KY Part)	–	0%	76	<1%
Greensboro-Winston-Salem-High Point, NC	–	0%	2,258	1%
Remainder of North Carolina	–	0%	16,767	11%
Charlotte-Concord, NC-SC (NC Part)	–	0%	2,387	2%
Raleigh-Durham-Chapel Hill, NC	–	0%	1,571	1%
Greenville-Spartanburg-Anderson, SC	–	0%	7,519	5%
Remainder of South Carolina	–	0%	13,873	9%
Charleston-North Charleston-Summerville, SC	–	0%	450	<1%
Knoxville-Morristown-Sevierville, TN	–	0%	183	<1%
Nashville-Davidson-Murfreesboro, TN	–	0%	300	<1%
Remainder of Tennessee	–	0%	3,278	2%
Memphis, TN-MS-AR (TN Part)	–	0%	<1	<1%
Remainder of Virginia	–	0%	393	<1%
Richmond, VA	–	0%	103	<1%
Washington-Arlington-Alexandria, DC-VA-MD-WV (VA Part)	–	0%	<1	<1%
Virginia Beach-Norfolk, VA-NC (VA Part)	–	0%	25	<1%
Total	**2,216,910**	**100%**	**153,457**	**100%**

(Source: Federal Highway Administration.)

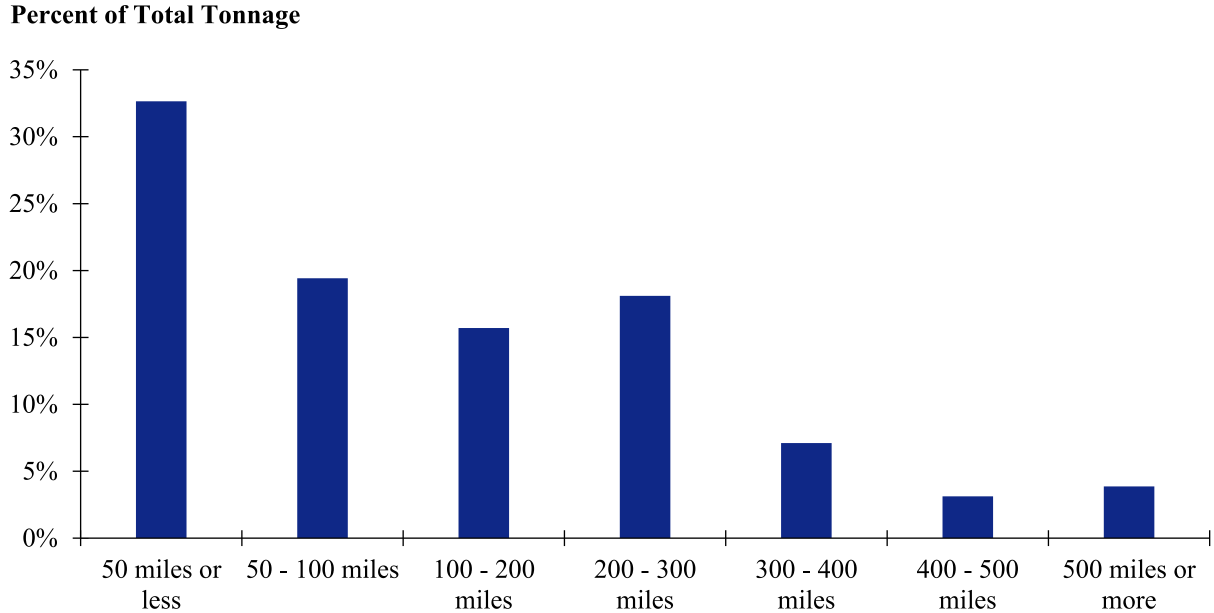

Figure 49. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Southeast production-consumption zone.
(Source: Federal Highway Administration.)

Figure 50 and figure 51 contain the trip length distributions for all hatchery-to-farm and farm-to-processing farm-based shipments of broilers in the contiguous U.S. For hatchery-to-farm farm-based shipments of broilers, the results in figure 50 indicate that about 20 percent of total tonnage travels 50 miles or less and about 66 percent travels 200 miles or less. About 95 percent of total tonnage for the Southeast zone is estimated to travel distances of 500 miles or less. The results for farm-to-processing farm-based shipments of broilers (see figure 51) is similar with 33 percent traveling 50 miles or less, 67 percent traveling 200 miles or less, and about 96 percent traveling 500 miles or less.

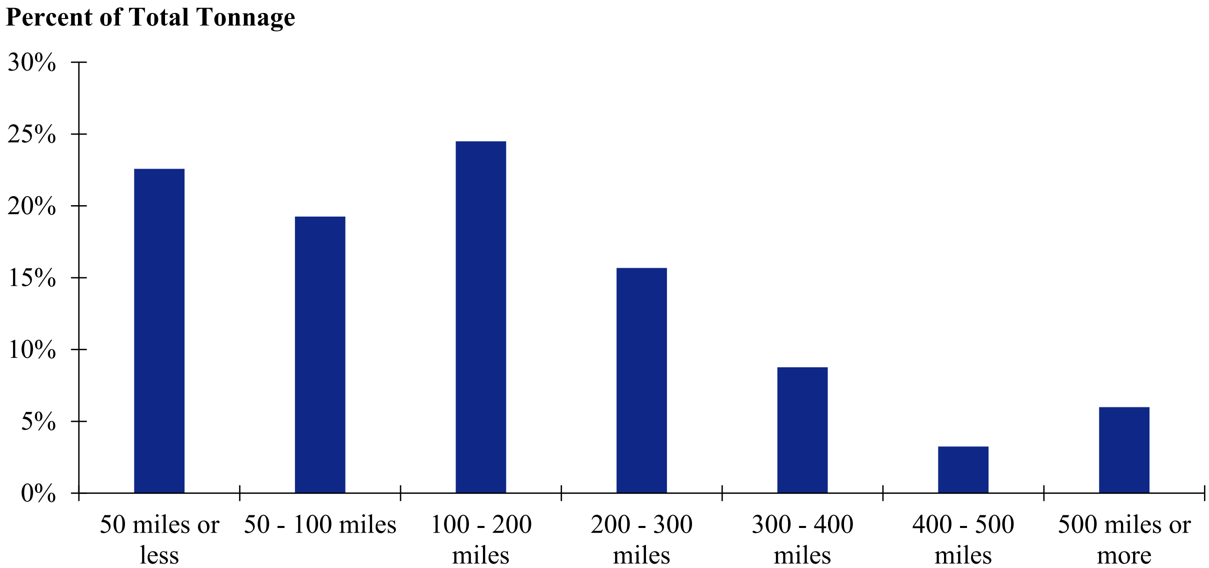

Figure 50. Bar chart. Distribution of shipment distances for all hatchery-to-farm farm-based shipments of broilers in the contiguous U.S.
(Source: Federal Highway Administration.)

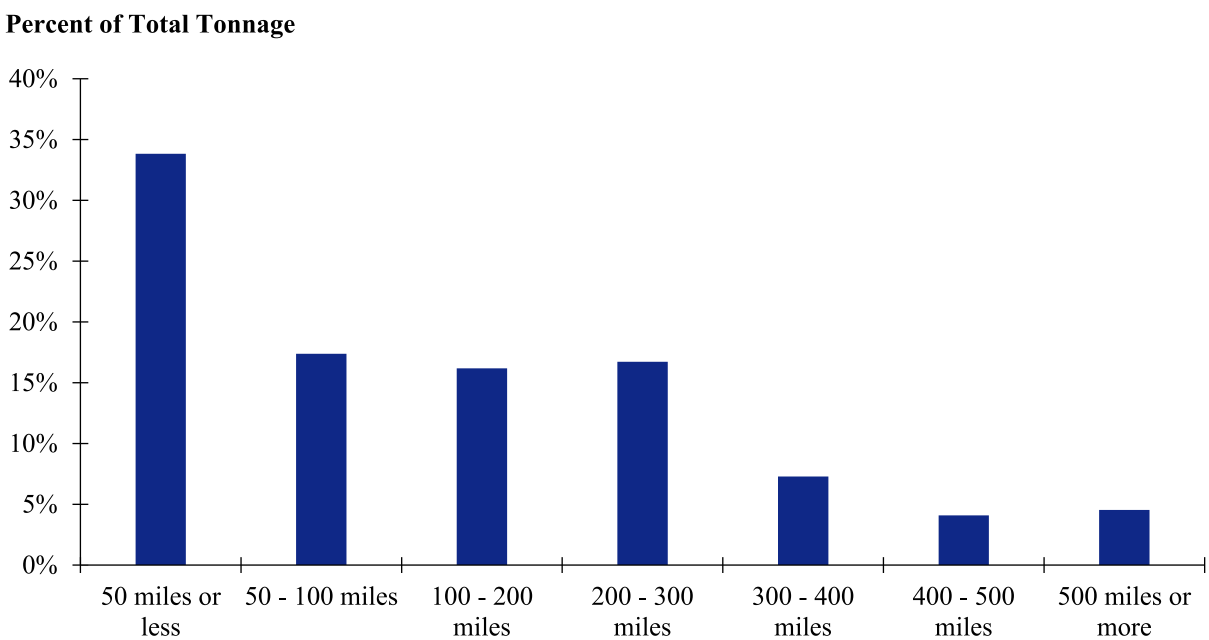

Figure 51. Bar chart. Distribution of shipment distances for all farm-to-processing farm-based shipments of broilers in the contiguous U.S.
(Source: Federal Highway Administration.)

Pullets

The production-consumption zones for farm-based shipments of pullets, shown in figure 52, are the same as those for broilers. Also depicted in figure 52 are the results of estimated pullet production, in terms of tons of chicks hatched, at the county level. In total, over 643,000 tons of pullets are estimated to have been produced (i.e., hatched) in 2017. The estimated destinations of these productions at the county level is shown in figure 53.

Table 21 shows the results of the analysis of hatchery-to-farm farm-based shipments for the Remainder of Georgia FAF4 zone. In total, nearly 41,000 tons of pullets are estimated to have an origin or destination within this zone. The results indicate that for the Remainder of Georgia zone about 37 percent, or nearly 16,000 tons, of hatchery-to-farm farm-based shipments of pullets are internal. About 41 percent (nearly 17,000 tons) of flows are outbound while the remainder (about 21 percent or nearly 8,700 tons) is inbound.

Figure 54 shows the distribution of tonnage by distance for hatchery-to-farm farm-based shipments of pullets in the Southeast production-consumption zone. The results indicate that about 21 percent of total tonnage travels 50 miles or less and about 64 percent travels 200 miles or less. About 94 percent of total tonnage for the Southeast zone is estimated to travel distances of 500 miles or less. Similar results are shown for the contiguous U.S. in figure 55.

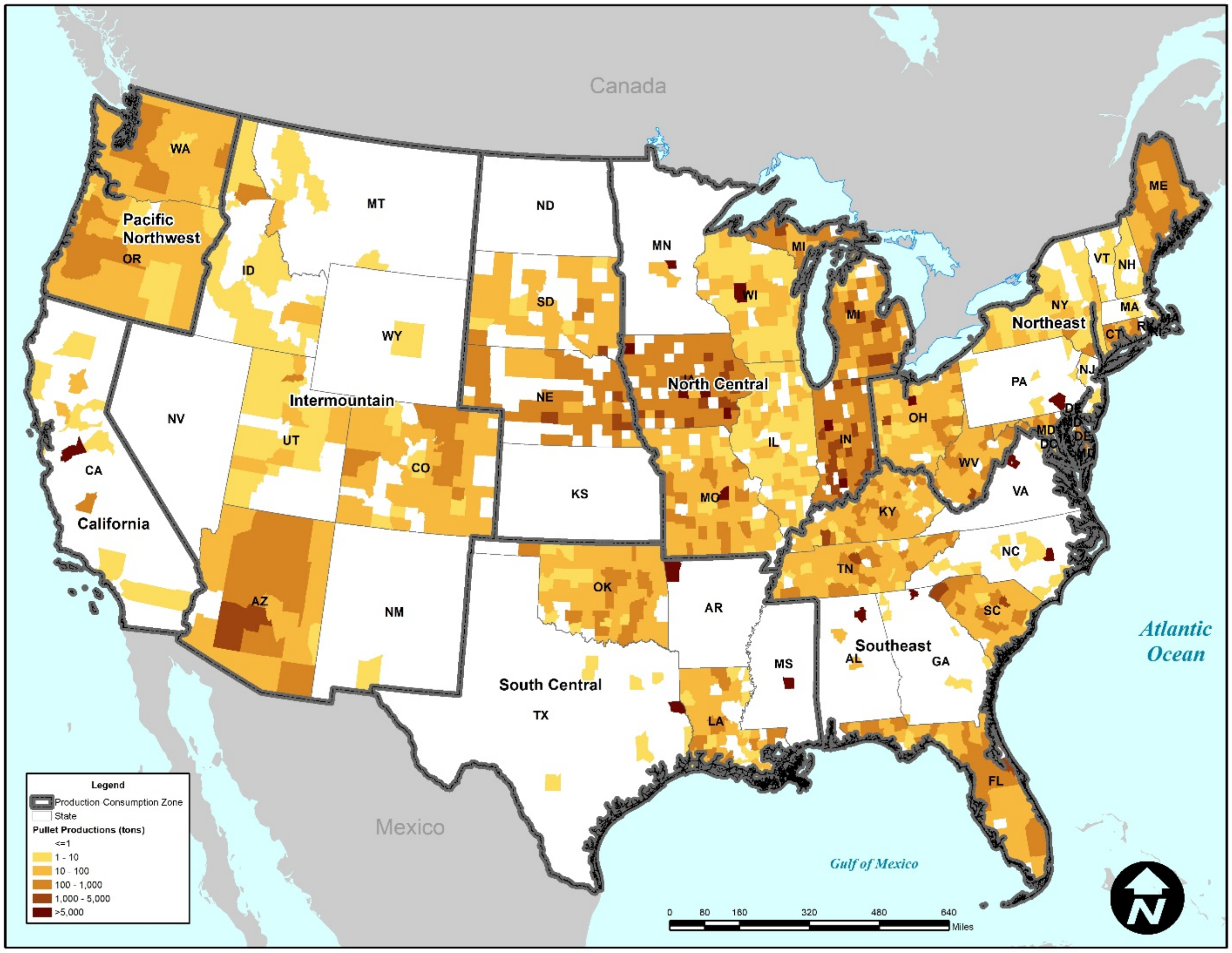

Figure 52. Map. Tons of pullets produced at the county level.
(Source: USDA NASS, 2017.)

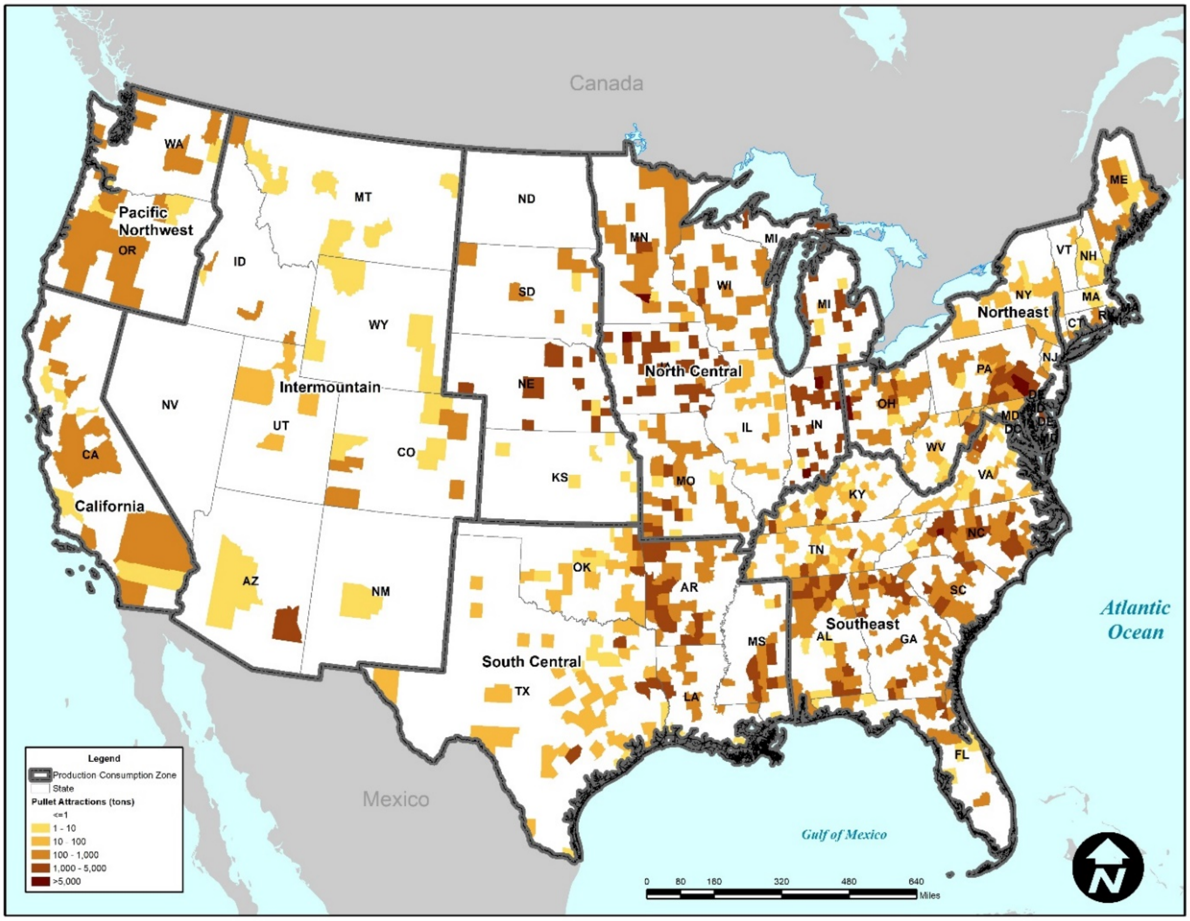

Figure 53. Map. Tons of pullets attracted at the county level for hatchery-to-farm movements. (Source: USDA NASS, 2017.)

Table 21. Hatchery-to-farm results for pullets for the remainder of Georgia freight analysis framework version 4 zone.

	Outbound from Remainder of Georgia		**Inbound to Remainder of Georgia**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Remainder of Alabama	4,394	26%	578	7%
Mobile-Daphne-Fairhope, AL CFS Area	104	1%	<1	<1%
Birmingham-Hoover-Talladega, AL CFS Area	613	4%	7	<1%
Remainder of Florida	565	3%	681	8%
Jacksonville-St. Mary's-Palatka, FL-GA CFS Area (FL Part)	559	3%	108	1%
Miami-Fort Lauderdale-Port St. Lucie, FL CFS Area	<1	<1%	229	3%
Orlando-Deltona-Daytona Beach, FL CFS Area	<1	<1%	542	6%
Tampa-St. Petersburg-Clearwater, FL CFS Area	<1	<1%	305	4%
Atlanta-Athens-Clarke County-Sandy Springs, GA CFS Area	10,144	60%	2	<1%

Table 21. Hatchery-to-farm results for pullets for the remainder of Georgia freight analysis framework version 4 zone (continuation).

	Outbound from Remainder of Georgia		**Inbound to Remainder of Georgia**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Savannah-Hinesville-Statesboro, GA CFS Area	114	1%	2	0%
Remainder of Kentucky	456	3%	368	4%
Cincinnati-Wilmington-Maysville, OH-KY-IN CFS Area (KY Part)	<1	<1%	47	1%
Louisville/Jefferson County-Elizabethtown-Madison, KY-IN CFS Area (KY Part)	17	<1%	64	1%
Greensboro-Winston-Salem-High Point, NC CFS Area	–	0%	<1	<1%
Remainder of North Carolina	–	0%	3,448	40%
Charlotte-Concord, NC-SC CFS Area (NC Part)	–	0%	1	<1%
Raleigh-Durham-Chapel Hill, NC CFS Area	–	0%	1	<1%
Greenville-Spartanburg-Anderson, SC CFS Area	–	0%	923	11%
Remainder of South Carolina	–	0%	537	6%
Charleston-North Charleston-Summerville, SC CFS Area	–	0%	25	<1%
Knoxville-Morristown-Sevierville, TN CFS Area	–	0%	124	1%
Nashville-Davidson-Murfreesboro, TN CFS Area	–	0%	129	1%
Remainder of Tennessee	–	0%	286	3%
Memphis, TN-MS-AR CFS Area (TN Part)	–	0%	9	<1%
Remainder of Virginia	–	0%	277	3%
Richmond, VA CFS Area	–	0%	<1	<1%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (VA Part)	–	0%	<1	<1%
Virginia Beach-Norfolk, VA-NC CFS Area (VA Part)	–	0%	<1	<1%
Total	**16,966**	**100%**	**8,694**	**100%**

(Source: Federal Highway Administration.)

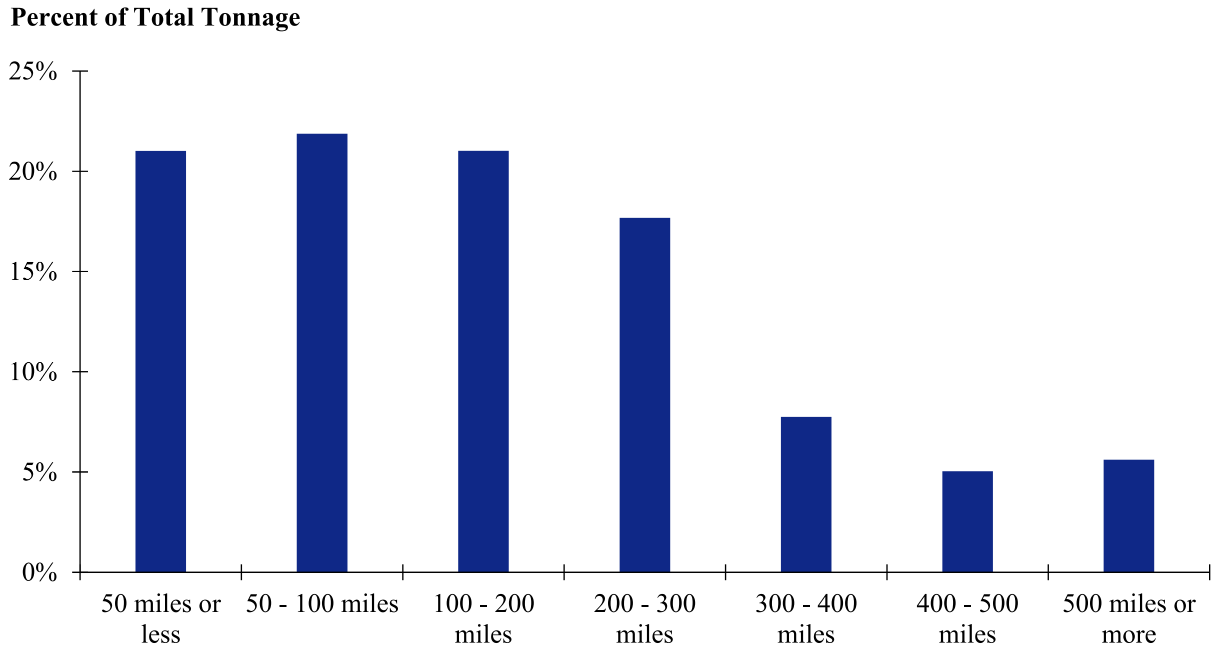

Figure 54. Bar chart. Distribution of shipment distances for all hatchery-to-farm farm-based shipments of pullets in the Southeast zone.
(Source: Federal Highway Administration.)

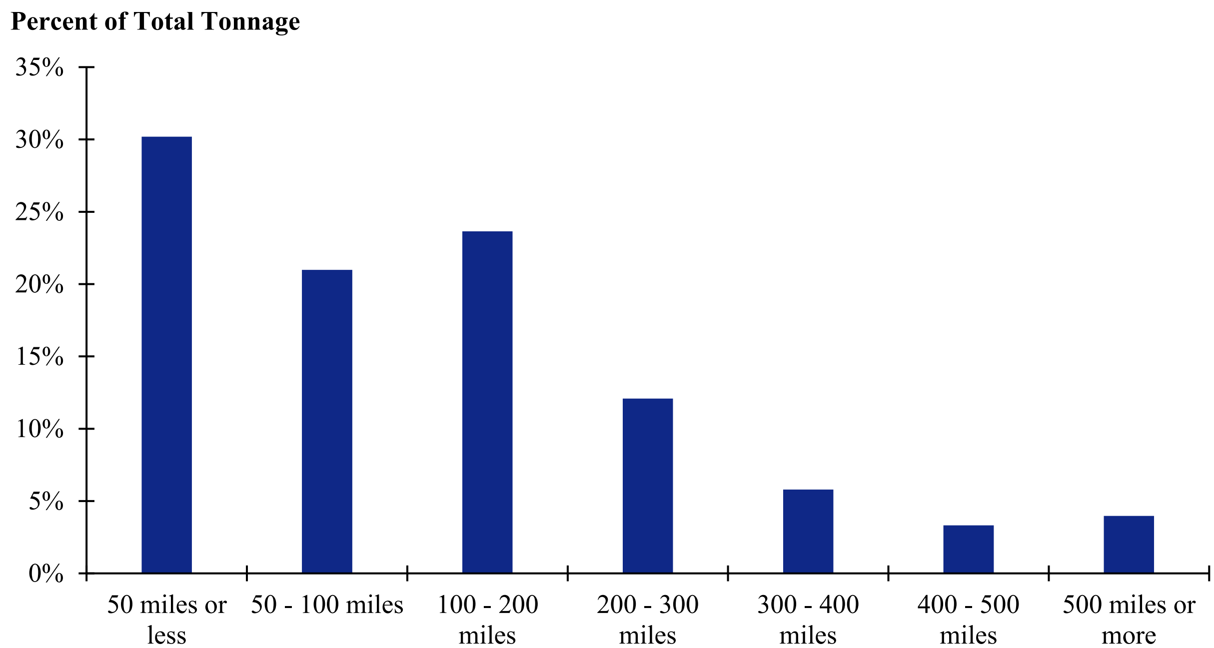

Figure 55. Bar chart. Distribution of shipment distances for all hatchery-to-farm farm-based shipments of pullets in the contiguous U.S.
(Source: Federal Highway Administration.)

CHAPTER 8. LOGS

METHODOLOGICAL APPROACH

As shown in figure 56, the process for modeling out-of-scope log commodity flows is based on the portion of the supply chain that constitutes the out-of-scope movement. This solely consists of the movement from the harvest site to the sawmill for processing. Once harvested timber reaches the sawmill, it is an in-scope movement since sawmills are categorized under North American Industry Classification System (NAICS) code 32111.[60]

The process uses the following data sources:

- United States Department of Agriculture (USDA) Forest Service's *Forestry Inventory Data Online* (FIDO)—The U.S. Forest Service's FIDO tool provides spatial (at the State and county levels) and temporal (at the annual level) data on timber production.
- USDA Forest Service's *Timber Product Output (TPO) Reports*—The TPO reports provide the quantity of soft and hard wood from the published "2012 State Level Core Tables."
- State and Region Price Reports—The prices of soft and hard woods provided in various State or Region Price Reports to determine the value of log commodity flows.
- Mill Location Data—Data on the location and size of mills. Potential sources for these data include a USDA geodatabase on mill locations and the U.S. Census Bureau County Business Patterns database. Sawmills are identified by NAICS code 32111.[61]

Key methodological steps include:

- **Estimate County-Level Log Productions—**County totals of timber produced are estimated using statistics published in the FIDO and TPO reports. The FIDO contains the amount of tonnage produced at the county level.
- **Estimate County-Level Log Attractions—**Estimate the State and county totals of timber attracted using the location and size of sawmills. The location and size of sawmills was estimated using data on the number of establishments by county and their total annual payroll for all employees as captured by the County Business Patterns database for establishments under NAICS code 32111. Consumptions zones are also defined at this step in the process which indicate where consumptions take place as shown in table 22. These zones largely follow those used by the USDA Forest Service for purposes of analyzing and reporting data.
- **Distribute Log Commodity Flows to Mills—**Distribute log commodity flows to mills at the county level using a gravity model (see figure 35). Impedance is a function of network distance between counties as captured by the Oak Ridge National Laboratory County Distance database (see figure 36).

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60 Bureau of Transportation Statistics (BTS), "Commodity Flow Survey Overview," https://www.bts.dot.gov/archive/publications/commodity_flow_survey/methodology_2012#industry%20coverage.

61 https://www.srs.fs.usda.gov/econ/data/mills/.

- **Aggregate to the Freight Analysis Framework Version 4 (FAF4) Zone Level**—After distribution, individually aggregate the county-level productions and attractions to the FAF4 zone level.

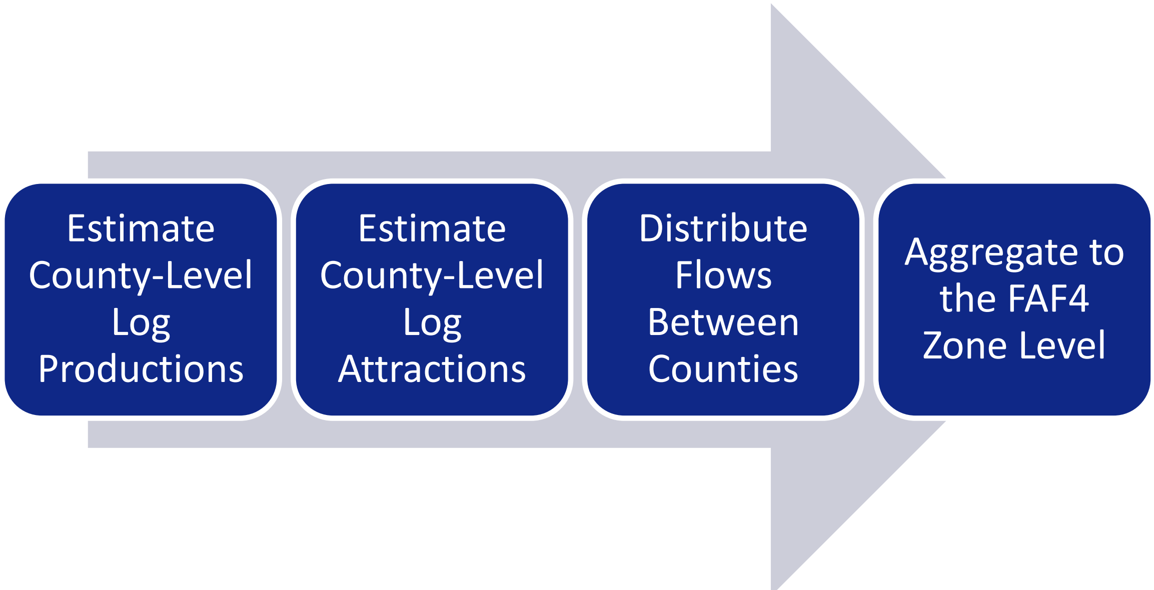

Figure 56. Flow chart. Framework for out-of-scope log shipments.
(Source: Federal Highway Administration.)

Table 22. States by zone for logs.

Zone	States
Northeast	• Connecticut. • Delaware. • District of Columbia. • Maine. • Maryland. • Massachusetts. • New Hampshire. • New Jersey. • New York. • Ohio. • Pennsylvania. • Rhode Island. • Vermont. • West Virginia.
Southeast	• Alabama. • Florida. • Georgia. • Kentucky. • North Carolina. • South Carolina. • Tennessee. • Virginia.

Table 22. States by zone for logs (continuation).

Zone	States
South Central	• Arkansas. • Louisiana. • Mississippi. • Oklahoma. • Texas.
Great Plains	• Kansas. • Nebraska. • North Dakota. • South Dakota.
North Central	• Illinois. • Indiana. • Iowa. • Michigan. • Missouri. • Minnesota. • Wisconsin.
Intermountain	• Arizona. • Idaho. • Nevada. • New Mexico. • Utah. • Montana. • Wyoming.
California	• California.
Pacific Northwest	• Oregon. • Washington.

(Source: Federal Highway Administration.)

RESULTS

Figure 57 depicts the assumed production-consumption zones for log shipments. These zones were based on the clustering of counties that produce timber across states. Six production-consumption zones are defined for the contiguous U.S.: Northeast, North Central, Southeast, South Central, Great Plains, Intermountain, California, and Pacific Northwest. In keeping with the observation that logging shipments are primarily local, the methodology assumes that out-of-scope (OOS) movements of logs are distributed within these zones.

Also depicted in figure 57 are the results of estimated logging production at the county level. The USDA FIDO database and TPO reports provide much of the information on annual estimates of county-level production by total tonnage directly. However, this data is not collected directly on an annual basis but is instead based on samples taken every five years from which USDA develops annual estimates.

In total, nearly 776,000 tons of logs are estimated to have been produced in 2017 as shown in table 23. Of that total, the Southeast region produced the highest share at 42 percent, followed by the South Central at 21 percent, and the Pacific Northwest at approximately 16 percent. The Northeast, North Central, Intermountain, and California regions are estimated to have produced approximately 20 percent of logs. Figure 39 depicts the methodology's results for the estimation of log attractions at the county level. In general, counties with higher numbers of sawmills and wood preservation establishments (NAICS 32111) as indicated by U.S. Census Bureau County Business Pattern data attract higher amounts of corn farm-based shipments than others.

Table 23. Logs production estimates by region.

Region	**Tons Produced**	**Percent of Total**
Southeast	328,208.28	42.30%
South Central	165,528.38	21.33%
Pacific Northwest	124,362.90	16.03%
Northeast	61,738.68	7.96%
North Central	35,676.64	4.60%
Intermountain	31,154.90	4.02%
California	25,402.68	3.27%
Great Plains	1,973.66	0.25%
Alaska	1,816.67	0.23%
Hawaii	–	0.00%
Grand Total	**775,862.80**	**100.00%**

(Source: USDA FIDO, 2012–2017.)

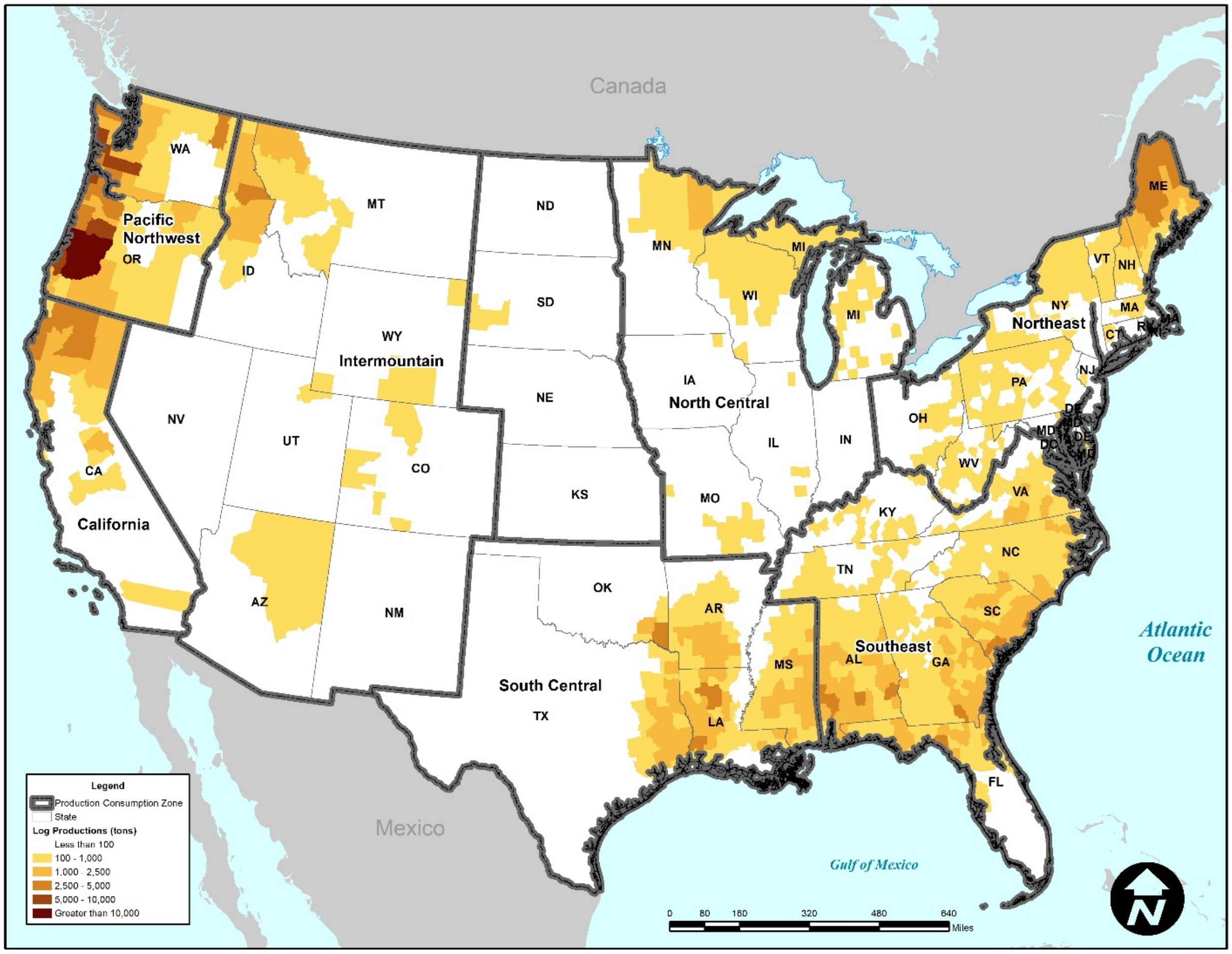

Figure 57. Map. Tons of logs produced at the county level.
(Source: USDA FIDO, 2012–2017.)

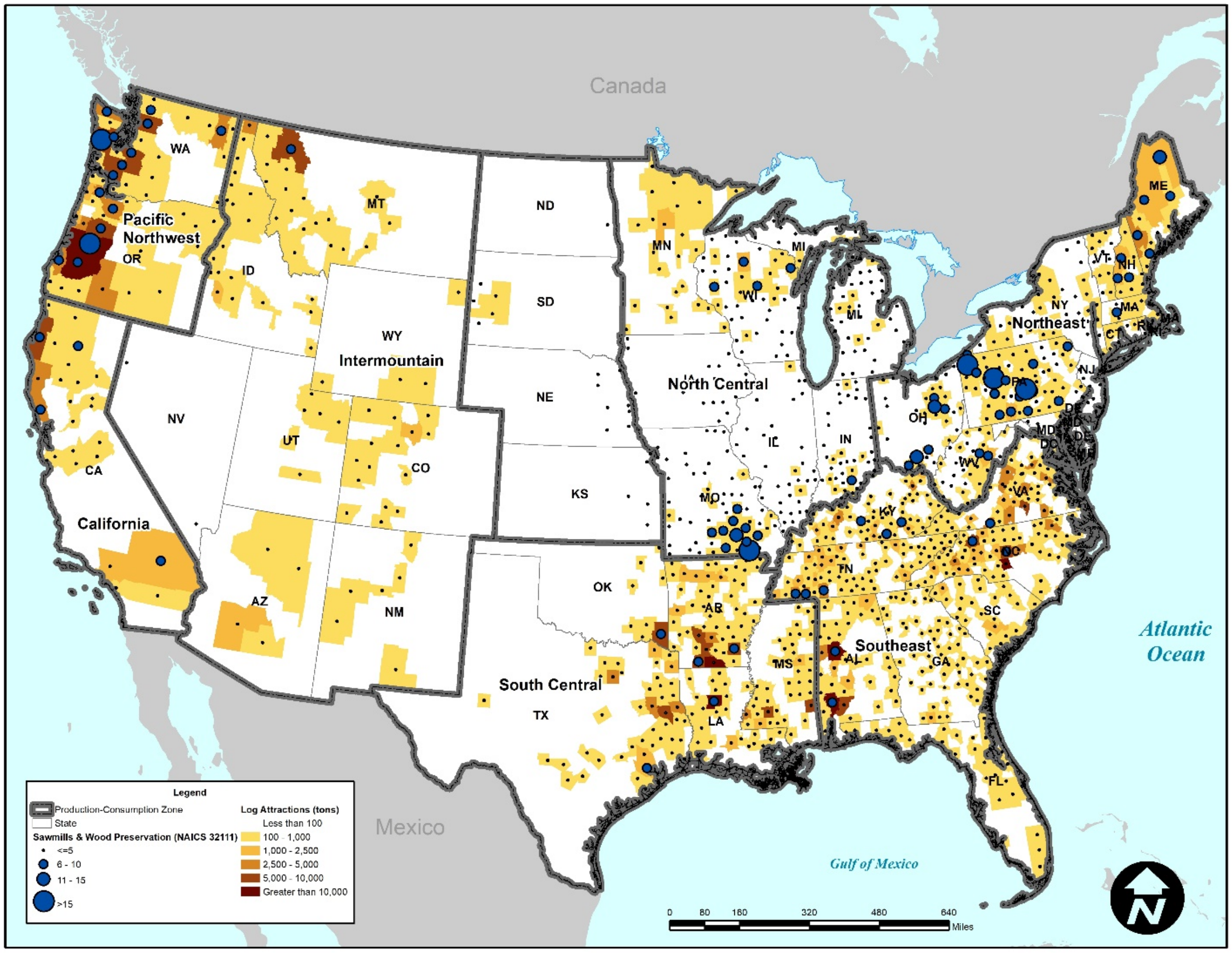

Figure 58. Map. Tons of logs attracted at the county level.
(Source: USDA FIDO, 2012-2017; U.S. Census Bureau County Business Patterns, 2016.)

As an example, table 24 shows the results of the analysis of logging shipments for the Remainder of Pennsylvania FAF4 zone. In total, nearly 20,000 tons of logs are estimated to have an origin or destination within this zone not including internal movements. The results indicate that for the Remainder of Pennsylvania zone nearly one-third, over 6,000 tons, log flows are internal. About 6 percent (over 1,200 tons) of flows are outbound while the remainder (about 60 percent or about 12,000 tons) is inbound. That the methodology estimates that over 90 percent of log flows for this zone are either inbound or internal is reflective of its relatively large number of sawmills and wood preservation establishments.

Figure 59 shows the distribution of tonnage by distance for all shipments in the Northeast production-consumption zone. The results indicate that about 34 percent of total tonnage travels 50 miles or less and approximately two-thirds (67 percent) travels 200 miles or less. About 86 percent of total tonnage for the Northeast zone is estimated to travel distances of 500 miles or less. While this is largely consistent with the current FAF4 assumption that log flows are entirely local, the draft methodology does result in about 14 percent of total tonnage traveling distances over 500 miles.

Figure 60 contains the trip length distributions for all harvest site-to-processing shipments of harvested logs in the contiguous U.S. The results indicate that about 31 percent of total tonnage travels 50 miles or less and about 64 percent travels 200 miles or less. About 90 percent of total tonnage for the contiguous U.S. is estimated to travel distances of 500 miles or less.

Table 24. Results for the remainder of Pennsylvania freight analysis framework version 4 zone.

	Outbound from Remainder of Pennsylvania		Inbound to Remainder of Pennsylvania	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
New York-Newark, NY-NJ-CT-PA Commodity Flow Survey (CFS) Area (CT Part)	5	<1%	88	1%
Hartford-West Hartford-East Hartford, CT CFS Area	2	<1%	26	<1%
Remainder of Connecticut	1	<1%	11	<1%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (DE Part)	–	0%	20	<1%
Remainder of Delaware	1	<1%	110	1%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (DC Part)	–	0%	–	0%
Remainder of Maine	5	<1%	4,043	34%
Remainder of Maryland	11	1%	679	6%
Baltimore-Columbia-Towson, MD CFS Area	9	1%	263	2%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (MD Part)	8	1%	53	<1%
Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part)	4	<1%	78	1%
Remainder of Massachusetts	9	1%	31	<1%
Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (NH Part)	4	<1%	91	1%
Remainder of New Hampshire	9	1%	283	2%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (NJ Part)	10	1%	14	<1%
New York-Newark, NY-NJ-CT-PA CFS Area (NJ Part)	15	1%	69	1%
Albany-Schenectady, NY CFS Area	12	1%	314	3%
Remainder of New York	218	17%	1,982	17%
New York-Newark, NY-NJ-CT-PA CFS Area (NY Part)	27	2%	71	1%
Buffalo-Cheektowaga, NY CFS Area	196	16%	215	2%
Rochester-Batavia-Seneca Falls, NY CFS Area	25	2%	128	1%
Remainder of Ohio	155	12%	667	6%
Cleveland-Akron-Canton, OH CFS Area	62	5%	175	1%
Cincinnati-Wilmington-Maysville, OH-KY-IN CFS Area (OH Part)	–	0%	18	<1%

Table 24. Results for the remainder of Pennsylvania freight analysis framework version 4 zone (continuation).

	Outbound from Remainder of Pennsylvania		Inbound to Remainder of Pennsylvania	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
Dayton-Springfield-Sidney, OH CFS Area	5	<1%	19	0%
Columbus-Marion-Zanesville, OH CFS Area	8	1%	195	2%
Pittsburgh-New Castle-Weirton, PA-OH-WV CFS Area (PA Part)	392	31%	508	4%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (PA Part)	3	<1%	101	1%
New York-Newark, NY-NJ-CT-PA CFS Area (PA Part)	–	0%	65	1%
Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (RI Part)	–	0%	8	0%
Remainder of Vermont	–	0%	399	3%
Remainder of West Virginia	52	4%	1,180	10%
Total	**1,248**	**100%**	**11,905**	**100%**

(Source: Federal Highway Administration.)

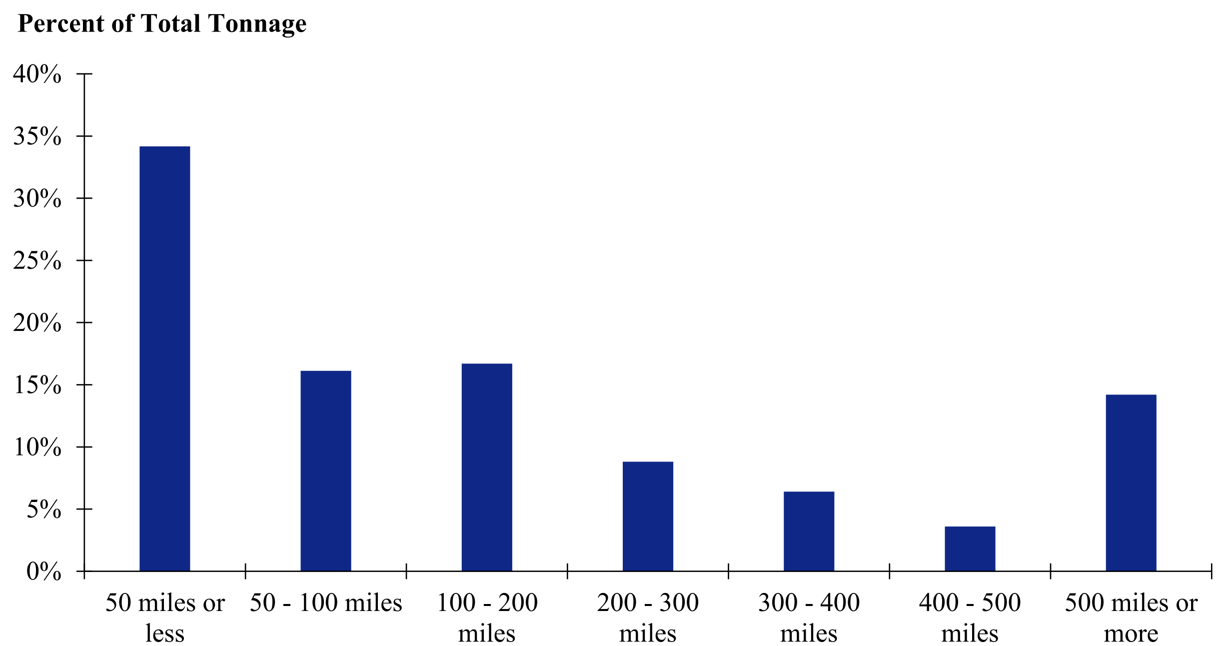

Figure 59. Bar chart. Distribution of shipment distances for logs in the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

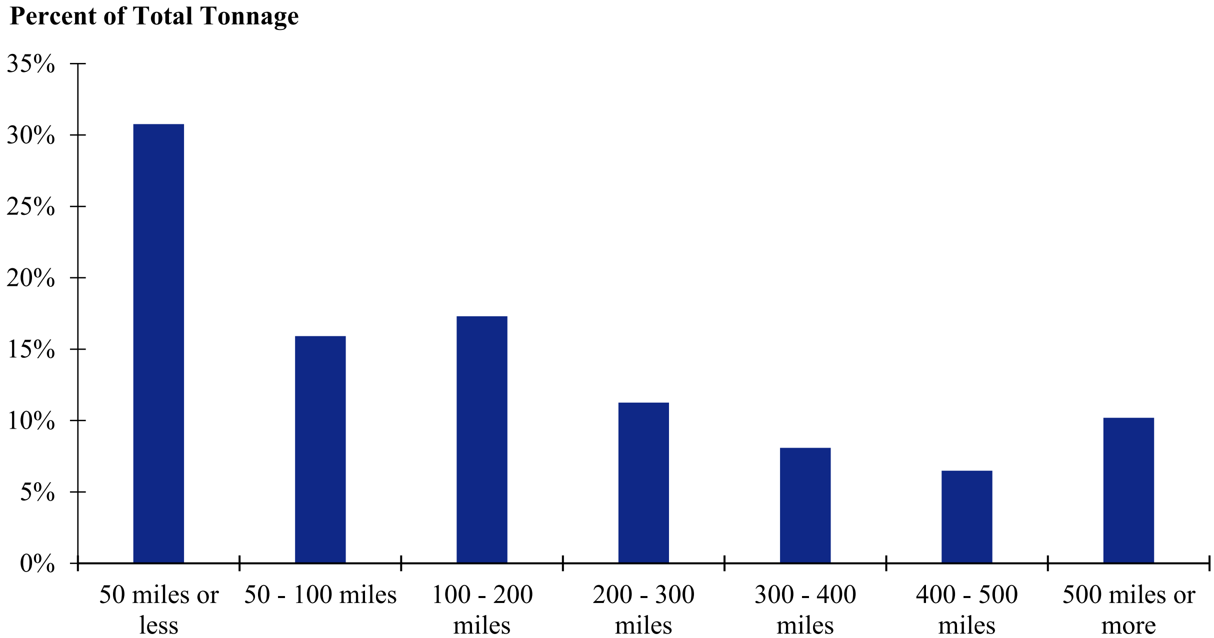

Figure 60. Bar chart. Distribution of shipment distances for logs in the contiguous U.S. (Source: Federal Highway Administration.)

CHAPTER 9. FISH

METHODOLOGICAL APPROACH

As shown in figure 61, the draft process for modeling out-of-scope fishery commodity flows is based on the portion of the supply chain that constitutes the out-of-scope movement. This solely consists of the movement from the port to a facility for cleaning, canning, freezing, or some other processing activity. Once seafood reaches the processing, it is an in-scope movement categorized under North American Industry Classification System (NAICS) code 311 for Food Manufacturing.[62]

The process would utilize the following data sources:

- Location of Ports and Annual Amount of Commercial Fishery Landings—Data on the location of ports and the amount of commercial fishery landings (tonnage and value) is available from the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA).[63]
- Location of Processing Facilities—Seafood processing facilities are identified by NAICS code 3117 (Seafood Product Preparation and Packaging). The locations of these facilities are identified using the County Business Patterns database from the U.S. Census Bureau. Based on the 2016 County Business Pattern (CBP) data, there are 219 counties with seafood processing facilities.

Key methodological steps include:

- **Estimate County-Level Fish Landings/Productions—**Port-level landing data from the NMFS was aggregated to the county level using data from the NMFS, which reports landings for the largest ports. State-level data on landings was obtained from the Fisheries of the United States report. Landings at ports for which disaggregate data was available was attributed to the port's county. The balance of landings (i.e., the difference between State totals and the total of the ports with data) was divided among counties with ports for which data were not provided. Consumption zones are also defined at this step in the process which indicate where productions and consumptions take place. These zones largely follow those used by the NMFS for purposes of analyzing and reporting data.

- **Estimate County-Level Fish Attractions—**Estimate the State and county totals of fish commodities attracted using the location and size of seafood product preparation and packaging establishments. The location and size of seafood product preparation and

62 Bureau of Transportation Statistics (BTS), "Commodity Flow Survey Overview," https://www.bts.dot.gov/archive/publications/commodity_flow_survey/methodology_2012#industry%20coverage.

63 https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/other-specialized-programs/total-commercial-fishery-landings-at-major-u-s-ports-summarized-by-year-and-ranked-by-dollar-value/index.

packaging establishments was estimated using data on the number of establishments by county and their total annual payroll for all employees.

- **Distribute Flows Between Counties**—Fish commodity flows were distributed to counties based on the location and size of processing plants using a gravity model (see figure 35). Impedance was a function of network distance between counties as captured by the Oak Ridge National Laboratory County Distance database (see figure 36). Unlike the current Freight Analysis Framework Version 4 (FAF4) procedure, fish commodity flows were allowed to cross State boundaries.

- **Aggregate to the FAF4 Zone Level**—After distribution, individually aggregate the county-level productions and attractions to the FAF4 zone level.

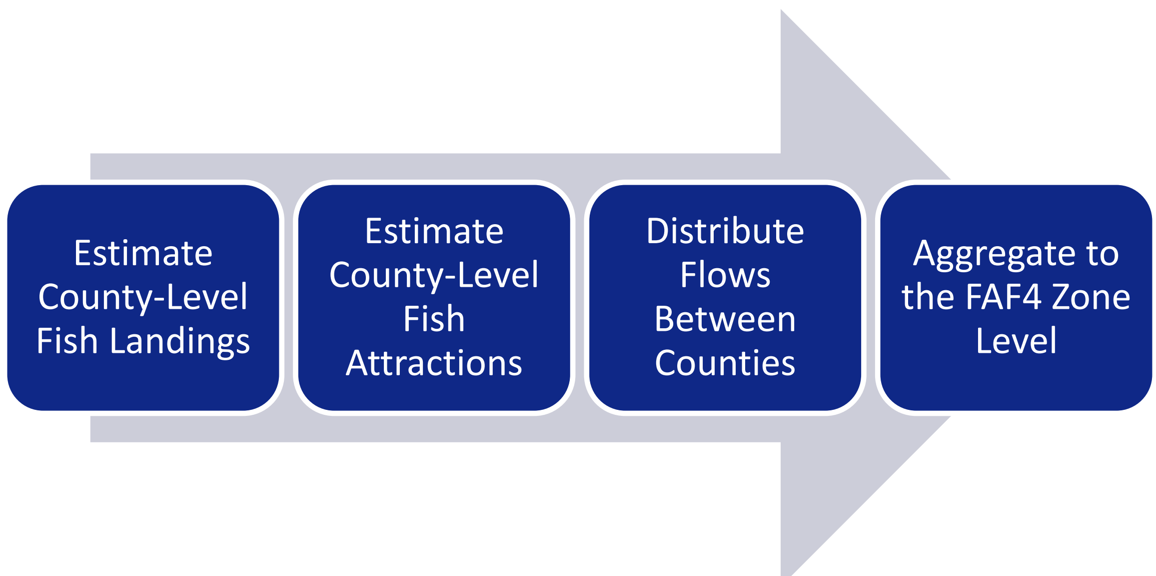

Figure 61. Flow chart. Framework for out-of-scope fish shipments.
(Source: Federal Highway Administration.)

Table 25. States by zone for fish.

Zone	States
Northeast	• Connecticut. • Delaware. • District of Columbia. • Maine. • Maryland. • Massachusetts. • New Hampshire. • New Jersey. • New York. • Pennsylvania. • Rhode Island. • Vermont. • West Virginia.

Table 25. States by zone for fish (continuation).

Zone	States
Coastal Southeast	• Florida (East Coast). • Georgia. • North Carolina. • South Carolina. • Virginia.
Gulf Coast	• Alabama. • Florida (West Coast). • Louisiana. • Mississippi. • Texas.
Great Lakes	• Illinois. • Indiana. • Michigan. • Missouri. • Minnesota. • Ohio. • Wisconsin.
California	• California.
Pacific Northwest	• Oregon. • Washington.

(Source: Federal Highway Administration.)

RESULTS

Figure 62 depicts the assumed production-consumption zones for fish shipments. These zones were based on the clustering of counties that produce fishery landings. Ten production-consumption zones are defined for the contiguous U.S.: Northeast, Coastal Southeast, Southeast, Southwest, Gulf Coast, Great Plains, Great Lakes, Mountain, California, and Pacific Northwest. In addition to these, Alaska and Hawaii were defined as individual zones. In keeping with the observation that fishery shipments are primarily local, the methodology assumes that out-of-scope (OOS) movements of landed fish are distributed within these zones.

Also depicted in figure 62 are the results of estimated fish landings at the county level. The NMFS Port Landings database and the Fisheries of the United States report provide data on annual estimates of port- and state-level landings by total tonnage. However, the NMFS does not report landings for ports, which requires that county-level totals be estimated.

In total, nearly 4.9 million tons of fish are estimated to have been produced in 2017 as shown in table 26. Of that total, the vast majority of landings are attributed to Alaska at over 62 percent. The Gulf Coast is a distant second at nearly 16 percent and is followed by the Northeast at less than 9 percent. The remaining zones are estimated to have produced approximately 14 percent of fish. Figure 63 depicts the methodology’s results for the estimation of fish attractions at the county level.

Table 26. Fish production estimates by region.

Region	Tons Produced	Percent of Total
Alaska	3,019,092.50	62.14%
Gulf Coast	767,390.00	15.79%
Northeast	411,123.00	8.46%
Pacific Northwest	279,227.50	5.75%
Coastal Southeast	259,814.50	5.35%
California	97,418.00	2.00%
Hawaii	17,311.50	0.36%
Great Lakes	7,428.00	0.15%
Mountain	-	0.00%
Southeast	-	0.00%
Great Plains	-	0.00%
Southwest	-	0.00%
Grand Total	**4,858,805**	**100.00%**

(Source: NMFS.)

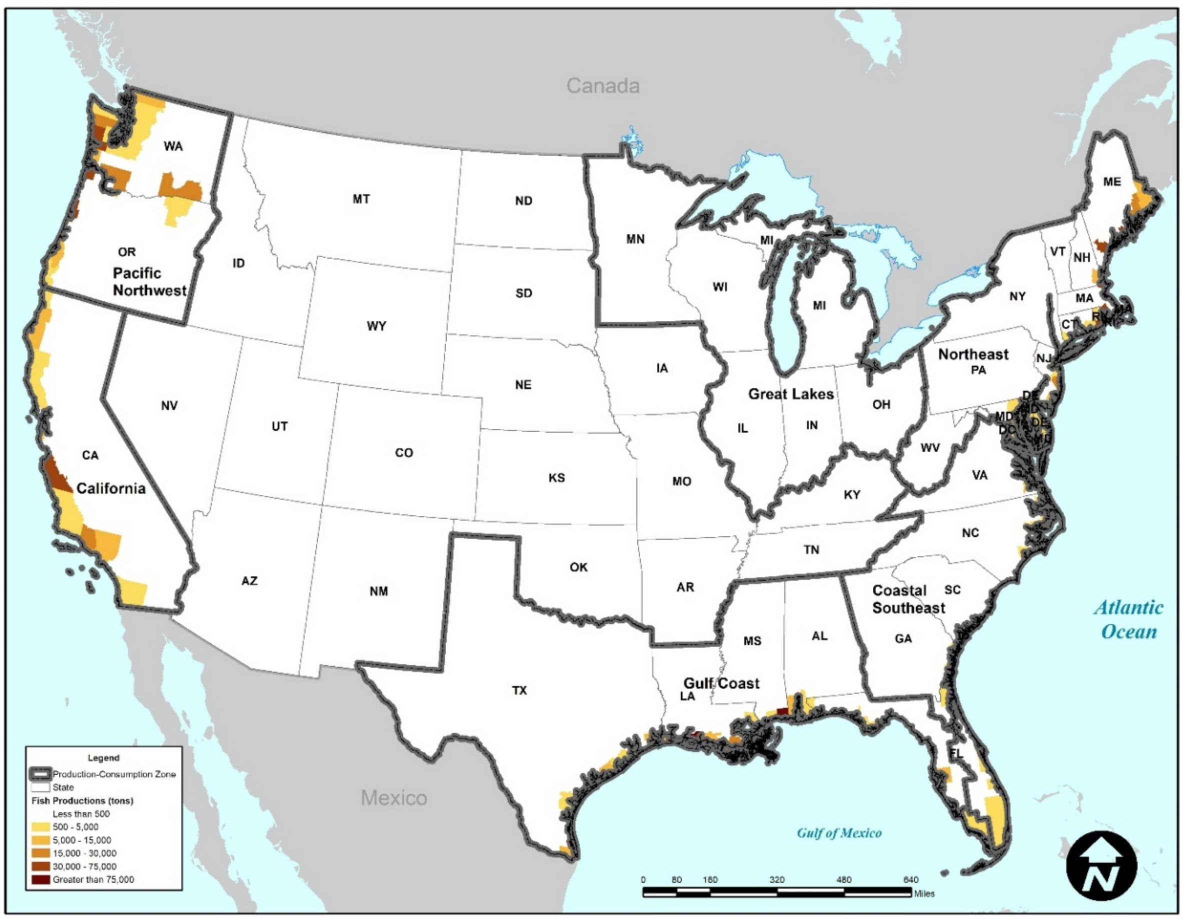

Figure 62. Map. Tons of fish landed (produced) at the county level.
(Source: NMFS.)

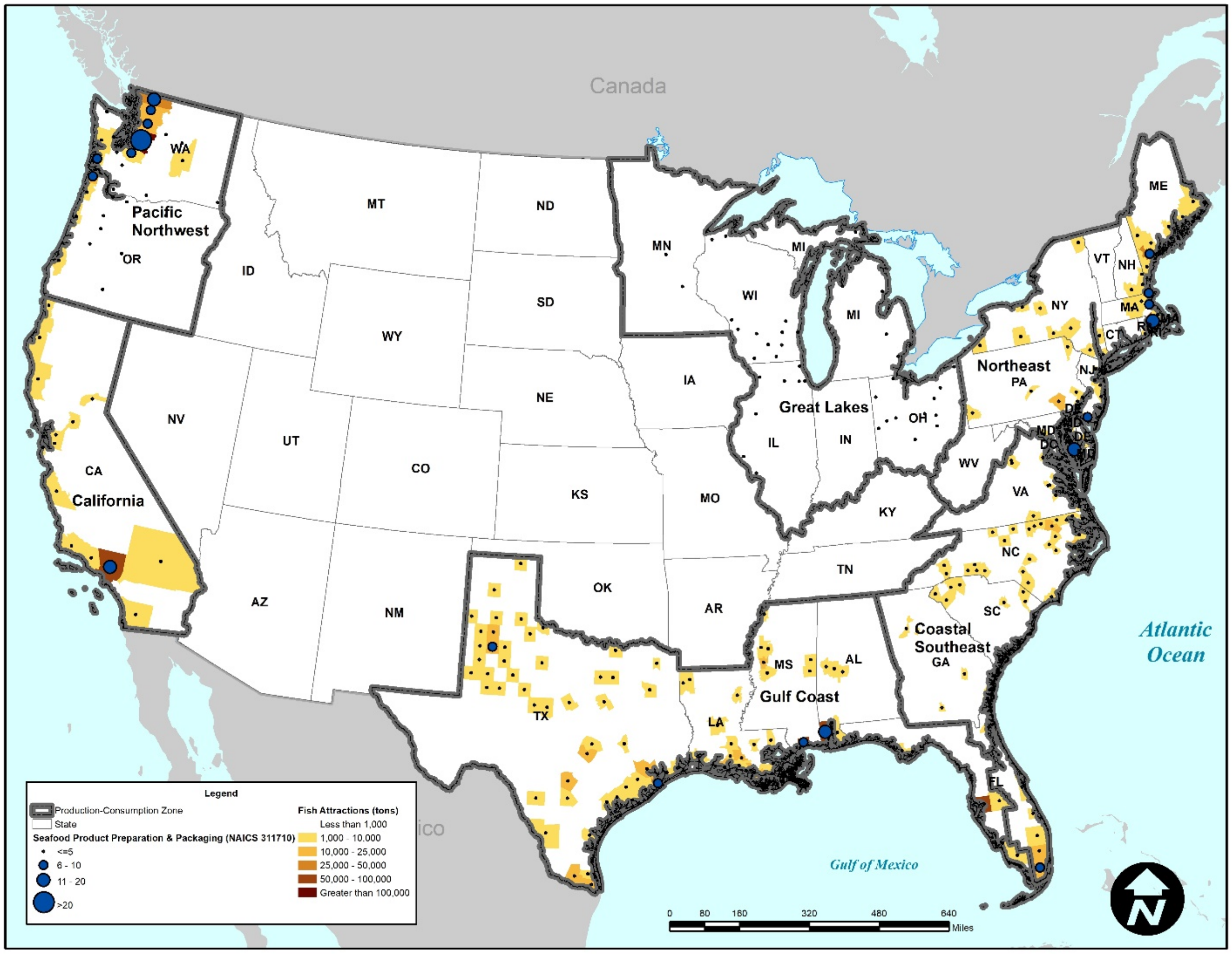

Figure 63. Map. Tons of fish attracted at the county level.
(Source: NMFS; U.S. Census Bureau County Business Patterns, 2016.)

As an example, table 27 shows the results of the analysis of fishery shipments for the Boston-Worcester-Providence, MA-RI-NH-CT Commodity Flow Survey (CFS) Area (MA Part) FAF4 zone. In total, over 78,000 tons of fish are estimated to have an origin or destination within this zone not including internal movements. The results indicate that for the Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part) zone nearly over 60 percent (over 124,000 tons) of fish flows are internal. Nearly 3 percent (nearly 5,600 tons) of flows are outbound while the remainder (about 37 percent or over 73,000 tons) is inbound.

Figure 64 shows the distribution of tonnage by distance for all shipments in the Northeast production-consumption zone. The results indicate that over half of total tonnage travels 50 miles or less and over three-quarters (86 percent) travels 200 miles or less. About 97 percent of total tonnage for the Northeast zone is estimated to travel distances of 500 miles or less.

Table 27. Results for the Boston-Worcester-Providence, Massachusetts-Rhode Island-New Hampshire-Connecticut commodity flow survey Area (Massachusetts Part) freight analysis framework version 4 zone.

	Outbound from Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part)		**Inbound to Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part)**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
New York-Newark, NY-NJ-CT-PA CFS Area (CT Part)	–	0%	117	<1%
Hartford-West Hartford-East Hartford, CT CFS Area	–	0%	–	0%
Remainder of Connecticut	–	0%	2,292	3%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (DE Part)	16	<1%	17	<1%
Remainder of Delaware	10	<1%	6	<1%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (DC Part)	–	0%	–	0%
Remainder of Maine	524	9%	35,281	48%
Remainder of Maryland	513	9%	133	<1%
Baltimore-Columbia-Towson, MD CFS Area	16	<1%	139	<1%
Washington-Arlington-Alexandria, DC-VA-MD-WV CFS Area (MD Part)	20	<1%	105	<1%
Remainder of Massachusetts	–	0%	–	0%
Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (NH Part)	1,444	26%	3,029	4%
Remainder of New Hampshire	–	0%	–	0%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (NJ Part)	104	2%	1,466	2%
New York-Newark, NY-NJ-CT-PA CFS Area (NJ Part)	298	5%	780	1%
Albany-Schenectady, NY CFS Area	–	0%	–	0%
Remainder of New York	561	10%	–	0%
New York-Newark, NY-NJ-CT-PA CFS Area (NY Part)	859	15%	479	1%
Buffalo-Cheektowaga, NY CFS Area	–	0%	–	0%
Rochester-Batavia-Seneca Falls, NY CFS Area	105	2%	–	0%
Remainder of Pennsylvania	365	7%	<1	0%
Pittsburgh-New Castle-Weirton, PA-OH-WV CFS Area (PA Part)	66	1%	–	0%
Philadelphia-Reading-Camden, PA-NJ-DE-MD CFS Area (PA Part)	95	2%	<1	0%

Table 27. Results for the Boston-Worcester-Providence, Massachusetts-Rhode Island-New Hampshire-Connecticut commodity flow survey Area (Massachusetts Part) freight analysis framework version 4 zone. (continuation).

	Outbound from Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part)		**Inbound to Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (MA Part)**	
FAF4 Zone	**Tons**	**Percent of Total**	**Tons**	**Percent of Total**
New York-Newark, NY-NJ-CT-PA CFS Area (PA Part)	–	0%	–	0%
Boston-Worcester-Providence, MA-RI-NH-CT CFS Area (RI Part)	602	11%	28,943	40%
Remainder of Vermont	–	0%	–	0%
Remainder of West Virginia	–	0%	–	0%
Total	**5,599**	**100%**	**72,787**	**100%**

(Source: Federal Highway Administration.)

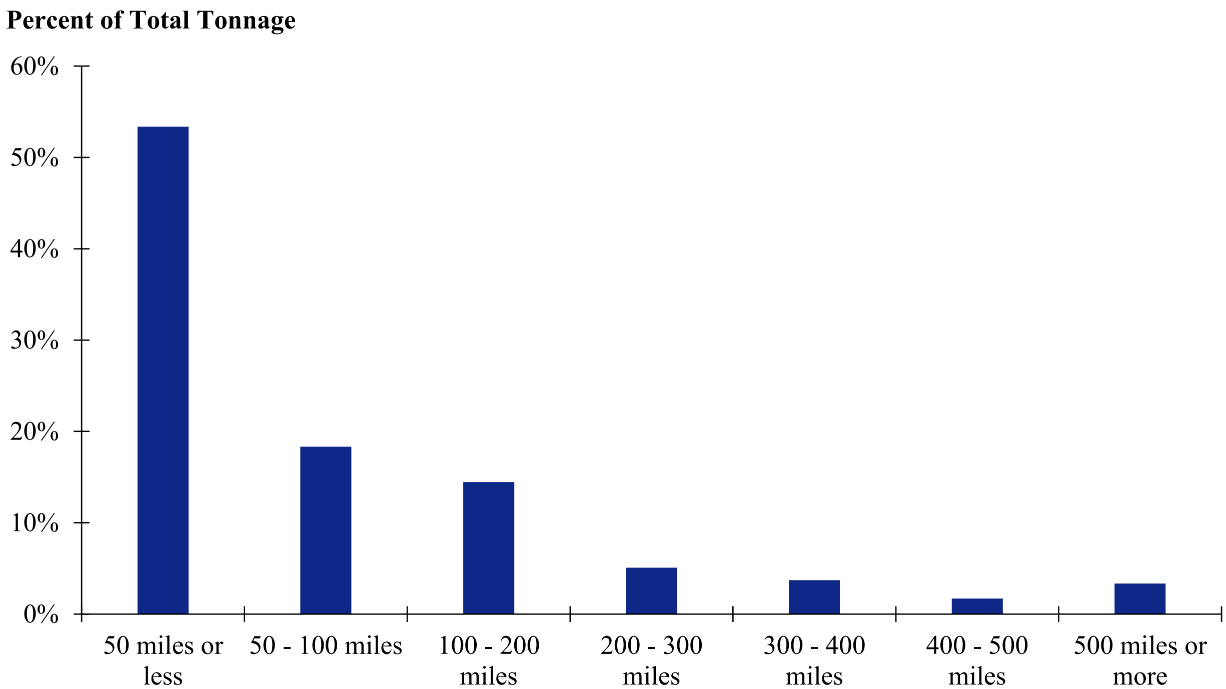

Figure 64. Bar chart. Distribution of shipment distances for fish in the Boston-Worcester-Providence, Massachusetts-Rhode Island-New Hampshire-Connecticut commodity flow survey area (Massachusetts Part) freight analysis framework version 4 zone.
(Source: Federal Highway Administration.)

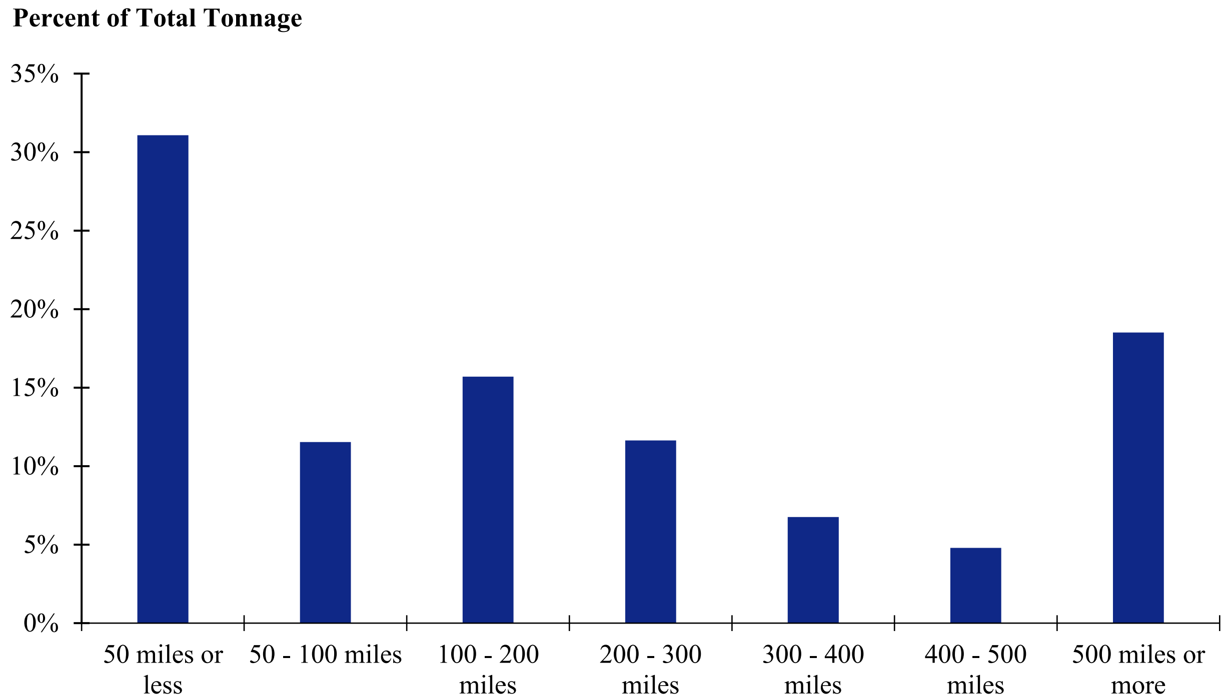

Figure 65. Bar chart. Distribution of shipment distances for fish in the contiguous U.S. (Source: Federal Highway Administration.)

CHAPTER 10. EXISTING FREIGHT ANALYSIS FRAMEWORK 4 TRUCK PAYLOAD FACTORS METHODS

Chapters 2 through 9 focused on the methods to update Freight Analysis Framework Out-of-Scope Commodity Flow Data. From Chapter 10, the focus shifts to the update and implementation of truck payload factors or Truck Payload Factors (TPF). This chapter reviews the existing Freight Analysis Framework Version 4 (FAF4) methodologies for computing payload, factors by commodity. The methods for FAF4 are described in the Oak Ridge National Laboratory report, FAF4 Freight Traffic Assignment (Maks Inc. 2016). The payload factor method as described is unchanged from those described for Freight Analysis Framework Version 3 (FAF3).

Transportation agencies analyze highway deficiencies based on the number of vehicles traveling on highway facilities and comparing that demand to the capacity of those facilities. The Freight Analysis Framework reports and forecasts annual flows in tons between origins and destinations by commodity according two-digit digit Standard Classification of Transported Goods (SCTG2) and mode. By filtering only flows for Freight Analysis Framework (FAF) truck modes, the flows can be reported as a standard origin destination table, by SCTG2 commodity. In order to convert those flows into truck trips, it is necessary to divide those tons by the average of tons per truck. Truck Payload Factors (TPF), often known as truck payload factors, are used to convert those flows in tons into flows by trucks.

The existing FAF4 method computes those payload factors by using information from the 2002 U.S. Vehicle Inventory and Usage Survey (VIUS). VIUS had been previously prepared as part of the U.S. Economic Census but has not been conducted since 2002. While VIUS asked a number of operation and usage questions, of particular interest for computing payload factors are those questions concerning trucks carrying commodities. While the VIUS commodity labels and codes are different than the SCTG2 commodity classification, there is a specific VIUS commodity reported for each SCTG2 commodity as used in FAF, as shown in appendix C.

VIUS, as a national survey, provides the information required to compute payload by SCTG2 commodity for the entire United States on all roads in the United States. The sampling was done from States registration databases. While the sampling is by State of registration, since the payload factors will be applied for all roads nationally, and registered trucks can operate on roads in States different than the State of registration, the difference between the sampling frame (by State of registration) and the application (on roads in any State) can be ignored.

The process used to apply payload factors in FAF4 is shown in figure 66.

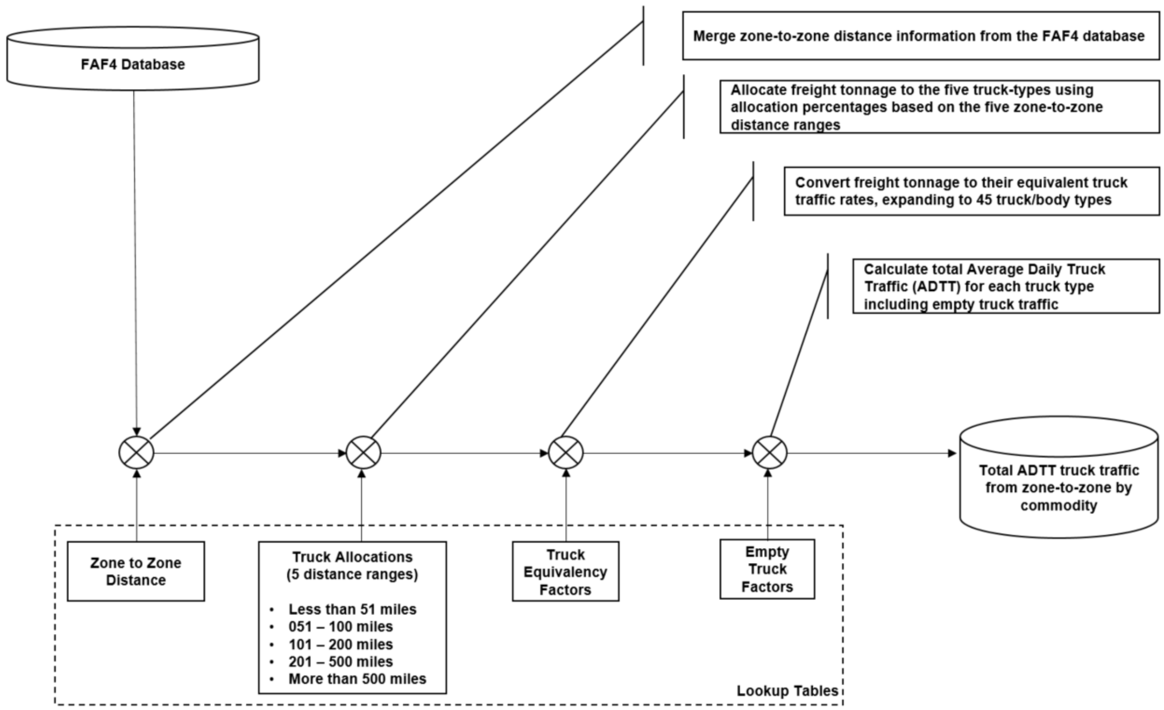

Figure 66. Flow chart. Freight analysis framework version 4 truck conversion flow diagram. (Source: FAF4 Freight Traffic Assignment (Maks Inc. 2016).)

The process develops payload factors by truck size and configuration by SCTG/VIUS commodity, according to 2002 VIUS. The truck configurations are from VIUS and are reported in table 28 (Maks Inc. 2016) and shown in figure 67.

Table 28. Vehicle inventory and use survey 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

(Source: FAF4 Freight Traffic Assignment (Maks Inc. 2016).)

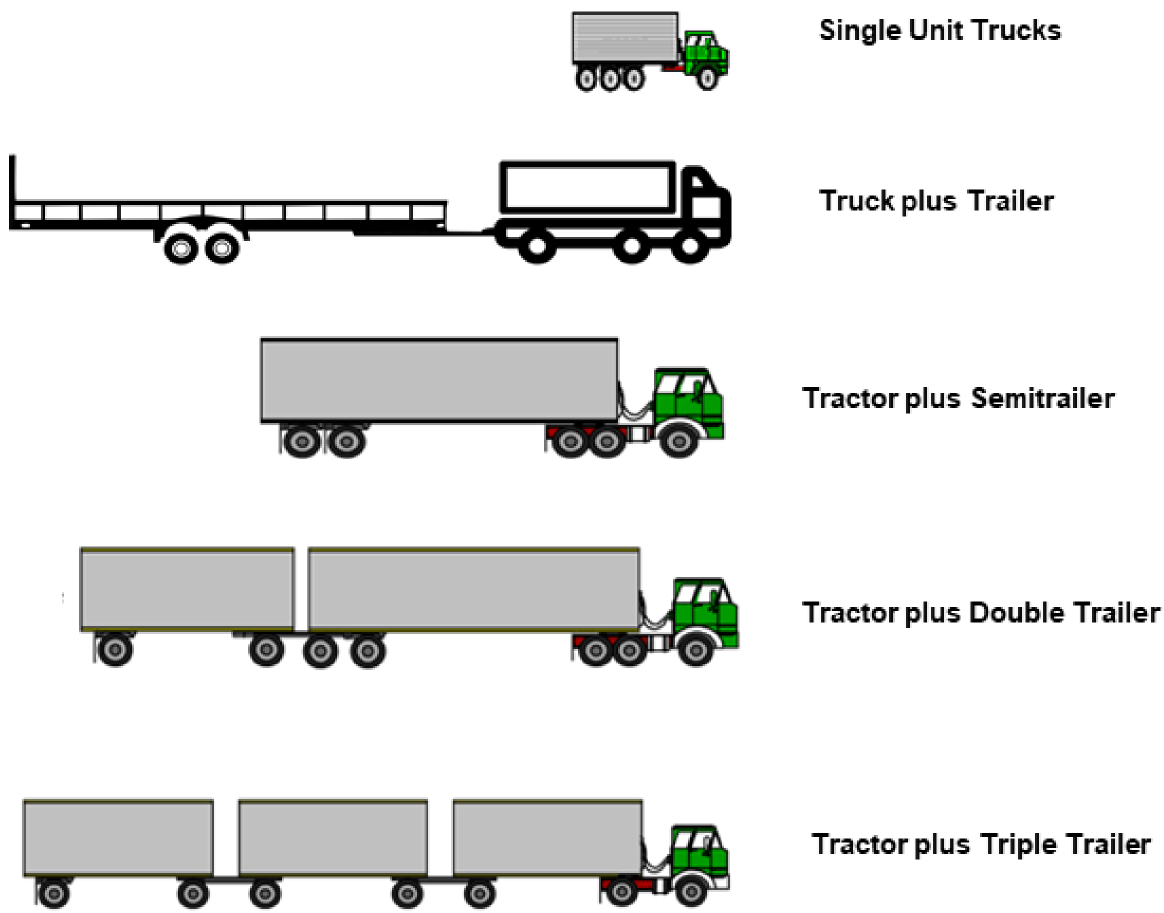

Figure 67. Illustration. Vehicle inventory and use survey truck configurations.
(Source: USDOT truck size and weight.)

These truck configurations are not sample strata. Single Unit (SU) trucks are the sum of two strata but the combination unit trucks are all within one sampling strata. The use of these "groups" that are not either sample strata, or aggregations of sample strata is not consistent with the VIUS sampling plan.

The truck body types, where the body type for trailers refers to the type of trailers, from VIUS, as reported in the FAF4 documentation is shown in table 29 and represents the population share of trucks by body type.

Table 29. Freight analysis framework/vehicle inventory and use survey 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	1.70%	Livestock
8	0.91%	Automobile
9	2.33%	Other

(Source: Federal Highway Administration.)

Allocation of tonnages to these body type and configurations were given by distance range as shown in table 30. The values in table 30 represent the share of reported trucks, using the axle configuration, body type and trailer types in VIUS, and those trucks were not sampled to ensure a representative sample of these body types. While the allocation factors in table 30 are correct, using VIUS's *Trip_Primary* distance attribute and the truck populations using table 28, and table 30 does show the usage of smaller trucks for shorter distances. These shorter distances also are reflected when computing the miles and ton-miles for each SCTG2 for each record. When this information is aggregated by SCTG2 commodity, it implicitly reflects this same distribution. Additionally, this distance range properly applies only to the Principal Product Carried. As its use is described, it most probably excludes all records where the Principal Product Carried was reported to be Multiple Categories, because this has no SCTG2 equivalent. By using the reported ton-miles and miles for every SCTG2 commodity, the information from surveys with commodities classified as Multiple Categories will be considered.

Table 30. Freight analysis framework/vehicle inventory and use survey 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	0.064660	0.014900	0.879727	0.034143	0.004225

(Source: Federal Highway Administration.)

As noted in table 28, the calculation of trucks from FAF tons by truck is a multi-step process. First, the mean payloads by truck type, body type, and commodity type were calculated using VIUS 2002 database and a study prepared by Battelle for Federal Highway Administration (FHWA) (Alam 2007). 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. These payload factors (in the report called TPFs) by SCTG2 commodity and truck size are applied to the allocation of truck and body size by distance range.

While the allocation factors may be reported from VIUS, those allocation factors also have an error range associated with them that could be reported. The sampling plan in the VIUS ensures that the error, and expansion factor, is within a prescribed standard for the sampling strata but those strata do not vary by commodity, truck body type and distance range as shown above. The sampling strata used in VIUS are shown in table 31.

Table 31. Vehicle inventory and use survey strata.

Stratum Code	Stratum Description
1	Pickups.
2	Minivans, other light vans, and sport utilities.
3	Light single-unit trucks (GVW[1] 26,000 lbs. or less).
4	Heavy single-unit trucks (GVW[1] 26,001 lbs. or more).
5	Truck-tractors.

(Source: U.S. VIUS.)

[1] GVW is Gross Vehicle Weight, the maximum load allowed for that truck.

The application of the empty truck factor according to the process shown is in the same direction as loaded trucks and applies equally for all commodities within the same body type. The usage of empty trucks is more complicated than this assumption. For example, for some commodities and body types, such as fuel oils in tanker trucks, the empty trucks are most probably in the opposite direction as loaded trucks.

Neglecting distance ranges and empty truck factors, using the methods and percentages described in the FAF4 documentation, the payloads by commodity can be computed as shown in table 32. These are the current payload factors excluding the empty truck and distance factors, which could be replaced. They are shown in table 32 to show what the payload factors would be without the distance and empty truck considerations, which is a closer comparison to what will be proposed.

It is not clear from the documentation if the survey record expansion factors in VIUS (there are separate expansion factors for trucks and miles) are used in computing the allocation factors. Even if the proper expansion factors were used, the allocation factors are treated as if they were without error. Those percentages have a standard error that can be computed from the standard deviation and the count of the records reported.

Finally, the payload factors shown are based on several calculations that include a number of steps (e.g., trucks by commodity based on truck size and body type). The error in computation increases at every step of the process and each time the calculations of payload factors are applied. The adjusted payload factors as shown in table 32 may exceed the legal payload for a truck of 80,000 lbs., when a default empty truck weight of 33,000 is added to those payload factors.[64] The implied GVW of a truck for each SCTG2 commodity is shown with those GVWs

[64] Load limits apply to the total weight of a truck, empty plus goods carried. The actual empty weight for any truck size is a range, not a single value. U.S. Environmental Protection Agency (EPA) has used a default empty weight for combination unit (CU) trucks, the most common

that exceed the typical legal limit shown in bold text. By computing ton-miles and miles by SCTG within each record and then calculating TPFs or payload factors, from these values with only a single calculation, the error associated with each step of a multiple step calculation process for the summary tables does not occur. It is incorrect to assume that the percentages of a commodity by truck body type and size are without error. It also is incorrect to assume that this error will not increase with each application of these percentages. In order to minimize these errors, the payload factors for FAF could be directly computed for a commodity within a VIUS survey record, not by body type and truck size which are summarized in table form before being used, and may be based on properly expanded information from survey records applicable to that commodity. The first step of a proposed method which minimizes the error and uses information for each record will be discussed in chapter 12.

Table 32. Adjusted freight analysis framework version 4 truck payload factors including a default empty truck weight by standard classification of transported goods 2 commodity.

Commodity	Commodity Name	Tons per Truck	Total GVW
SCTG 1	Live animals/fish	21.72	76,440
SCTG 2	Cereal grains	28.43	**89,860**
SCTG 3	Other agriculture products	22.19	77,380
SCTG 4	Animal feed	22.92	78,840
SCTG 5	Meat/seafood	15.72	64,440
SCTG 6	Milled grain products	9.37	51,740
SCTG 7	Other foodstuffs	17.81	68,620
SCTG 8	Alcoholic beverages	18.69	70,380
SCTG 9	Tobacco products	11.29	55,580
SCTG 10	Building stone	26.69	**86,380**
SCTG 11	Natural sands	29.78	**92,560**
SCTG 12	Gravel	32.96	**98,920**
SCTG 13	Nonmetallic minerals	31.56	**96,120**
SCTG 14	Metallic ores	31.00	**95,000**
SCTG 15	Coal	34.95	**102,900**
SCTG 16	Crude petroleum	24.01	**81,020**
SCTG 17	Gasoline	21.11	**75,220**
SCTG 18	Fuel oils	27.88	**88,760**
SCTG 19	Coal-n.e.c.	20.01	73,020
SCTG 20	Basic chemicals	21.79	76,580
SCTG 21	Pharmaceuticals	14.41	61,820
SCTG 22	Fertilizers	23.79	**80,580**
SCTG 23	Chemical products	20.05	73,100
SCTG 24	Plastics/rubber	14.26	61,520

truck size carrying commodities, as 28K to 36K lbs. 2002 U.S. VIUS for tractor trailers reporting an empty weight, reports an average empty weight of 30,794, but this precision is misleading because there is an also an unknown error associated with this value. 33K lbs. was chosen because it represents the start of the tractor trailer GVW category (33K and above).

Table 32. Adjusted freight analysis framework version 4 truck payload factors including a default empty truck weight by standard classification of transported goods 2 commodity (continuation).

Commodity	Commodity Name	Tons per Truck	Total GVW
SCTG 25	Logs	25.77	**84,540**
SCTG 26	Wood products	19.50	72,000
SCTG 27	Newsprint/paper	21.81	76,620
SCTG 28	Paper articles	11.04	55,080
SCTG 29	Printed products	10.26	53,520
SCTG 30	Textiles/leather	12.38	57,760
SCTG 31	Nonmetal mineral products	31.39	**95,780**
SCTG 32	Base metals	15.10	63,200
SCTG 33	Articles-base metal	15.07	63,140
SCTG 34	Machinery	16.76	66,520
SCTG 35	Electronics	13.14	59,280
SCTG 36	Motorized vehicles	17.43	67,860
SCTG 37	Transport equip.	23.54	**80,080**
SCTG 38	Precision instruments	9.49	51,980
SCTG 39	Furniture	14.17	61,340
SCTG 40	Misc. manufactured products	14.84	62,680
SCTG 41	Waste/scrap	23.44	79,880
SCTG 43	Mixed freight	26.53	**86,060**

(Source: Federal Highway Administration.)

CHAPTER 11. REVIEW OF ALTERNATIVE TRUCK PAYLOAD FACTORS METHODS

A number of methods to compute Payload factors were reviewed as shown in table 33. The methods, and their sources will be discussed in the subsections that follow.

Table 33. Current and alternative methods.

Truck Payload Factors (TPF) Method	Notable Features	Comments
Freight Analysis Framework (FAF) 2 method	Different payload factors by Truck Size and Weight (TSW) Region.	TSW regions by State of registration, not State of operation.
FAF 3 and 4 Method	Payload factors, by 3 dimensions from Vehicle Inventory and Use Survey (VIUS). Also includes distance variable.	3 dimensions are not part of sampling frame. While shares are stated precisely, those shares ignore standard errors. This method increases standard error. Distance variable does not consider all Standard Classification of Transported Goods (SCTG) information and may not be properly applied. Even as computed, payload factors are fairly constant for miles > 100.
VIUS Revisited	Ton-miles and miles by SCTG2 for each sample record. Distribution could reflect proper expansion sampling. Payload factors as sum of Ton-miles divided by sum of Miles.	Payloads can be computed for each record by SCTG based on reported data. Expanded based on sampling frame.
CA-VIUS	Reporting uses California Statewide Freight Forecasting Model Commodity Groups.	More recent survey than 2002 U.S. VIUS. Compare findings with VIUS revisited.
Weigh-in-motion (WIM) alone	Inferred empty weight. Payload uses this inferred empty weight subtracted from average observed weight.	Does not include commodity detail. Inferred empty weight only.
WIM with Loop Inferences	Add payload by inferred body type.	Infers body type based on reported data. Can only do payload by body type. Possibly compare with, and modify, FAF, payload factors by SCTG.

Table 33. Current and alternative methods (continuation).

TPF Method	Notable Features	Comments
WIM with Timestamp Video	Add payload by confirmed body type.	Can only do payload by body type. Possibly compare with and modify FAF payload factors by SCTG.
WIM with Enhanced Electronic Clearance/ Electronic Logging Devices (ELD)	Add payload by confirmed entry weight, commodity type, body type.	Aspirational only, if possible could confirm empty weight, body type, commodity type (current information does not support SCTG2 codes. Current ELD/Electronic Clearances only report restricted commodities.).
Possible VIUS Replacement, VIUS Pilot	Consistent with above. Integrated with Freight Performance Measurement system and National Performance Management Research Dataset. Performance Management System Rules.	VIUS Pilot and Replacement suspended because no suitable methods could be identified.
Canadian VIUS	Subject to Canadian operating rules by selected drivers; commodity detail added by driver by electronic box.	Canadian economy and operational rules may not be directly applicable to U.S./FAF. Considered under Replacement of VIUS.

(Source: Federal Highway Administration.)

FREIGHT ANALYSIS FRAMEWORK 2 METHOD

FAF1 was based on the commercial TRANSEARCH database which reports trucks, and thus payload factors were not needed. FAF2 used a method that apparently varied the payloads by SCTG commodity by TSW region. These TSW regions were applied to the information from VIUS. However, the State, as reported in VIUS, is the State of registration, which may not be the TSW State, the State in which a truck is operating, which would be required for variation by TSW region.

FREIGHT ANALYSIS FRAMEWORK 3 AND 4 METHOD

The current Freight Analysis Framework Version 3 (FAF3)/FAF4 methods have been discussed previously in chapter 2. The current method uses:

- Distance ranges which show little variation.
- Are only for the principal commodity carried and not for each individual commodity carried.
- May have not been computed using the correct expansion factors as applied to the survey records.

- Have standard errors that will differ by SCTG2 commodity, and that standard error will increase for each mathematical computation that is used. The payload factors in the current Freight Analysis Framework Version 4 (FAF4) use at least 3 computations.

2002 VEHICLE INVENTORY AND USE SURVEY REVISITED

From the 2002 VIUS micro data, tons and ton-miles by SCTG2 commodity were calculated for each record, using the mileage expansion factor. With this calculation, it is possible to compute the standard deviations, counts, means, etc., and compute the standard error. The payload factors by SCTG2 could be computed by only one mathematical operation as ton-miles divided by miles for each SCTG2 commodity. In addition to minimizing the increase in errors, basing the payload factor on tons and miles, where changes in tons and miles can be validated against other sources, is a better option than using body type and truck configuration. Truck configuration and body type data are not easily available or on a consistent basis thereby preventing the ability to update payload factors.

CALIFORNIA VEHICLE INVENTORY AND USE SURVEY

California Vehicle Inventory and Use Survey (CA-VIUS) microdata are not yet available, but the payloads by its commodities, which were aggregations of SCTG2 commodities, were provided to the project team and are shown in table 10. It is noted that CA-VIUS sampling frame was trucks registered in California that travel on California roads, and trucks registered in other States (according to the International Registration Plan (IRP)) that also travel on California roads. While CA-VIUS is more recent than 2002 U.S. VIUS, the calculation of payloads for CA-VIUS commodities was according to the truck sizes as used in the California Statewide Travel Demand model.

WEIGH-IN-MOTION ALONE

A number of researchers have proposed determining payloads factors using truck weigh-in-motion (WIM) data, which is required to be submitted by each State Department of Transportation. That research highlighted a number of issues. First the WIM data never reports the cargo of the trucks but only the weight distributions of observed trucks. The most frequently observed weights are often assumed to be the average empty load and the average full loads. This allows the inference of the cargo payload as the difference between the inferred fully loaded trucks and the inferred empty trucks. Trucks are differentiated by the number and spacing of axles which is used to infer truck type. WIM is an indirect set of observations which does not provide any method to determine the commodity of the cargo being transported. Relying on percentages of use by different commodities as in the VIUS will help determine the commodity distribution but doing so will ignore the errors that are associated with these percentages in the VIUS.

WEIGH-IN-MOTION WITH LOOP INFERENCES

The inferences of truck size, which is based on the number and spacing of axles, can be supplemented by an inference of the truck body type. The magnetic or other signature of the truck is detected by WIMs or supplemented with loop detectors, and that is used to infer the truck body type based on the signature detected. While these inferences have shown promise (Hernandez 2016), they do not include any information about the contents of the truck, i.e., the commodities being transported. Using the VIUS percentages by body type and size typically ignores the error associated with these percentages.

WEIGH-IN-MOTION WITH TIMESTAMP VIDEO

The inferences of truck size and body type can be confirmed with video images. A problem is reconciling the observed video image with the inferred truck and body size. This requires that the video image and the WIM observations be of the same truck, perhaps by timestamping both observations. This method has been proposed and shows promise, but its practical widespread application has not been demonstrated. Additionally, the video cannot observe the contents of the truck and using percentages from 2002 VIUS will be problematic if the errors associated with those percentages are ignored.

WEIGH-IN-MOTION WITH ENHANCED ELECTRONIC CLEARANCE/ELECTRONIC LOGGING DEVICES

Enhanced Electronic Clearances, which requires trucks with this required technology, can report the contents of the truck. Typically, only restricted commodities are reported, and to be useful in calculating payload factors by SCTG2 commodity, reporting would have to be expanded and all commodities reported using the SCTG2 codes. While Electronic Clearances are associated with a truck, ELD drivers records the Hours of Service by truck drivers. While these ELDs report only the restricted commodities that are permitted for a given driver, these could be expanded to report the SCTG2 commodities. Even if these methods could report the commodity being carried, it would still be necessary to associate a truck with a driver. If these issues could be overcome, and the SCTG2 commodity could be determined, to be useful in computing payload factors the bias in ELD usage also need to be addressed.

VEHICLE INVENTORY AND USE SURVEY REPLACEMENT

The Vehicle Inventory and Use Survey (VIUS) was the principal data source on the physical and operational characteristics of the United States truck population from 1963 through 2002. The survey was discontinued prior to the 2007 survey due to budget constraints. Since that time, State departments of transportation (DOT), metropolitan planning organizations (MPO), as well as many Federal agencies have had no other alternative than to use the outdated 2002 VIUS data. The need to update the payload factors that could be computed from VIUS was addressed by FHWA in the VIUS Replacement project, but no suitable methods could be identified. In sum, these efforts determined that the best course of action would be to pursue the traditional VIUS survey model.

CANADIAN VEHICLE INVENTORY AND USE SURVEY

Canada has deployed units in certain trucks that assist in collecting information similar to what was reported in VIUS. The commodity being carried must still be entered by the driver into a unit installed in certain trucks. Canada also uses the SCTG system and commodity information is being collected according to this system. However, the differences in operations and legal regulations, such as weight limits, cost controls, or Hour of Service rules, will probably mean that payload factors that can be computed based on Canadian data are not necessarily directly transferable to the U.S. as required by the FAF.

CHAPTER 12. PROPOSED METHODOLOGY TO REVISE PAYLOAD FACTORS

This section proposes a new methodology to revise the estimation of payload factors in light of the shortcomings of the existing methods highlighted in chapter 11. The method relies on the 2002 Vehicle Inventory and Use Survey (VIUS) data along with weigh-in-motion (WIM) and Highway statistics data from 2012 and 2017. The proposed methodology is a three-step process and is detailed below.

STEP 1: REVISIT 2002 VEHICLE INVENTORY AND USE SURVEY

As a first step, the 2002 VIUS was revisited. The micro data for 2002 VIUS was obtained and examined. The responses to questions in the VIUS allow for the calculation of ton miles and miles by commodity and for error ranges, e.g., standard errors, to be compared for the calculations.

While this new analysis uses the weighting of tons according to the sampling plan, and the weighting of miles also from the sampling plan, the existing method merely presents the percentages of truck size, distance range and truck body type by commodity, but it does not state whether those percentages were derived from the weighted or unweighted survey responses.

The weighed annual trucks for each record was reported as:

> *TAB_TRUCKS = Expansion (Weighting) Factor for Trucks. Expansion factor used to weight each estimate for calculating trucks.*

The weighted annual miles driven were reported for each survey record as:

> *TAB_MILES = Weighted Annual Miles Driven During 2002. Expansion factor used to weight each estimate for calculating truck miles traveled.*

The load carried for each record was computed to be the average weight while loaded,

> *WEIGHTAVG = Average Weight of Vehicle or Vehicle/Trailer Combination. Question: What was the average weight (vehicle weight plus cargo weight) of this vehicle or vehicle/trailer combination as it was most often operated when carrying a typical payload during 2002?*[65]

Minus the empty weight of the vehicle as reported for each VIUS response.

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[65] It is acknowledged that the average payload weight can be expected to vary by commodity, and even vary within commodities depending on whether they are carried with other commodities within the same truck. However, this is the only payload weight question that is asked of respondents and, as such, it is assumed that it is applicable for all conditions.

> *WEIGHTEMPTY = Empty Weight of Vehicle or Vehicle/Trailer Combination. Question: What was the empty weight of this vehicle or vehicle/trailer combination?*

The Principal Product Carried was used in previous analysis to define the commodity carried. While the VIUS commodity codes can be cross walked to the Standard Classification of Transported Goods (SCTG) 2 commodity codes, the Principal Product Carried was not used in this analysis because any record (truck) could carry more than one commodity. Instead the percentage of miles carrying each commodity for each survey response was used.

The reported percentage of miles carrying each VIUS commodity code is given for each record. An example, for Sand—SCTG 11, is shown below.

> *PSANDS = Percent of Loaded Miles Carrying Natural Sands, SCTG 11. Question: During 2002, what products, tools, equipment, or materials did this vehicle carry, and what approximate percent of LOADED mileage were they carried?*

This information can be used to allocate the miles traveled by a truck record to each commodity. This information is sufficient to calculate the cargo load for each record, and the weighted miles for each SCTG2 commodity. The weighted cargo multiplied by weighted miles for each record multiplied by the percentage of miles carrying each commodity gives the ton-miles for each commodity for each record.

It is appropriate for any reported or derived statistic to be differentiated by the sample stratum for those records only. For example, it would not be correct to say with statistically certainty that a certain commodity is carried in certain body types, because neither the body type nor the commodity carried are in the sample stratum.

The ton miles per truck from the 2002 VIUS are as shown in table 34. Also shown in table 34 are the results for strata as defined in table 31. The results for Stratum 1 and 2 are typically combined as Light Trucks. The results for Stratum 3 and 4 are typically combined as Single Units (SU) trucks. The results for Stratum 5 are typically called Combination Unit (CU) trucks. Also shown are the results for all truck strata combined, for only SU and CU trucks, and the standard error using the customary formulae for each for each as calculated from the standard deviation, counts and means of the survey records.

The miles per truck from the 2002 VIUS are as shown in table 35. VIUS also reports miles that are used by truck to transport Tools (powered and nonpowered), and for personal uses. Those miles as well as the percentage of all miles in Service, i.e., carrying tools, in personal use, and carrying cargo by commodities are shown in table 35. The payload factors by SCTG2, as tons per truck, are calculated by dividing the ton-miles in table 34 by the miles per truck in table 35 and are shown in table 36.

It is not proposed that Light Trucks be included for use in the Freight Analysis Framework (FAF). As shown in table 35, light trucks are predominately used for personal purposes, 82 percent of all miles, not to transport SCTG freight. By contrast the combined total of miles for SU and CU trucks are predominately used to transport SCTG2 freight, 81 percent of all miles.

Table 34. 2002 vehicle inventory and use survey ton miles (in billions) by standard classification of transported goods 2 commodity and by truck size.

Commodity	Stratum 1&2 Also known as Light Trucks	Relative Standard Error	Stratum 3&4 Also known as SU trucks	Relative Standard Error	Stratum 5 Also known as CU trucks	Relative Standard Error	All Stratums	Relative Standard Error	Combined SU and CU trucks	Relative Standard Error
01	3.22	17.9%	0.55	37.3%	10.55	9.8%	14.32	7.3%	11.10	6.6%
02	1.54	26.4%	2.04	9.3%	25.30	3.3%	28.88	2.1%	27.34	4.5%
03	4.80	26.4%	2.69	9.3%	38.25	3.3%	45.75	2.1%	40.94	5.9%
04	3.03	19.8%	1.59	16.5%	17.63	4.0%	22.25	2.8%	19.22	7.8%
05	1.67	35.3%	1.56	14.6%	47.41	1.4%	50.65	2.8%	48.97	2.9%
06	1.77	36.0%	1.76	11.1%	43.18	1.6%	46.70	2.8%	44.93	3.1%
07	3.29	26.3%	4.80	7.4%	88.76	1.1%	96.85	2.8%	93.56	2.2%
08	0.43	45.8%	0.94	16.9%	16.90	1.7%	18.27	2.8%	17.84	3.8%
09	0.40	39.8%	0.43	34.0%	6.66	3.7%	7.49	2.8%	7.09	8.3%
10	0.52	62.5%	1.40	13.6%	5.07	8.2%	6.99	2.8%	6.47	14.4%
11	0.18	56.6%	6.35	6.1%	11.09	3.4%	17.63	2.8%	17.45	6.3%
12	1.18	52.9%	18.54	4.0%	27.31	4.0%	47.03	2.8%	45.85	6.0%
13	0.09	42.2%	2.51	10.0%	6.24	3.5%	8.83	2.8%	8.75	7.7%
14	0.00	100.0%	0.14	35.5%	0.59	6.3%	0.73	2.8%	0.73	17.0%
15	0.00	57.8%	0.99	16.1%	6.07	2.0%	7.07	2.8%	7.07	5.7%
16	#N/A	#N/A	0.34	25.7%	1.77	3.8%	2.11	2.8%	2.11	10.5%
17	0.67	35.6%	0.80	17.1%	14.48	2.1%	15.94	2.8%	15.27	4.4%
18	3.08	26.0%	3.75	8.5%	12.07	7.6%	18.90	2.8%	15.82	12.1%
19	0.87	25.4%	2.67	8.3%	9.53	3.7%	13.07	2.8%	12.20	7.1%
20	1.32	49.1%	1.19	17.6%	10.48	6.7%	12.99	2.8%	11.67	12.3%
21	1.06	39.9%	0.45	30.9%	3.08	15.0%	4.60	2.8%	3.54	26.7%
22	3.15	36.3%	1.11	11.5%	7.96	13.3%	12.23	2.8%	9.07	21.1%
23	10.44	48.2%	1.11	13.7%	17.70	24.6%	29.25	2.8%	18.81	39.4%
24	3.07	28.0%	0.91	17.3%	15.49	5.4%	19.46	2.8%	16.39	9.7%

Table 34. 2002 vehicle inventory and use survey ton miles (in billions) by standard classification of transported goods 2 commodity and by truck size (continuation).

Commodity	Stratum 1&2 Also known as Light Trucks	Relative Standard Error	Stratum 3&4 Also known as SU trucks	Relative Standard Error	Stratum 5 Also known as CU trucks	Relative Standard Error	All Stratums	Relative Standard Error	Combined SU and CU trucks	Relative Standard Error
25	1.18	34.6%	1.33	13.5%	18.21	2.6%	20.72	2.8%	19.54	5.2%
26	10.33	17.9%	3.76	6.5%	43.91	4.0%	58.00	2.8%	47.67	6.7%
27	0.14	45.6%	0.19	50.5%	16.10	0.8%	16.43	2.8%	16.29	2.0%
28	0.99	33.3%	0.84	17.4%	32.94	1.2%	34.77	2.8%	33.77	2.4%
29	4.96	50.1%	0.60	15.2%	9.09	23.7%	14.65	2.8%	9.69	38.2%
30	3.17	33.3%	0.62	17.4%	19.87	1.2%	23.66	2.8%	20.49	16.1%
31	6.64	30.5%	15.19	4.0%	28.80	7.5%	50.63	2.8%	43.99	9.9%
32	9.16	25.1%	2.06	12.9%	38.12	5.6%	49.34	2.8%	40.19	9.7%
33	28.84	16.5%	3.84	10.0%	17.31	24.8%	49.99	2.8%	21.15	36.0%
34	14.38	23.6%	2.31	11.8%	35.44	8.6%	52.12	2.8%	37.74	14.4%
35	25.04	28.4%	1.54	14.4%	17.28	35.6%	43.85	2.8%	18.81	55.8%
36	5.29	27.4%	3.94	10.6%	38.02	4.0%	47.24	2.8%	41.95	7.3%
37	0.72	53.7%	0.35	42.8%	11.47	3.8%	12.54	2.8%	11.82	7.7%
38	15.62	29.7%	0.90	23.9%	4.57	89.0%	21.09	2.8%	5.47	128.4%
39	3.07	23.1%	1.12	10.9%	19.78	3.5%	23.96	2.8%	20.90	6.2%
40	13.36	38.0%	1.84	12.8%	32.30	13.8%	47.50	2.8%	34.13	22.5%
41	2.80	19.1%	17.87	5.5%	19.07	6.2%	39.74	2.8%	36.94	8.6%
42	7.34	26.1%	8.36	21.5%	33.49	8.9%	49.19	2.8%	41.85	17.2%
43	0.26	44.6%	1.14	15.8%	237.94	0.1%	239.34	2.8%	239.08	0.3%
All SCTGs	**199.06**	**29.1%**	**126.42**	**9.5%**	**1,117.28**	**5.2%**	**1,442.72**	**4.3%**	**1,243.66**	**8.9%**

(Source: Federal Highway Administration.)

Table 35. 2002 vehicle inventory and use survey miles (in billions) by standard classification of transported goods 2 commodity and by truck size.

Commodity	Stratums 1&2 Light Trucks	Relative Standard Error	Stratums 3&4 SU trucks	Relative Standard Error	Stratum 5 CU trucks	Relative Standard Error	All Stratums	Relative Standard Error	Combined SU and CU trucks	Relative Standard Error
01	1.21	23%	0.18	39%	0.53	9%	1.93	35%	0.71	23%
02	0.41	26%	0.22	8%	1.11	6%	1.73	20%	1.32	11%
03	1.33	15%	0.57	8%	1.87	6%	3.77	17%	2.44	10%
04	1.08	16%	0.22	12%	1.84	7%	3.13	19%	2.06	12%
05	0.87	24%	0.43	12%	2.46	5%	3.76	18%	2.89	9%
06	1.09	37%	0.93	7%	2.43	5%	4.45	24%	3.36	9%
07	1.60	21%	1.1	6%	6.03	3%	8.72	13%	7.12	6%
08	0.27	66%	0.17	13%	0.93	6%	1.37	33%	1.09	11%
09	0.23	47%	0.07	29%	0.36	13%	0.67	48%	0.43	25%
10	0.25	37%	0.16	16%	0.26	11%	0.67	38%	0.41	19%
11	0.06	36%	0.48	6%	0.49	9%	1.03	17%	0.97	11%
12	0.51	43%	1.25	3%	1.20	6%	2.96	20%	2.45	7%
13	0.05	64%	0.19	8%	0.26	12%	0.50	29%	0.45	16%
14	0.00	100%	0.02	35%	0.03	27%	0.04	55%	0.04	45%
15	0.00	59%	0.05	17%	0.24	14%	0.29	28%	0.29	23%
16	#N/A	#N/A	0.05	31%	0.08	28%	0.13	54%	0.13	44%
17	0.53	40%	0.15	13%	0.61	9%	1.29	39%	0.76	15%
18	2.13	32%	0.59	9%	0.51	9%	3.22	42%	1.1	12%
19	0.61	33%	0.63	8%	0.44	12%	1.68	32%	1.07	14%
20	0.56	27%	0.29	13%	0.53	10%	1.39	30%	0.83	16%
21	0.81	30%	0.13	20%	0.17	22%	1.10	48%	0.29	31%
22	0.98	49%	0.22	9%	1.41	9%	2.60	43%	1.63	14%
23	4.29	24%	0.35	10%	0.93	9%	5.56	36%	1.27	15%
24	1.53	25%	0.36	10%	1.92	7%	3.81	26%	2.28	12%
25	0.50	31%	0.17	14%	0.78	6%	1.45	27%	0.95	12%
26	4.39	15%	1.03	6%	2.13	4%	7.55	19%	3.16	8%

Table 35. 2002 vehicle inventory and use survey miles (in billions) by standard classification of transported goods 2 commodity and by truck size (continuation).

Commodity	Stratums 1&2 Light Trucks	Relative Standard Error	Stratums 3&4 SU trucks	Relative Standard Error	Stratum 5 CU trucks	Standard Error	All Stratums	Standard Error	Combined SU and CU trucks	Relative Standard Error
27	0.14	46%	0.05	32%	1.86	7%	2.06	20%	1.92	13%
28	0.76	28%	0.24	12%	2.84	5%	3.85	19%	3.09	10%
29	2.83	20%	0.22	12%	0.49	12%	3.53	31%	0.71	18%
30	1.35	32%	0.28	12%	1.13	7%	2.76	35%	1.41	13%
31	3.04	19%	1.47	4%	1.28	6%	5.79	22%	2.75	8%
32	3.53	18%	0.77	9%	1.93	6%	6.23	23%	2.7	10%
33	12.48	10%	1.63	6%	0.91	7%	15.03	17%	2.54	9%
34	4.85	15%	0.89	7%	1.90	7%	7.64	21%	2.79	10%
35	9.39	12%	0.69	9%	2.00	7%	12.08	19%	2.69	11%
36	3.02	19%	1.41	10%	2.18	6%	6.61	22%	3.59	10%
37	0.19	33%	0.05	20%	0.53	15%	0.77	37%	0.57	25%
38	6.66	14%	0.35	13%	0.24	18%	7.26	25%	0.59	22%
39	1.43	20%	0.58	8%	1.16	6%	3.18	22%	1.75	10%
40	5.59	18%	0.68	8%	2.84	6%	9.12	24%	3.53	9%
41	1.39	17%	2.34	4%	0.91	7%	4.63	15%	3.25	7%
42	4.47	21%	2.26	18%	1.99	8%	8.72	29%	4.25	18%
43	0.07	38%	0.38	12%	14.09	3%	14.54	8%	14.47	6%
All SCTGs	86.49	19%	24.3	9%	67.81	7%	178.58	24%	92.13	12%
Tools Powered	34.21	6%	41.03	5%	0.62	9%	38.93	10%	41.65	7%
Tools Nonpowered	46.28	5%	55.68	6%	0.43	10%	52.27	9%	56.11	8%
Total Service (Tools)	80.48		96.8		1.06		91.21		97.77	
Personal	750.55		68.68	10%	0.05	21%	757.47	2%	68.73	13%
Total	917.45		189.69	10%	68.93	8%	1,012.72	6%	258.62	12%
Personal	82%		36%		0%		74%		27%	
Service	9%		51%		2%		9%		38%	

Table 35. 2002 vehicle inventory and use survey miles (in billions) by standard classification of transported goods 2 commodity and by truck size (continuation).

Commodity	Stratums 1&2 Light Trucks	Relative Standard Error	Stratums 3&4 SU trucks	Relative Standard Error	Stratum 5 CU trucks	Relative Standard Error	All Stratums	Relative Standard Error	Combined SU and CU trucks	Relative Standard Error
SCTGs	9%		13%		98%		17%		36%	

(Source: Federal Highway Administration.)

Table 36. 2002 vehicle inventory and use survey tons per truck by standard classification of transported goods 2 commodity and by truck size.

Commodity	Stratum 1&2 Light Trucks	Relative Standard Error	Stratum 3&4 SU trucks	Relative Standard Error	Stratum 5 CU trucks	Relative Standard Error	All Stratums	Relative Standard Error	Combined SU and CU trucks	Relative Standard Error
01	2.65	29%	3.06	54%	19.91	13%	7.44	13%	15.63	11%
02	3.80	37%	9.27	12%	22.79	7%	16.72	6%	20.71	6%
03	3.61	30%	4.72	12%	20.45	7%	12.14	5%	16.78	7%
04	2.82	25%	7.23	21%	9.58	8%	7.10	6%	9.33	9%
05	1.92	43%	3.63	19%	19.27	5%	13.47	6%	16.94	5%
06	1.62	51%	1.89	13%	17.77	6%	10.50	7%	13.37	5%
07	2.06	33%	4.36	10%	14.72	4%	11.10	4%	13.14	3%
08	1.56	80%	5.53	21%	18.17	6%	13.35	9%	16.37	6%
09	1.71	62%	6.14	45%	18.50	14%	11.25	14%	16.49	13%
10	2.05	72%	8.75	21%	19.50	14%	10.49	12%	15.78	17%
11	2.83	67%	13.23	8%	22.63	10%	17.06	6%	17.99	8%
12	2.30	68%	14.83	5%	22.76	7%	15.87	7%	18.71	7%
13	1.69	77%	13.21	13%	24.00	12%	17.60	9%	19.44	10%
14	1.00	141%	7.00	50%	19.67	28%	17.30	16%	18.25	26%
15	4.04	83%	19.80	24%	25.29	14%	24.41	8%	24.38	11%
16	#N/A	#N/A	6.80	40%	22.13	29%	16.60	16%	16.23	22%
17	1.27	54%	5.33	21%	23.74	9%	12.39	12%	20.09	7%
18	1.45	41%	6.36	12%	23.67	12%	5.86	14%	14.38	13%

Table 36. 2002 vehicle inventory and use survey tons per truck by standard classification of transported goods 2 commodity and by truck size (continuation).

Commodity	**Stratum 1&2 Light Trucks**	**Relative Standard Error**	**Stratum 3&4 SU trucks**	**Relative Standard Error**	**Stratum 5 CU trucks**	**Relative Standard Error**	**All Stratums**	**Relative Standard Error**	**Combined SU and CU trucks**	**Relative Standard Error**
19	1.44	41%	4.24	12%	21.66	13%	7.79	11%	11.40	10%
20	2.35	56%	4.10	22%	19.77	12%	9.35	10%	14.06	14%
21	1.31	50%	3.46	37%	18.12	26%	4.17	16%	12.21	30%
22	3.23	61%	5.05	15%	5.65	16%	4.70	12%	5.56	22%
23	2.44	54%	3.17	17%	19.03	26%	5.26	12%	14.81	40%
24	2.01	37%	2.53	20%	8.07	9%	5.11	8%	7.19	11%
25	2.37	46%	7.82	19%	23.35	7%	14.26	8%	20.57	7%
26	2.35	23%	3.65	9%	20.62	6%	7.68	7%	15.09	7%
27	1.00	65%	3.80	60%	8.66	7%	7.99	6%	8.48	5%
28	1.30	43%	3.50	21%	11.60	6%	9.03	6%	10.93	4%
29	1.75	54%	2.73	20%	18.55	26%	4.14	11%	13.65	39%
30	2.35	46%	2.21	21%	17.58	8%	8.58	11%	14.53	17%
31	2.18	36%	10.33	6%	22.50	10%	8.74	8%	16.00	11%
32	2.59	31%	2.68	16%	19.75	8%	7.92	8%	14.89	11%
33	2.31	19%	2.36	11%	19.02	26%	3.33	6%	8.33	36%
34	2.97	28%	2.60	14%	18.65	11%	6.82	7%	13.53	15%
35	2.67	31%	2.23	17%	8.64	36%	3.63	7%	6.99	56%
36	1.75	33%	2.79	14%	17.44	7%	7.14	7%	11.69	9%
37	3.75	63%	7.00	47%	21.64	15%	16.36	10%	20.74	12%
38	2.34	33%	2.57	27%	19.04	91%	2.91	9%	9.27	129%
39	2.14	30%	1.93	13%	17.05	7%	7.54	7%	11.94	8%
40	2.39	42%	2.71	15%	11.37	15%	5.21	8%	9.67	23%
41	2.02	26%	7.64	7%	20.96	10%	8.58	6%	11.37	9%
42	1.64	33%	3.70	28%	16.83	12%	5.64	10%	9.85	19%
43	3.50	59%	3.00	20%	16.89	3%	16.46	3%	16.52	2%
All SCTGs	2.30	35%	5.20	13%	16.47	9%	15.66	24%	13.50	15%

(Source: Federal Highway Administration.)

Comparison of Proposed Payload Factors with California Vehicle Inventory and Use Survey

The microdata for California's VIUS (CA-VIUS is not yet publicly available). CA-VIUS, like 2002 U.S. VIUS, is a statistical survey. As such the factors that can be derived cannot be exact, but instead have standard errors associated with them. The sampling was conducted in a manner to minimize the error within the sampling strata. When attributes that are not sampling strata are used, the error associated with factors for these attributes can be computed but will not be the error associated with the sampling strata.

The California Department of Transportation (Caltrans) undertook the CA-VIUS project, a sampling of trucks registered in California which also travel on California roads, and of International Registration Plan (IRP) trucks traveling on California roads, because its ongoing responsibilities required payload factors, tons per truck, which were more current than those available from 2002 U.S. VIUS, which was its current source of those payloads.

Caltrans has not yet made the microdata for CA-VIUS available to this project. This means that the errors and statistics associated with its payload factors cannot be computed or restated for particular attributes. However, the payload factors for the California Statewide Freight Forecasting Model (CSFFM) are available. The computation of those payload CSFFM payload factors was in fact a major impetus for CA-VIUS. The CSFFM commodity groups are aggregations of SCTG2/U.S. VIUS commodity groups. Those aggregations are shown in table 37.

Table 37. California statewide freight forecasting model and standard classification of transported goods 2 commodity groups.

CSFFM Commodity Group	SCTG Code
G1 Agriculture products	1–4
G2 Wood, printed products	26–29
G3 Crude petroleum	16
G4 Fuel and oil products	17, 18, 19
G5 Gravel/sand and nonmetallic minerals	8–13
G6 Coal / metallic minerals	14–15
G7 Food, beverage, tobacco products	5–7
G8 Manufactured products	24, 30, 39, 40, 42, 43
G9 Chemical/pharmaceutical products	20–23
G10 Nonmetal mineral products	31
G11 Metal manufactured products	32–34
G12 Waste material	41
G13 Electronics	35, 38
G14 Transportation equipment	36–37
G15 Logs	25

(Source: Federal Highway Administration.)

The payloads for the CSFFM have been computed and are reported for trucks by GVW, as shown in table 38.

Table 38. California statewide freight forecasting model payloads by truck gross vehicle weight.

CSFFM Commodity Group	**14–26 k lbs. GVW 4 thru 6**	**26–33 k lbs. GVW 7**	**>33 k lbs. GVW 8**
G1 Agriculture products	4,856	14,943	39,350
G2 Wood, printed products	3,206	14,160	31,161
G3 Crude petroleum	3,640		34,458
G4 Fuel and oil products	8,946		33,078
G5 Gravel/sand and nonmetallic minerals	2,870	14,458	26,792
G6 Coal/metallic minerals	5,013	13,298	38,141
G7 Food, beverage, tobacco products	3,202	9,669	35,812
G8 Manufactured products	4,448	14,745	40,352
G9 Chemical/pharmaceutical products	4,131	6,192	40,471
G10 Nonmetal mineral products	4,089	10,457	33,166
G11 Metal manufactured products	3,820	9,352	37,046
G12 Waste material	3,243	18,637	39,257
G13 Electronics	4,223	10,993	35,151
G14 Transportation equipment	3,602	9,419	30,004
G15 Logs	4,381	10,861	38,919

(Source: Federal Highway Administration.)

There is no CSFFM payload provided for all commodity groups (CG) combined. While the 2002 U.S. VIUS also could be used to compute payload factors by GVW, this has not been done. Payload factors by GVW will not be used in the FAF. There is overlap between the proposed method and CA-VIUS for Combination Unit (CU) tractor-trailer trucks, which are primarily GVW 8. It is possible to compute the standard error for payload factors, from the standard deviation, count of records, and means, for ton miles and miles by SCTG2 commodity, and then to compare those with those for the CSFFM CGs. This can only be done for a comparison to the VIUS derived payload factors. Any updates to the payload factors for years other than 2002 will create additional changes to the standard error, error range, but those new error ranges cannot be computed. If the CA-VIUS payload factors for GVW 8 trucks fall within the error range for the 2002 VIUS payload factors (i.e., Truck Payload Factors) for CU trucks, then it can be assumed that CA-VIUS and 2002 U.S. VIUS derived payload factors are statistically the same. If they are not the same, it could be that the difference reflects usage of trucks by CG that is different in CA than in the United States, or that the more recent CA-VIUS reflects changes in trucking practices. The comparison between the U.S. and CA-VIUS for GVW8/CU truck is shown in table 39.

Table 39. Comparison of 2002 U.S. vehicle inventory and use survey and California vehicle inventory and use survey payload factors.

	2002 U.S. VIUS				CA-VIUS GVW 8	
CSFFM Commodity	**Tons per Truck**	**RSE**	**Low Lbs.**	**High Lbs.**	**Lbs. per truck**	**CA-VIUS = 2002 U.S. VIUS**
G1 Agriculture products	17.15	22%	26,923	41,688	39,350	TRUE
G2 Wood, printed products	13.93	21%	22,110	33,607	31,161	TRUE
G3 Crude petroleum	21.89	32%	29,709	57,865	34,458	TRUE
G4 Fuel and oil products	23.06	24%	34,994	57,241	33,078	FALSE
G5 Gravel/sand and nonmetallic minerals	20.96	28%	30,185	53,642	26,792	FALSE
G6 Coal/metallic minerals	25.60	29%	36,450	65,933	38,141	TRUE
G7 Food, beverage, tobacco products	16.44	10%	29,748	36,014	35,812	TRUE
G8 Manufactured products	15.51	17%	25,736	36,323	40,352	FALSE
G9 Chemical/pharmaceutical products	12.91	53%	12,088	39,558	40,471	FALSE
G10 Nonmetal mineral products	22.45	14%	38,684	51,121	33,166	FALSE
G11 Metal manufactured products	19.17	29%	27,165	49,534	37,046	TRUE
G12 Waste material	21.02	14%	36,311	47,768	39,257	TRUE
G13 Electronics	9.74	70%	5,831	33,139	35,151	FALSE
G14 Transportation equipment	18.29	16%	30,669	42,501	30,004	FALSE
G15 Logs	23.25	9%	42,380	50,610	38,919	FALSE

Note: CSFFM reports in lbs. In FAF payload factors are reported as tons per truck while CSFFM reports payload as lbs. per truck.

(Source: Federal Highway Administration.)

It cannot be concluded that there is no statistical difference between the CA-VIUS and proposed payload factors from 2002 U.S. VIUS. Only 7 of 15 CGs from CA-VIUS are within the error ranges computed from 2002 U.S. VIUS. However, for three additional CGs, shown as shaded rows in table 39, the CA-VIUS payload for GVW Class 8 differs from the CU proposed payload factors from 2002 U.S. VIUS by less than one ton per truck. For the remaining commodities, it is probable that the differences reflect differences in operations on California roads compared to national roads. For example, the GVW 8 trucks used to transport Sand and Gravel can be expected to be different from the U.S. average. It has not been demonstrated that the proposed truck payload factors (TPF), payload factors, derived from U.S. VIUS, for the CGs and truck sizes used in the CSFFM, are substantially different. It is probable that payload factors in the U.S. have not changed substantially based on a comparison with CA-VIUS. Payload factors from 2002 U.S. VIUS could be computed using the methods that are proposed.

STEP 2: ALLOCATION OF TONS TO COMBINATION UNIT AND SINGLE UNIT TRUCKS

The FAF Origin-Destination (O-D) database reports commodity flows by tons that are carried by truck, but it does not report commodity carried by unit truck. In the current FAF assignment results does not differentiate between SU and CU trucks. A method to convert FAF tons by commodity to FAF trucks by commodity and by truck size (limited to Single Unit, SU, and Combination Unit, CU, trucks, not the many truck sizes in current FAF TPF methods) would be desirable. This allocation of FAF truck volumes could be stated as the more commonly reported CU and SU trucks.

Information to make this allocation can be developed using the 2002 U.S. VIUS. For example, allocating by the share of ton-miles, the payload factor will be applied to tons by truck moving between an Origin and a Destination with a defined distance. Because the flow unit will be tons for a defined number of miles, allocating to SU and CU trucks based on their share of ton-miles would be consistent. The expanded ton-miles for each record by SCTG2 commodity estimated by truck strata (which can be aggregated to SUs and CUs) is shown in table 34. The percentage split between SU and CU trucks by annual ton-miles is shown in table 40. Also shown in that table is the Standard Error, SE, associated with that percentage, (which is square root of the sum of the squares of the SEs of SU and CU ton-miles).

Table 40. Single unit and combination unit ton-miles by standard classification of transported goods 2 from 2002 U.S. vehicle inventory and use survey.

SCTG2	Commodity	SU Trucks	CU trucks	Standard Error
01	Live Animals and Fish	5%	95%	39%
02	Cereal Grains (including seed)	7%	93%	10%
03	Other Agricultural Products, except for Animal Feed	7%	93%	10%
04	Animal Feed and Products of Animal Origin, n.e.c.	8%	92%	17%
05	Meat, Fish, and Seafood, and Their Preparations	3%	97%	15%
06	Milled Grain Products and Preparations, and Bakery Products	4%	96%	11%
07	Other Prepared Foodstuffs, and Fats and Oils	5%	95%	7%
08	Alcoholic Beverages	5%	95%	17%
09	Tobacco Products	6%	94%	34%
10	Monumental or Building Stone	22%	78%	16%
11	Natural Sands	36%	64%	7%
12	Gravel and Crushed Stone	40%	60%	6%
13	Nonmetallic Minerals, n.e.c.	29%	71%	11%
14	Metallic Ores and Concentrates	19%	81%	36%
15	Coal	14%	86%	16%
16	Crude Petroleum Oil	16%	84%	26%
17	Gasoline and Aviation Turbine Fuel	5%	95%	17%
18	Fuel Oils	24%	76%	11%
19	Coal and Petroleum Products, n.e.c.	22%	78%	9%

Table 40. Single unit and combination unit ton-miles by standard classification of transported goods 2 from 2002 U.S. vehicle inventory and use survey (continuation).

SCTG2	Commodity	SU Trucks	CU trucks	Standard Error
20	Basic Chemicals	10%	90%	19%
21	Pharmaceutical Products	13%	87%	34%
22	Fertilizers	12%	88%	18%
23	Chemical Products and Preparations, n.e.c.	6%	94%	28%
24	Plastics and Rubber	6%	94%	18%
25	Logs and Other Wood in the Rough	7%	93%	14%
26	Wood Products	8%	92%	8%
27	Pulp, Newsprint, Paper, and Paperboard	1%	99%	51%
28	Paper or Paperboard Articles	2%	98%	17%
29	Printed Products	6%	94%	28%
30	Textiles, Leather, and Articles of Textiles or Leather	3%	97%	17%
31	Nonmetallic Mineral Products	35%	65%	9%
32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	5%	95%	14%
33	Articles of Base Metal	18%	82%	27%
34	Machinery	6%	94%	15%
35	Electronic and Other Electrical Equipment and Components, and Office Equipment	8%	92%	38%
36	Motorized and Other Vehicles (including parts)	9%	91%	11%
37	Transportation Equipment, n.e.c.	3%	97%	43%
38	Precision Instruments and Apparatus	17%	83%	92%
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	5%	95%	11%
40	Miscellaneous Manufactured Products	5%	95%	19%
41	Waste and Scrap	48%	52%	8%
42	Mail, Empty Containers and Other Special	20%	80%	23%
43	Mixed Freight	0%	100%	16%
All SCTGs		**10%**	**90%**	**11%**

(Source: Federal Highway Administration.)

As expected, the usage across all SCTG commodities by ton-miles is primarily by CU trucks, 90 percent, and its standard error is only 11 percent. However, the usage by individual commodities for CU trucks ranges from a high of 100 percent by CU for SCTG 43 to a low of 52 percent for SCTG 41. Additionally, the Standard Error for an SCTG2 commodity varies from a low of 6 percent for SCTG 12 to a high of 92 percent for SCTG 38.

With the caution that the split between SU and CU trucks is based on nationally observed percentages, the Tons per Truck, payload factor, by SCTG2 for both SU and CU trucks can be applied. The payload factors by individual SCTG2 commodity and truck size are shown in table 36.

A method to produce FAF truck assignments by SCTG2, differentiated between SU and CU trucks, is described below.

- Step 1. For each O/D/C/Truck cell, apply the percentage usage by SU and CU trucks to the flow in Tons reported in FAF. This will produce two additional tables for each SCTG2: 1) FAF tons by SU trucks and 2) FAF tons by CU trucks.
- Step 2. For each O-D table created in Step 1, convert from tons to trucks using the payload factors as shown in table 36. This will not change the number of tables but will produce SCTG2 tables of annual SU FAF trucks and annual CU FAF trucks, in addition to the current table of total FAF trucks.

It is cautioned that the VIUS used to develop this information was only intended to produce overall national averages. While those national percentages themselves have errors associated with them, and that error typically increases with increasing commodity detail, the national averages may not be applicable to the actual trip distances for any given O-D pair. On average, aggregating nationally, the estimated number of trucks and vehicle miles traveled (VMT) across all commodities can be expected to be correct, but the application and assignment on any given link can be expected to vary from observed counts.

The annual national information in VIUS does not support any analysis for individual trips or distances. The average distance range as reported in VIUS applies to all miles traveled by the surveyed truck, not the miles for specific commodities.

If an assignment is done with all three tables, SU trucks, CU trucks, and Combined SU and CU trucks, then the Combined SU and CU truck volume on any highway link will not be equal to the sum of the SU and CU truck volumes. As noted in table 36, these payload factors have an error associated with them. Additionally, the allocation percentages proposed in table 40 also are not exact but have associated standard errors. If the payload factors are applied to each O-D cell for SU, CU and Total, i.e., Combined SU and CU, FAF Trucks, and each cell is assigned to the network, then it is highly improbable for the flows on a link level for the assignment of SU and CU tables to be equal to the assigned volumes of Combined SU and CU trucks. Instead, the following method is proposed.

Assign only two tables, 1) SU FAF trucks, and 2) CU FAF trucks, and never create or assign a table of Total trucks. Define the Combined SU and CU FAF truck volumes on a link as the sum of the assigned SU and CU trucks. This will ensure that, on each highway link, the addition of the volume of SU and CU FAF trucks will be equal to volume of the Combined SU and CU FAF trucks.

It is cautioned that while the assignment is expected to produce reasonable results in the aggregate, the results on any given link be used with care. Because the observed flows on a link will not only include trucks carrying FAF commodities, but also trucks that do not carry FAF commodities (e.g., non-FAF trucks can carry payloads not considered to be freight, e.g., are part of the manufacturing process or local delivery of reported freight, or to provide services) there will be no way to validate these FAF truck assignments.

STEP 3: FACTORING 2002 VEHICLE INVENTORY AND USE SURVEY TRUCK PAYLOAD FACTORS USING MILES AND TONS GROWTH

The previous step, step 2, describes methods to apply payload factors that will result in SU and CU truck assignments. However, these methods rely on values from the 2002 VIUS that are not consistent with the 2012 base year of the FAF and have not been updated for future years. VIUS had previously been collected as part of the U.S. Economic Census conducted in years ending in 2 and 7. VIUS was discontinued in 2002 and no new data collection is expected. Regardless, VIUS still remains the only viable source for the SCTG2 usage of the contents of trucks.

While the changes in payload factors by SCTG2 commodity are not available, the overall changes in miles and payloads are reported separately. National changes in miles traveled by truck size are reported in Highway Statistics table VM-1. Changes in payload is reported by State in Vehicle Travel Information System (VTRIS) table W-3 and can be summarized to develop national changes. If it is assumed that the changes by SCTG2 are the same as these overall changes, the revisited 2002 VIUS payload factors can be updated to any year.

Table 41 shows the changes in VMT from 2002, the year of VIUS, to 2012, the base year of Freight Analysis Framework Version 4 (FAF4), and to 2017, the presumed base year for the upcoming FAF5.

Table 41. Vehicle miles traveled growth in single unit and combination unit trucks.

	SU VMT (millions)	CU VMT (millions)	SU Truck Registrations	CU Truck Registrations
2002	75,866	138,737	5,650,619	2,276,661
2012	105,605	163,602	8,190,286	2,469,094
Growth 02 to 12	39%	18%	45%	8%
CAGR 02 to 12	3.4%	1.7%	3.8%	0.8%
2017	116,102	181,490	8,746,518	2,752,043
Growth 02 to 17	53%	31%	55%	21%
CAGR 02 to 17	2.9%	1.8%	3.0%	1.3%

(Source: Federal Highway Administration.)

The growth in Vehicle Miles of Travel, VMT, is consistent with the growth in registrations. The growth in ton-miles will be a function of both the growth in tons and the growth in miles. The share of ton-miles is used to allocate tables of total tons to separate tables of tons by SU and tons by CU Trucks.

WIM data is submitted by States to Federal Highway Administration's (FHWA) VTRIS, which is part of its Travel Monitoring Analysis System (*TMAS*). WIM data only reports the average weight and vehicle class of a truck, where the classification is based on the truck types and number of axles that are used in FHWA's 13 vehicle classification system. As passively collected data, WIM cannot directly determine the contents of the truck, either the type of commodity that is being carried, or whether a truck is empty, or fully, or partially, loaded. VTRIS table W-3 makes an estimate of loaded and empty trucks and then uses that information to estimate the payload of loaded vehicles. This estimation is made with user-defined "breakpoints," which are not the empty weight of a truck, but the point which minimizes the errors of that estimation. Ideally, the actual empty weights follow a normal distribution. The breakpoints are total observed weights that are designed to minimize false negatives (e.g., a vehicle is estimated to be empty when in fact it is partially loaded). From W-3, the national estimates of payload are shown in table 42. While the ratios to 2002 are shown, it does appear from the data that changes in payloads, particularly for observed CU trucks, may be expected statistical variation, and payloads are not changing significantly over time.

Table 42. Weigh-in-motion estimated payloads.

		Total Observed	**Estimated loaded**	**Estimated Total Payload (tons)**	**Estimated Average Payload (tons)**	**Ratio to 2002**
2002	SU	18,687	10,638	70,269	6.61	1.000
	CU	35,154	30,313	492,145	16.24	1.000
	Total	53,841	40,951	562,414		
2012	SU	18,262	11,152	88,291	7.92	1.199
	CU	34,586	29,959	491,794	16.42	1.011
	Total	52,848	41,111	580,085		
2017	SU	424,351	256,372	1,610,721	6.28	0.951
	CU	1,205,516	1,058,233	16,804,501	15.88	0.978
	Total	1,629,867	1,314,605	18,415,222		

(Source: National Summaries developed from State W-3 tables.)

If it is assumed that the changes in miles and the changes in tons can be applied equally to each SCTG2 commodity in VIUS/FAF, then the changes from 2002 can be used to adjust the payload factors from 2002 VIUS.

The basic equation for Ton miles by commodity can be expressed as:

$$\boldsymbol{TM_{s,y}^{c} = TPF_{s,y}^{c} * M_{s,y}^{c}}$$

Figure 68. Equation. Ton miles by commodity.
(Source: Federal Highway Administration.)

Where

$TM_{s,y}^{c}$ = Ton-Miles for truck size *s* during year *y* for commodity *c*.

$TPF_{s,y}^{c}$ = Truck Payload Factor for truck size *s* during year *y* for commodity *c.*

$M_{s,y}^{c}$ = Loaded Miles for truck size *s* during year *y* for commodity *c.*

Then by definition

$$\boldsymbol{TPF^{c}_{s,y} = TM^{c}_{s,y}/M^{c}_{s,y}}.$$

Figure 69. Equation. Payload factors by size, year, commodity.
(Source: Federal Highway Administration.)

The 2002 VIUS reports truck sizes as SU and CU trucks, commodities as SCTG2, loaded miles, and an expansion factor, for each survey record. It also reports the average loaded weight, the empty weight and the percentage of loaded miles carrying each VIUS commodity.

As proposed in chapter 12, the ton-miles and miles carrying each SCTG2 commodity, in VIUS can be used to compute payload factors by truck size, e.g., Single Unit (SU) and Combination Unit (CU) trucks, for the VIUS year of 2002.

The truck sizes in VIUS can be expressed as SU and CU trucks. The commodities are the SCTG2 commodities. The Loaded Miles and Ton-miles for 2002 by SCTG2 commodity in VIUS records can be found as:

$$\boldsymbol{M^{SCTG2}_{2002} = \%M^{SCTG2}_{2002} * M_{2002}}$$

Figure 70. Equation. Loaded miles (2002).
(Source: Federal Highway Administration.)

And

$$\boldsymbol{TM^{SCTG2}_{2002} = (AVGWGT - EMPWGT)_{2002} * M^{SCTG2}_{2002}}$$

Figure 71. Equation. Ton miles (2002).
(Source: Federal Highway Administration.)

Where

$\%M^{SCTG2}_{2002}$ = Percentage of loaded miles carrying commodity SCTG2 for each survey record.

M_{2002} = Expanded loaded miles for each survey record.

$AVGWGT$ = Average loaded weight reported for a survey record.

$EMPWGT$ = Empty weight reported for a survey record.

The Ton-Miles and Miles by SCTG2 for Single Unit trucks are found by summing over VIUS records whose size is reported as SU. The Ton-Miles and Miles by SCTG2 for Combination Unit trucks are found by summing over VIUS records whose size is reported as CU. The payload factors for 2002 VIUS, for Combined SU and CU trucks by SCTG2, are found by dividing the sum of their ton-miles by the sum of their miles.

The payload factors for the combined SU and CU trucks payload factor is also the payload factors for the individual payload factors by truck size weighted by the share of miles of that particular truck size. Using the miles and payload factors from 2002 VIUS, that combined payload factor is:

$$\boldsymbol{TPF_{2002,SU\&CU}^{SCTG2}} = \frac{\boldsymbol{M_{2002,SU}^{SCTG2}}}{\boldsymbol{M_{2002,SU}^{SCTG2}} + \boldsymbol{M_{2002,CU}^{SCTG2}}} * \boldsymbol{TPF_{SU,2002}^{SCTG2}} + \frac{\boldsymbol{M_{2002,CU}^{SCTG2}}}{\boldsymbol{M_{2002,SU}^{SCTG2}} + \boldsymbol{M_{2002,CU}^{SCTG2}}} * \boldsymbol{TPF_{CU,2002}^{SCTG2}}$$

Figure 72. Equation. Combined single unit/combined unit payload factors.
(Source: Federal Highway Administration.)

In order to update these payload factors to a year *y* other than 2002, it would be necessary to know the following variables:

$\%M_y^{SCTG2}$ = Percentage of loaded miles carrying commodity SCTG2 in year y.

M_y = The expanded loaded miles in year y.

$AVGWGT$ = The average loaded weight in year y.

$EMPWGT$ = The empty weight reported in year y.

There is no source besides the VIUS to estimate how the percentage of miles by SCTG2 commodity have changed for a year *y* other than 2002. If it is assumed that this percentage did not change, then it is only necessary to estimate how the miles and the cargo weight (e.g., the difference between average loaded and empty weight) have changed between 2002 and a future year *y*.)

As shown in table 41, Highway Statistics table VM-1 reports the total miles for CU and SU trucks. If it is assumed that the percentage of loaded miles to total miles has not changed, then the growth in VMT for those trucks can be found by examining table VM-1 for 2002 and some additional year *y*.

As shown in table 42, VTRIS/TMAS table W-3 reports the loaded weight for trucks observed by State WIM stations and estimates the number of loaded and empty trucks, as well as their cargo weights, from user defined breakpoints between empty and loaded trucks. Since what is being sought is only the growth over all trucks nationally, the average loaded weight (empty plus cargo weight) is computed for all WIM stations. Using the default (no variation among States or years) breakpoints, empty trucks, the growth in cargo weight also can be computed if:

a = the growth in SU miles between 2002 and year *y*, according to VM-1.

b = the growth in CU miles between 2002 and year *y*, according to VM-1.

c= the growth in SU Cargo weight between 2002 and year *y*, according to W-3.

d = the growth in CU Cargo weight between 2002 and year *y*, according to W-3.

Then for truck sizes SU and CU, the following equations can be developed:

$$M_{y,SU}^{SCTG2} = a * \%M_{2002,SU}^{SCTG2} * M_{2002,SU} = a * M_{2002,SU}^{SCTG2}$$

Figure 73. Equation. Single unit miles.
(Source: Federal Highway Administration.)

$$M_{y,CU}^{SCTG2} = b * \%M_{2002,CU}^{SCTG2} * M_{2002,CU} = b * M_{2002,CU}^{SCTG2}$$

Figure 74. Equation. Combination unit miles.
(Source: Federal Highway Administration.)

$$TM_{y,SU}^{SCTG2} = c * (AVGWGT - EMPWGT)_{2002,SU} * M_{y,SU}^{SCTG2} = a * c * TM_{2002,SU}^{SCTG2}$$

Figure 75. Equation. Single unit ton miles.
(Source: Federal Highway Administration.)

And

$$TM_{y,CU}^{SCTG2} = d * (AVGWGT - EMPWGT)_{2002,CU} * M_{20y,CU}^{SCTG2} = b * d * TM_{2002,CU}^{SCTG2}$$

Figure 76. Equation. Combination unit ton miles.
(Source: Federal Highway Administration.)

If TPF = TM/M, Payload factor =Ton-Miles/ Miles, then

$$TPF_{SU,y}^{SCTG2} = \frac{TM_{SU,y}^{SCTG2}}{M_{SU,y}^{SCTG2}} = \frac{a * c * TM_{2002,SU}^{SCTG2}}{a * M_{2002,SU}^{SCTG2}} = c * TPF_{SU,2002}^{SCTG2}$$

Figure 77. Equation. Single unit payload factors.
(Source: Federal Highway Administration.)

$$TPF_{CU,y}^{SCTG2} = \frac{TM_{CU,y}^{SCTG2}}{M_{CU,y}^{SCTG2}} = \frac{b * d * TM_{2002,CU}^{SCTG2}}{b * M_{2002,CU}^{SCTG2}} = d * TPF_{CU,2002}^{SCTG2}$$

Figure 78. Equation. Combination unit payload factors.
(Source: Federal Highway Administration.)

$$TPF_{SU\&CU,y}^{SCTG2} = Share\ Of\ M_{SU,y}^{SCTG2} * c * TPF_{SU,2002}^{SCTG2} + Share\ Of\ M_{CU,y}^{SCTG2} * d * TPF_{CU,2002}^{SCTG2}$$

Figure 79. Equation. Single unit/combination unit payload factors.
(Source: Federal Highway Administration.)

Figure 79 is equivalent to:

$$\boldsymbol{TPF_{SU\&CU,y}^{SCTG2}} = \frac{\boldsymbol{a * M_{2002,SU}^{SCTG2}}}{\boldsymbol{a * M_{2002,SU}^{SCTG2} + b * M_{2002,CU}^{SCTG2}}} * \boldsymbol{c} * \boldsymbol{TPF_{SU,2002}^{SCTG2}} + \frac{\boldsymbol{b * M_{2002,CU}^{SCTG2}}}{\boldsymbol{a * M_{2002,SU}^{SCTG2} + b * M_{2002,CU}^{SCTG2}}} * \boldsymbol{d} * \boldsymbol{TPF_{CU,2002}^{SCTG2}}$$

Figure 80. Equation. Single unit/combination unit payload factors (expanded form).
(Source: Federal Highway Administration.)

Appendix D works through an example for SCTG 20—Basic Chemicals so that it is clear how these equations are used.

From the 2002 VIUS payload factors, the change in miles for SU and CU trucks from VM-1, and the change in payloads according to W-3, it is possible to compute the payload factors for SU, CU, and the Combined SU and CU trucks, for any year for which VM-1 and W-3 have been reported. From table 41 and table 42, the ratios between 2002 and 2012 can be determined to be a=1.39, b = 1.18, c=1.199 and d=1.011. Using the 2002 payload factors shown in table 36 and figure 77, figure 79, and figure 80 the payload factors, TPFs, for 2012 are as shown in table 43.

Table 43. Proposed freight analysis framework version 4 payload factors (2012).

SCTG2 Commodity	Tons per SU truck	Tons per CU truck	Weighted tons per SU and CU truck	Share of total tons carried by SU trucks	Share of total tons carried by CU trucks
1	3.66	20.12	15.42	6.8%	93.2%
2	11.12	23.04	20.79	10.1%	89.9%
3	5.66	20.68	16.71	8.9%	91.1%
4	8.67	9.69	9.56	11.2%	88.8%
5	4.35	19.48	16.90	4.4%	95.6%
6	2.27	17.97	13.09	5.4%	94.6%
7	5.23	14.88	13.17	7.0%	93.0%
8	6.63	18.37	16.29	7.2%	92.8%
9	7.37	18.70	16.59	8.3%	91.7%
10	10.49	19.71	15.84	27.8%	72.2%
11	15.86	22.88	19.12	44.4%	55.6%
12	17.78	23.01	20.13	48.7%	51.3%
13	15.84	24.26	20.37	36.0%	64.0%
14	8.39	19.88	14.83	24.9%	75.1%
15	23.74	25.57	25.21	18.6%	81.4%
16	8.15	22.37	16.34	21.2%	78.8%
17	6.39	24.00	20.04	7.2%	92.8%
18	7.62	23.93	14.52	30.3%	69.7%
19	5.08	21.90	11.34	28.1%	71.9%
20	4.92	19.99	14.08	13.7%	86.3%
21	4.15	18.32	11.60	17.0%	83.0%
22	6.05	5.71	5.76	16.3%	83.7%

Table 43. Proposed freight analysis framework version 4 payload factors (2012) (continuation).

SCTG2 Commodity	Tons per SU truck	Tons per CU truck	Weighted tons per SU and CU truck	Share of total tons carried by SU trucks	Share of total tons carried by CU trucks
23	3.80	19.24	14.50	8.1%	91.9%
24	3.03	8.16	7.23	7.6%	92.4%
25	9.38	23.60	20.70	9.3%	90.7%
26	4.38	20.84	14.87	10.7%	89.3%
27	4.56	8.75	8.62	1.6%	98.4%
28	4.20	11.73	11.04	3.4%	96.6%
29	3.27	18.76	13.40	8.4%	91.6%
30	2.65	17.78	14.36	4.2%	95.8%
31	12.39	22.75	16.79	42.4%	57.6%
32	3.21	19.97	14.61	7.0%	93.0%
33	2.82	19.23	8.10	23.7%	76.3%
34	3.11	18.86	13.26	8.3%	91.7%
35	2.68	8.74	6.98	11.1%	88.9%
36	3.35	17.63	11.46	12.6%	87.4%
37	8.39	21.88	20.53	4.1%	95.9%
38	3.08	19.25	9.03	21.6%	78.4%
39	2.32	17.24	11.71	7.3%	92.7%
40	3.24	11.50	9.68	7.4%	92.6%
41	9.16	21.19	12.14	56.7%	43.3%
42	4.44	17.01	9.82	25.9%	74.1%
43	3.60	17.07	16.66	0.7%	99.3%
All SCTGs	6.24	16.65	13.56	13.6%	86.4%

(Source: Federal Highway Administration.)

From table 41 and table 42, the ratios between 2002 and 2017 can be determined to be a=1.53, b = 1.31, c=0.951 and d= 0.978. Using the 2002 TPFs as shown in table 36 and figure 77, figure 79, and figure 80, the payload factors, TPFs, for 2017 are as shown in table 44.

Table 44. Proposed freight analysis framework version 4 payload factors (2017).

SCTG2 Commodity	Tons per SU trucks	Tons per CU trucks	Weighted tons per SU and CU trucks	Share of total tons carried by SU trucks	Share of total tons carried by CU trucks
1	2.91	19.47	14.76	5.6%	94.4%
2	8.82	22.29	19.76	8.4%	91.6%
3	4.49	20.00	15.93	7.4%	92.6%
4	6.87	9.37	9.06	9.3%	90.7%
5	3.45	18.85	16.24	3.6%	96.4%
6	1.80	17.38	12.57	4.4%	95.6%
7	4.15	14.40	12.60	5.8%	94.2%
8	5.26	17.77	15.57	5.9%	94.1%

Table 44. Proposed freight analysis framework version 4 payload factors (2017) (continuation).

SCTG2 Commodity	Tons per SU trucks	Tons per CU trucks	Weighted tons per SU and CU trucks	Share of total tons carried by SU trucks	Share of total tons carried by CU trucks
9	5.84	18.09	15.83	6.8%	93.2%
10	8.32	19.07	14.58	23.9%	76.1%
11	12.58	22.13	17.04	39.4%	60.6%
12	14.11	22.26	17.78	43.5%	56.5%
13	12.56	23.47	18.45	31.4%	68.6%
14	6.66	19.23	13.73	21.2%	78.8%
15	18.83	24.74	23.58	15.6%	84.4%
16	6.47	21.64	15.24	17.9%	82.1%
17	5.07	23.22	19.17	5.9%	94.1%
18	6.04	23.15	13.32	26.1%	73.9%
19	4.03	21.18	10.45	24.1%	75.9%
20	3.90	19.34	13.32	11.4%	88.6%
21	3.29	17.72	10.91	14.2%	85.8%
22	4.80	5.52	5.41	13.7%	86.3%
23	3.02	18.61	13.85	6.6%	93.4%
24	2.40	7.89	6.90	6.3%	93.7%
25	7.44	22.83	19.71	7.7%	92.3%
26	3.47	20.16	14.14	8.9%	91.1%
27	3.61	8.47	8.32	1.3%	98.7%
28	3.33	11.34	10.62	2.8%	97.2%
29	2.59	18.14	12.79	7.0%	93.0%
30	2.11	17.20	13.81	3.4%	96.6%
31	9.83	22.01	15.03	37.5%	62.5%
32	2.54	19.32	13.99	5.8%	94.2%
33	2.24	18.60	7.53	20.1%	79.9%
34	2.47	18.24	12.66	6.9%	93.1%
35	2.12	8.45	6.63	9.2%	90.8%
36	2.66	17.06	10.86	10.5%	89.5%
37	6.66	21.17	19.73	3.3%	96.7%
38	2.45	18.62	8.43	18.3%	81.7%
39	1.84	16.68	11.21	6.0%	94.0%
40	2.57	11.12	9.25	6.1%	93.9%
41	7.26	20.50	10.57	51.6%	48.4%
42	3.52	16.46	9.08	22.1%	77.9%
43	2.85	16.52	16.10	0.5%	99.5%
All SCTGs	4.95	16.11	12.82	11.4%	88.6%

(Source: Federal Highway Administration.)

In looking at the payloads in table 43 and table 44, commodities SCTG 4—Animal Feed and Products, SCTG 15—Coal, and SCTG 22—Fertilizer show SU payloads that are within 40 percent of the CU payloads. This can be attributed to several factors.

- For SCTG 4—Animal Feed and Products, this is a time sensitive commodity, and while most commodities could wait until a truck became fully loaded, it possible that these goods are shipped in whatever equipment is available, either SU or CU trucks. In this case the "payload" computed is most probably a reflection of the shipment size, and not the capacity of CU trucks transporting this commodity. Record the information if the TPFs for CU trucks are ever used to assign only this commodity.

- For SCTG 15—Coal, while typically an SU truck has a smaller payload than CU truck, according to VIUS of the survey records whose principal product carried is Coal, 81 percent of the Sus have a body type of dump truck, and 100 percent of the CUs are transported in dump trailers. It is probable that the payload of very large SU dump trucks is not appreciably different than the payload of CU trucks hauling dump trailers. This may be why the analysis based on VIUS shows that the payload for SU trucks is close to the payload for CU trucks for SCTG 15. Record the information if the TPFs for SU trucks are ever used to assign only this commodity.

- For SCTG 22—Fertilizer, most of the CU survey records in VIUS are in trailers whose Principal Product is Powered or Unpowered tools, which do not contribute to the ton-miles reported for SCTG2 commodities. If a truck carries mixed commodities, as reported in VIUS, it cannot be determined if this is 25 percent of the contents of 100 percent of the trips, or 25 percent of the trips. It has been assumed that it is the latter in this analysis. If it is former, this will significantly understate the payload factors for SCTG 22 that are included shipped with Powered or Unpowered tools, since these uses do not contribute to the ton miles reported for SCTG2 commodities. This may be why the CU payload is so low for this commodity and record the information if the TPFs for CU trucks are ever used to assign only this commodity.

If used in isolation, caution is suggested when using VIUS payloads for these three SCTG2 commodities. If they are bundled with other commodities, as is shown in the next chapter, these issues are not apparent.

CHAPTER 13. BUNDLING OF COMMODITIES AND IMPLEMENTATION

The proposed method supports the development of truck payload factors (TPF), for individual Standard Classification of Transported Goods (SCTG) 2 commodities. However, the sampling plan in Vehicle Inventory and Use Survey (VIUS) was developed to provide statistically valid responses over an entire subgroup, e.g., Single Unit and Combination Unit trucks, and not for the SCTG2 commodities carried by those subgroups. The Standard Deviation, Number of Records, Means, etc., for the ton-miles and miles that are used to compute payloads can have a reasonable standard error when aggregated over all commodities, but a less desirable standard error when computed separately for each commodity. Tables 34 through 36 report the Relative Standard Error for ton-miles, miles, and payloads for each SCTG2 commodity, as well as for all commodities combined.

Payload factors for the individual 43 SCTG2 commodities may not only have large relative standard errors, this large number of payload factors can itself create data management problems. It is common practice to group or bundle commodities before using their payloads. However, the grouping of commodities is dependent on how they will be used. A grouping of commodities that support infrastructure analysis may not be useful in supporting economic analysis. Some common applications are shown in table 45.

Table 45. Bundling of commodities by selected applications.

Application	Bundling	Issues
Infrastructure	Group commodities with similar impacts (e.g., tons per truck)	Infrastructure impacts are related to link usage, i.e., assignments. Payloads will be applied to trip tables prior to assignment. Groupings that support assignment may not be appropriate for trip tables.
Economic	Group commodities that are inputs to, or outputs of, important industries.	Important industries will vary by jurisdiction.
Modeling	Group commodities with similar behavior: e.g. tons per truck, correlation with industry employment, average trip lengths, etc.	Similarity will be based on trips beginning or ending in a specific modeling area.
Vehicle Impacts (e.g. environmental, energy, etc.)	Group commodities that use equipment with similar impacts	Usage of equipment may be specific to an area.

(Source: Federal Highway Administration.)

The grouping of the 43 SCTG2 commodities into 15 bundles of those commodities for the California Statewide Freight Forecasting Model is shown in table 37. The resulting payloads and their Relative Standard Error for Combination Unit trucks from VIUS are shown in table 38. These statistics are for the behaviors that were found to be significant in freight modeling in California.

Additionally, the SCTG2 commodities themselves were developed in a way that support groupings based on the characteristics of similar commodities. The Commodity Flow Survey, (CFS), and the definition of SCTG2 commodities includes a grouping of SCTG2 commodities. As noted, this is not the only or best grouping of commodities, only an example of how commodities can be grouped. However, this grouping can show how the information in table 34 and table 35 can be used to compute initial payload factors for any grouping of the SCTG2 commodities. The CFS grouping of SCTG2 commodities is shown in table 46.

Table 46. Commodity flow survey bundling of standard classification of transported goods 2 commodities.

SCTG	Description	Bundles
01	Live Animals and Fish	01-05 Agriculture products and fish
02	Cereal Grains (including seed)	
03	Other Agricultural Products, except for Animal Feed	
04	Animal Feed and Products of Animal Origin, n.e.c.	
05	Meat, Fish, and Seafood, and Their Preparations	
06	Milled Grain Products and Preparations, and Bakery Products	06-09 Grains, alcohol, and tobacco products
07	Other Prepared Foodstuffs, and Fats and Oils	
08	Alcoholic Beverages	
09	Tobacco Products	
10	Monumental or Building Stone	10-14 Stones, nonmetallic minerals, and metallic ores
11	Natural Sands	
12	Gravel and Crushed Stone	
13	Nonmetallic Minerals, n.e.c.	
14	Metallic Ores and Concentrates	
15	Coal	15-19 Coal and petroleum products
16	Crude Petroleum Oil	
17	Gasoline and Aviation Turbine Fuel	
18	Fuel Oils	
19	Coal and Petroleum Products, n.e.c.	
20	Basic Chemicals	20-24 Pharmaceutical and chemical products
21	Pharmaceutical Products	
22	Fertilizers	
23	Chemical Products and Preparations, n.e.c.	
24	Plastics and Rubber	
25	Logs and Other Wood in the Rough	25-30 Logs, wood products, and textile and leather
26	Wood Products	
27	Pulp, Newsprint, Paper, and Paperboard	
28	Paper or Paperboard Articles	
29	Printed Products	
30	Textiles, Leather, and Articles of Textiles or Leather	

Table 46. Commodity flow survey bundling of standard classification of transported goods 2 commodities (continuation).

SCTG	Description	Bundles
31	Nonmetallic Mineral Products	31-34 Base metal and machinery
32	Base Metal in Primary or Semi-Finished Forms and in Finished Basic Shapes	
33	Articles of Base Metal	
34	Machinery	
35	Electronic and Other Electrical Equipment and Components, and Office Equipment	35-38 Electronic, motorized vehicles, and precision instruments
36	Motorized and Other Vehicles (including parts)	
37	Transportation Equipment, n.e.c.	
38	Precision Instruments and Apparatus	
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	39-43 Furniture, mixed freight and misc. manufactured products
40	Miscellaneous Manufactured Products	
41	Waste and Scrap	
42	Mail, Empty Containers and Other Special	
43	Mixed Freight	

(Source: Federal Highway Administration.)

This grouping reduces the 43 SCTG2 commodities to 9 bundles of commodities. The ton-miles and tons for the SCTG2 commodities can be obtained from table 34 and table 35. An example for one specific bundle, “35-38 Electronic, motorized vehicles, and precision instruments” is shown in table 47. The ton-miles and miles for the entire bundle is the sum of the values for its individual SCTG2 commodities.

Table 47. 2002 Payloads for an example bundle.

	SU Trucks	RSE	CU trucks	RSE
2002 VIUS Ton Miles (in billions) by SCTG2				
35	1.54	14%	17.28	36%
36	3.94	11%	38.02	4%
37	0.35	43%	11.47	4%
38	0.90	24%	4.57	89%
Bundle of 35 through 38	6.73	N/A	71.34	N/A
2002 VIUS Miles (in billions) by SCTG2				
35	0.69	0.09	2.00	7%
36	1.41	0.1	2.18	6%
37	0.04	0.2	0.53	15%
38	0.35	0.13	0.24	18%
Bundle 35 through 38	2.49	N/A	4.95	N/A
2002 TPF for Bundle	2.70	N/A	14.41	N/A
2002 Share of Ton-Miles for Bundle	8.6%	N/A	91.4%	N/A

(Source: Federal Highway Administration.)

The payload is computed by dividing the total of ton-miles for SU trucks, e.g. 6.73 billion ton-miles, by the total of miles for SU trucks, e.g., 2.50 billion miles. For this bundle "SCTG 35 through 38" is the payload factor is 2.70 tons per SU truck. The share of the ton-miles, which is used to allocate total tons among truck sizes, is found by dividing the share of ton-miles for SU trucks, 6.73 billion ton miles for that bundle by the total of SU and CU trucks ton-miles for that bundle, 6.73 billion plus 71.34 billion ton-miles. The resulting payload factors for these bundles is shown in table 48. The allocation of tons between SU and CU trucks, based on the share of ton-miles, is in table 49. The Relative Standard Errors for the bundles are shown as Not Available, N/A, because these cannot be computed without examining all the relevant records in the 2002 VIUS microdata.

Table 48. Payloads, tons per truck, for 2002 commodity flow survey bundles.

CFS Bundle	**SU trucks**	**CU trucks**
01-05 Agriculture products and fish	5.24	17.82
06-09 Grains, alcohol, and tobacco products	3.52	15.95
10-14 Stones, nonmetallic minerals, and metallic ores	13.91	22.46
15-19 Coal and petroleum products	5.82	23.36
20-24 Pharmaceutical and chemical products	3.56	11.03
25-30 Logs, wood products, and textile and leather	3.65	15.18
31-34 Base metal and machinery	4.92	19.88
35-38 Electronic, motorized vehicles, and precision instruments	2.70	14.41
39-43 Furniture, mixed freight and misc. manufactured products	4.85	16.32
Grand Total	5.21	16.47

(Source: Federal Highway Administration.)

Table 49. 2002 allocation of total tons to single unit and combination unit trucks for commodity flow survey bundles.

CFS Bundle	**SU trucks**	**CU trucks**
01-05 Agriculture products and fish	5.7%	94.3%
06-09 Grains, alcohol, and tobacco products	4.9%	95.1%
10-14 Stones, nonmetallic minerals, and metallic ores	36.5%	63.5%
15-19 Coal and petroleum products	16.3%	83.7%
20-24 Pharmaceutical and chemical products	8.0%	92.0%
25-30 Logs, wood products, and textile and leather	5.0%	95.0%
31-34 Base metal and machinery	16.4%	83.6%
35-38 Electronic, motorized vehicles, and precision instruments	8.6%	91.4%
39-43 Furniture, mixed freight and misc. manufactured products	8.1%	91.9%
Grand Total	10.2%	89.8%

(Source: Federal Highway Administration.)

The values in table 48 and table 49 are the values for the bundles of commodities according to 2002 U.S. VIUS. This replaces the bundling of the tables in Step 1 and Step 2 of the proposed method. These values still must be adjusted to later years using the methods described in Step 3, but this application is the same regardless of whether the adjustment is applied to individual SCTG2 commodities or to bundles of those SCTG2 commodities. It is noted that if all of the commodities are combined into a single bundle, those proposed values for payloads, allocation of tons to SU and CU trucks, updated to 2012 and 2017 are already reported for all SCTGs in table 43 and table 44. Table 50 shows the payloads per truck and allocation of total tons (based on the share of ton-miles) for each CFS commodity group shown in table 46 for 2012 and 2017.

Table 50. Payloads and total tons allocations to single unit and combination unit trucks for commodity flow survey bundles (2012, 2017).

	2012				**2017**			
Commodity Group	**TPF**		**Share of Ton-miles**		**TPF**		**Share of Ton-miles**	
	SU	**CU**	**SU**	**CU**	**SU**	**CU**	**SU**	**CU**
01–05 Agriculture products and fish	6.18	17.96	8%	92%	5.11	17.51	6%	94%
06–09 Grains, alcohol, and tobacco products	4.16	16.08	7%	93%	3.44	15.68	5%	95%
10–14 Stones, nonmetallic minerals, and metallic ores	16.42	22.64	44%	56%	13.57	22.07	39%	61%
15–19 Coal and petroleum products	6.86	23.55	21%	79%	5.67	22.96	18%	82%
20–24 Pharmaceutical and chemical products	4.20	11.12	11%	89%	3.47	10.84	9%	91%
25–30 Logs, wood products, and textile and leather	4.31	15.30	7%	93%	3.56	14.92	5%	95%
31–34 Base metal and machinery	5.80	20.04	21%	79%	4.79	19.54	18%	82%
35–38 Electronic, motorized vehicles, and precision instruments	3.19	14.53	11%	89%	2.64	14.17	9%	91%
39–43 Furniture, mixed freight and misc. manufactured products	5.72	16.45	11%	89%	4.72	16.04	9%	91%
Grand Total	6.15	16.60	13%	87%	5.08	16.19	11%	89%

(Source: Federal Highway Administration.)

Another potential bundling of commodities that is possible is to bundle commodities based on the type of commodity and the type of truck carrying the commodity. While this will be helpful from the perspective of the overall Freight Analysis Framework (FAF) program and truck assignment, some jurisdictions may not want these groupings and may want to separate out certain commodities for their own purposes because of their importance to their region.

Table 51 shows another potential bundling of commodities based on the type of commodity and type of truck carrying the commodity. Table 52 shows the 2002, 2012, and 2017 payload factors after bundling commodities like table 51.

The bundling in table 51 reflects both the commodity and the behavior of the trucks which are loaded with FAF Origin-Destination (O-D) annual commodity tons. These trucks will travel empty in the reverse direction back their origin or will be repositioned to accept another load of the same or potentially a different commodity. This is different than the behavior of empty trucks implied in the existing FAF methodology as shown in figure 66. Not all trucks will travel empty on the same path as when it is loaded. When aggregated over all highway links and all directions, the magnitude of empty truck demand might be reasonable, but the assigned flows of empty trucks on individual highway links will not be correct. Some trucks and/or their trailers are specialized (e.g., refrigerated, beverage, log carriers, livestock, etc.) such that while the origin and destination might be reversed, one-way traffic, toll usage, or truck restrictions might require different paths in the loaded and reverse empty direction. Other truck/trailer types are generalized (e.g., dry-van, flat/platform, etc.) and can be repositioned to a new location to transport commodities of the same or a different SCTG2. For example, SCTG 36, which may use auto carriers when it is transporting SCTG_361, Automobiles, but dry-van equipment when it is transporting SCTG 364, Auto parts. Because the FAF does not support commodity classifications below STCG2, all a commodity must be assigned to only one bundle. Still other truck/trailers, while not specialized (e.g., dump, open, tank) carry bulk unpacked commodities that would require cleaning before they could be repositioned and are likely to be backhauled empty.

Table 51. Proposed commodity bundles.

Bundled Commodity Name	**SCTG2 Code**	**Commodity Type**	**Truck/ Trailer Type**	**Empty Bundle Name**
Farm Products	1-5	Bulk	Specialized	Backhauled
Food, Beverage and Tobacco	6-9			
Solid Stone	10			
Sand, Gravel and Ores	11-15			
Liquid and Gases (except Chemicals)	16-19			
Chemicals (except Chemical Products n.e.c.)	20-22			
Logs	25			
Waste (Recyclables)	41			
Consumer Manufacturing (include Chemical Products n.e.c.)	23-24, 26-30	Packaged	General	Repositioned
Durable Manufacturing (low tech)	31-34, 39			
Durable Manufacturing (high tech)	35, 37-38			
Vehicles	36			
Mixed Freight	40, 42-43			

(Source: Federal Highway Administration.)

Table 52. Proposed commodity bundles: payload factors and share of ton-miles.

Commodity Bundle Name	2002				2012				2017			
	Payload Factors		Share of Ton-miles		Payload Factors		Share of Ton-miles		Payload Factors		Share of Ton-miles	
	SUs	CUs	SUs	CUs	SUs	CUs	SUs	CUs	SUs	CUs	SUs	CUs
Farm Products	5.24	17.82	6%	94%	6.18	17.96	8%	92%	6.02	17.65	6%	94%
Food, Beverage and Tobacco	3.52	15.95	5%	95%	4.16	16.08	7%	93%	4.05	15.80	5%	95%
Solid Stone	9.33	19.50	22%	78%	11.01	19.66	27%	73%	10.74	19.32	23%	77%
Sand, Gravel and Ores	14.41	23.11	36%	64%	17.00	23.29	43%	57%	16.58	22.90	38%	62%
Liquid and Gases (except Chemicals)	5.32	23.08	17%	83%	6.28	23.26	21%	79%	6.13	22.87	18%	82%
Chemicals (except Chemical Products n.e.c.)	4.30	10.20	11%	89%	5.07	10.28	15%	85%	4.94	10.11	12%	88%
Logs	7.82	23.35	7%	93%	9.23	23.53	9%	91%	9.00	23.13	7%	93%
Waste (Recyclables)	7.64	20.96	48%	52%	9.01	21.12	56%	44%	8.79	20.76	51%	49%
Backhauled Subtotal	**7.06**	**17.62**	**14%**	**86%**	**8.33**	**17.76**	**18%**	**82%**	**8.12**	**17.46**	**15%**	**85%**
Consumer Manufacturing (and Chemical Products n.e.c.)	3.16	13.73	5%	95%	3.73	13.84	7%	93%	3.64	13.60	5%	95%
Durable Manufacturing (low tech)	4.58	19.42	15%	85%	5.41	19.58	19%	81%	5.27	19.24	16%	84%
Durable Manufacturing (high tech)	2.58	12.03	8%	92%	3.05	12.13	10%	90%	2.97	11.92	8%	92%
Vehicles	2.79	17.44	9%	91%	3.30	17.58	12%	88%	3.21	17.28	10%	90%
Mixed Freight	3.41	16.05	4%	96%	4.02	16.18	5%	95%	3.92	15.91	4%	96%
Repositioned Subtotal	**3.70**	**15.74**	**7%**	**93%**	**4.37**	**15.87**	**9%**	**91%**	**4.26**	**15.60**	**8%**	**92%**

(Source: Federal Highway Administration.)

Table 52 supports the calculation of empty truck tables of those trucks transporting FAF tonnages. For those commodities designated as backhauled, the empty trucks O-D table would be merely the transpose of the loaded truck O-D table. For the commodities designated as repositioned, the payload factors support the sum of the production truck origin rows and the attraction truck columns which could be distributed by a model. The friction factor in the gravity model is a negative exponential equation of the distance between FAF regions. Using this gravity model trip distribution, the empty repositioned trucks are calculated.

CHAPTER 14. ASSIGNMENT RESULT COMPARISON

The Truck Payload Factors (TPF) developed in this section were assigned to the Federal Highway Administration (FHWA) Reinventing Conditions & Performance (RIC&P) Freight Analysis Framework (FAF) Sketch planning tool. The reason for using the RIC&P tool is because of the need to check how comparable the flows are to existing methods and validate the methodology by seeing how close the new methods are to existing methods. This tool has a network that is a subset of the FAF network and is useful for comparing the truck flows using the current payload factors with the new payload factors. These truck flows include empty trucks as well that are backhauled or repositioned as discussed in chapter 13. Overall, the proposed methods when applied to the RIC&P FAF sketch planning tool work as well as the current methods as shown in figure 81.

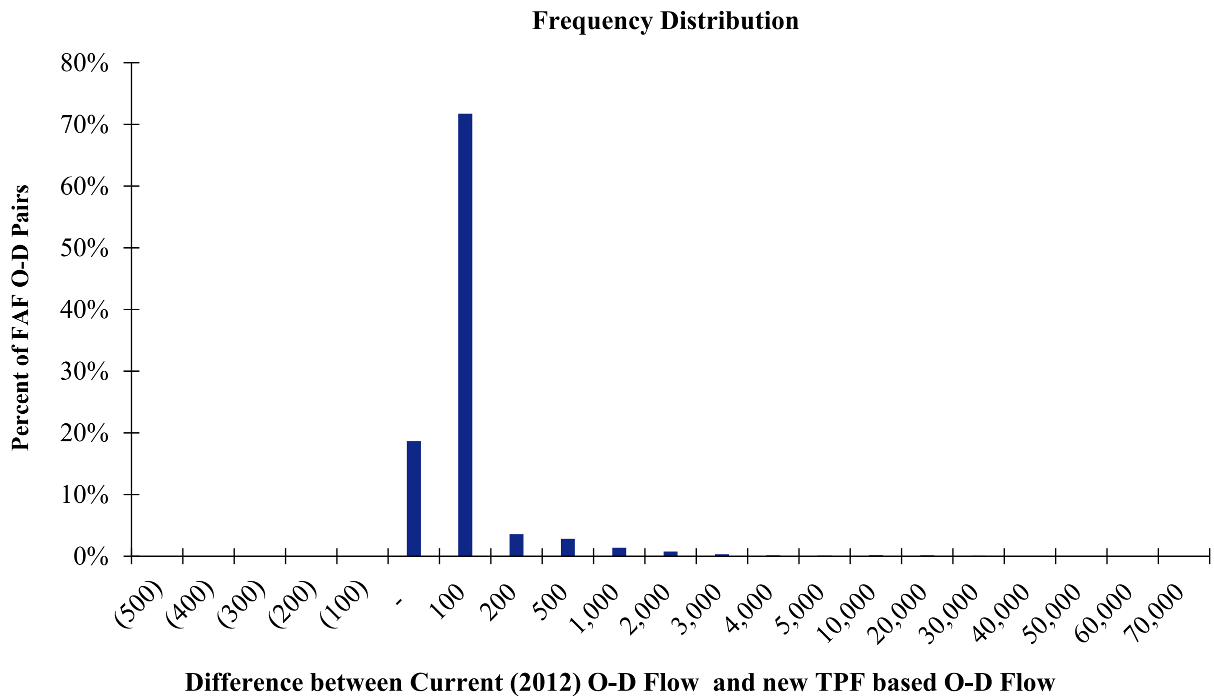

Figure 81. Bar chart. Comparison with current truck trip tables.
(Source: Federal Highway Administration.)

CHAPTER 15. SUMMARY

This chapter is divided into two sections. The first section focuses on the methods to estimate commodity flow data that are Out-of-Scope (OOS) to Commodity Flow Survey (CFS) and the second section details the summary and future research for payload factors.

OUT OF SCOPE COMMODITIES

At the outset of this task, the study identified limitations/opportunities for improvement of the Freight Analysis Framework Version 4 (FAF4) regarding the data and methodologies used to develop the out-of-scope commodity flows. These were in the areas including the sufficiency of current data, the future availability of data, and the appropriateness of the methodological approach. One of the most significant issues related to data quality is that the estimation processes for farm-based and service commodities rely on the Vehicle Inventory and Use Survey (VIUS). Given that the 2002 version represents the most recent VIUS, it is possible that the underlying industry-specific logistics patterns regarding vehicle types and operating distances that are captured in the VIUS have changed.

The results of the literature review also found that other research efforts into modeling commodity flows offer alternative approaches to current FAF4 methods for estimating commodity flow data that are OOS to CFS. Notably, the UT Austin Center for Transportation Research and the National Cooperative Freight Research Program examined the movements of several out-of-scope commodities. The preliminary investigation determined that aspects of those methodologies could be used to develop alternative approaches for farm-based, fishery, and logging OOS shipments and potentially yield benefits to future versions of the Freight Analysis Framework (FAF).

Following the preliminary investigation, the project team went on to develop and test alternative estimation methodologies for that select group of OOS commodities. The alternative methodologies each share the same basic structure of distributing productions to attractions based on the physical locations of the facilities that comprise the nodes of the out-of-scope portion of the commodities' respective supply chains. These locations were determined primarily using information from the U.S. Census Bureau County Business Patterns database. The effectiveness of the methodological approach at the national level was demonstrated for the select group of OOS commodities. Overall, the methodological approach largely results in OOS commodity flows being distributed to FAF4 zones that contain greater numbers of agricultural facilities that represent the first step in the supply chain, which is the portion of the supply chain that is not currently captured by the CFS. Importantly, the results also demonstrate that the approach can be applied to the national level, which is critical for the Freight Analysis Framework.

It is important to note that the most direct approach to address many of the challenges of estimating OOS commodity flows is to either expand the sampling frame of the CFS so that those commodities are within-scope or to start a new information collection aimed at those establishments that determines from where they receive goods (i.e., a receiver survey as opposed to a shipper survey). For example, a new information collection could survey sawmills to ask from which counties their logs are sourced. The same could be asked of grain elevators and other agricultural storage establishments (see table 53 for relevant establishments for the OOS commodities included in this report). This would obviate the need to model OOS commodity flows. However, the approaches developed in this research effort provide an improvement in the estimation of OOS commodity flows until these and other longer-term improvements can take place. While the results demonstrate that the methodological approach can effectively model OOS commodity flows, it is not without its limitations. These limitations are primarily in the areas of data limitations and calibration and validation of results. These limitations are discussed in greater detail below.

Table 53. Crosswalk of out-of-scope commodity and establishment North American industry classification system code.

OOS Commodity	In-Scope Establishment (NAICS)
Corn	Grain elevators (NAICS 493130 and 424510)
Chickens	Poultry processing plants (NAICS 311615)
Logs	Sawmills (NAICS 321113)
Fish	Seafood Product Preparation and Packaging (NAICS code 3117)

(Source: Federal Highway Administration.)

Limitations and Future Improvements

Data Availability

The main premise of the methodological approach is that by using information on the counties in which productions of OOS commodities occur and the counties containing facilities that attract those productions (representing the OOS component of the supply chain), the FAF can shift away from approaches that rely on the VIUS and those that assume that all flows are within-zone. However, county-level data was not available for all the commodities considered in this research which limits the efficacy of the proposed approach. For example, the number of broilers hatched was only available at the state level which required further assumptions on where those productions occurred at the county level. The necessity of assumptions on county-level production limits the ability of the proposed method to yield improvements over current FAF4 methods.

Data limitations exist with estimating attractions at the county level as well. The approach relies on the locations of facilities that represent the first step in the supply chain and information on payroll, as a proxy for capacity, to determine county-level attractions. While the U.S. Census Bureau County Business Patterns database is enough for determining the locations of facilities, payroll information may not be a sufficient proxy for capacity. Furthermore, for some agricultural activities, such as the locations and capacities of broiler farms at the county level, neither the U.S. Census Bureau County Business Patterns database nor the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) provide information at the desired level of detail for the approach.

Calibration and Validation

Related to limitations in data availability is the ability to calibrate and validate the methodological approach. Without observed data on the actual amount of tonnage produced and attracted to each county, it is impossible to calibrate the methodological approach and validate its results. This is evident in the trip length distributions resulting from the methodological approach. Shipments of OOS commodities are generally assumed to be local movements with few shipments traveling distances of 500 miles or greater. While the majority flows across commodities examined in this research effort are estimated to travel distances of 200 miles or less, there are occurrences where commodities are estimated to travel distances greater than 500 miles. This is generally more pronounced in western states than others as can be seen in the results included in appendix B. Trip Length Distributions by Commodity and Zone. While calibration and validation is also a limitation of current FAF4 methods, further effort in this area would be needed for the proposed approach to move forward.

Definition of Production-Consumption Zones

One technique the methodological approach uses to develop reasonable estimates of commodity flows is the defining of production-consumption zones. OOS commodity flows are balanced within these zones so that commodity flows do not travel across zones. This is analogous to current FAF4 methods for some commodities which require commodity flows to begin and end in the same FAF4 zone (e.g., fish and logs), but expands that assumption to a broader geography. The goal of the technique is to allow movements of these commodities across state lines, but to retain reasonable trip lengths. The definition of these zones presents an opportunity for future improvements. The zones were defined by observing where productions of commodities appeared to be clustered and in some cases using zones as defined by USDA or other agencies with expertise in a particular commodity. A future improvement could be taking a more rigorous approach to defining these zones by undertaking a formal cluster analysis, for example. In addition, the zones could be further refined to place a ceiling on trip lengths of commodity flows.

TRUCK PAYLOAD FACTORS

The payload factors computed by revisiting U.S. VIUS, for Single Unit (SU) and Combination Unit (CU) trucks, as updated by changes in miles from Highway Statistics table VM-1 and payloads from Vehicle Travel Information System (VTRIS) table W-3, as shown for 2012 in table 43, and for 2017 in table 44, could be used in any new FAF assignments. These payload factors consider the standard error in VIUS and are computed using a minimum of calculations. These payload factors do not exceed the typical legal payload, even if all the miles and ton-miles are assumed to be by GVW 8, CU, trucks.

While 2002 U.S. VIUS is dated, the payload factors that can be computed using the more recent CA-VIUS are within acceptable error ranges from the proposed payload factors from 2002 VIUS. Revisiting 2002 VIUS and expressing the payloads by Standard Classification of Transported Goods (SCTG) 2 using miles and ton-miles, allows the FAF assignment to be reported for SU and CU trucks, and allows the payload factors to be updated to more current years, if it is assumed that the overall changes in miles and payloads, apply to each payload factor by SCTG2.

As VIUS-like surveys are conducted by additional States, their findings with respect to payloads could be compared with the proposed payload factors, with error ranges.

The VIUS remains the best source of information about cargo carried by trucks and remains the most viable source to determine the payload factors, tons per truck, that are needed for the FAF. While considerable advances have been made in passive detection of truck weight, those methods still only infer truck body types and total payload weights but are unable to determine the commodity carried by the trucks.

Advances in electronic clearance and electronic logs for drivers could be monitored and if commodity information is collected, efforts may be undertaken to make the classification system that is used compatible with the SCTG2 system used by the FAF.

Research could be undertaken to determine the bias and usage of these passive detections system so that any findings can be expanded to produce the payload factors for the universe of all trucks.

APPENDIX A. AGRICULTURAL COMMODITY—STANDARD CLASSIFICATION OF TRANSPORTED GOODS CROSSWALK

AGRICULTURAL COMMODITY BY STANDARD CLASSIFICATION OF TRANSPORTED GOODS CROSSWALK

Standard Classification of Transported Goods 01[66]

- Calves sold (number).
- Cattle sold (number).
- Hogs and pigs sold (number).
- Any poultry sold, layers 20 weeks old and older (number).
- Any poultry sold, pullet chicks (number).
- Any poultry sold, broilers (number).
- Any poultry sold, turkeys sold (number).
- Sheep and lambs sold (number).
- Horses and ponies, sales (number).
- Miscellaneous livestock (number).
- Mink and their pelts, sales (number).
- Ducks, sales (number).
- Geese, sales (number).
- Pigeons or squab, sales (number).
- Pheasants, sales (number).
- Quail, sales (number).
- Emu and ostrich, sales (number).
- Miscellaneous poultry, sales (number).
- Other poultry, sales (number).
- Poultry hatched, sales (number).
- Mules, burros, and donkeys—sales (number).
- Goats, total sales (number).
- Rabbits and their pelts -sales (number).
- Catfish, pounds (1,000).
- Trout, pounds (1,000).
- Hybrid Striped Bass, pounds (1,000).
- Other fish, pounds (1,000).
- Crawfish, clam, mussels, oysters, snails, pounds (1,000).
- Other aquaculture products, pounds (1,000).

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[66] Oak Ridge National Laboratory, *The Freight Analysis Framework Version 4 (FAF4) Building the FAF4 Regional Database: Data Sources and Estimation Methodologies,* September 2016.

Standard Classification of Transported Goods 02

- Corn for grain or seed (bushels), harvested.
- Rye for grain (bushels), harvested.
- Sorghum for grain or seed (bushels), harvested.
- Wild rice (cwt), harvested.
- Wheat for grain, total (bushels), harvested.
- Popcorn (pounds, shelled), harvested.
- Barley for grain (bushels), harvested.
- Proso millet (bushels), harvested.
- Buckwheat (bushels), harvested.
- Safflower (pounds), harvested.
- Emmer and spelt (bushels), harvested.
- Triticale (bushels), harvested.
- Oats for grain (bushels), harvested.
- Corn for grain or seed (bushels), harvested.
- Rice (hundredweight), harvested.

Standard Classification of Transported Goods 03

- Canola and other rapeseed (pounds), harvested.
- Lespedeza seed (pounds), harvested.
- Canola (pounds), harvested.
- Orchardgrass seed (pounds), harvested.
- Other rapeseed (pounds), harvested.
- Red clover seed (pounds), harvested.
- Flaxseed (bushels), harvested.
- Ryegrass seed (pounds), harvested.
- Mustard seed (pounds), harvested.
- Sudangrass seed (pounds), harvested.
- Sunflower seed (pounds), harvested.
- Timothy seed (pounds), harvested.
- Cotton (bales), harvested.
- Vetch seed (pounds), harvested.
- Tobacco (pounds), harvested.
- Wheatgrass seed (pounds), harvested.
- Soybeans for beans (bushels), harvested.
- White clover seed (pounds), harvested.
- Dry edible beans, excluding dry limas (hundredweight).
- Other seeds (pounds), harvested.
- Dry limas beans (hundredweight), harvested.
- Vegetables harvested, harvested (acres).
- Dry edible peas (hundredweight), harvested.
- Fruits Total Production in 1,000 tons.

- Dry cowpeas and dry southern peas (bushels), harvested.
- Dill for oil (pounds), harvested.
- Lentils (hundredweight), harvested.
- Ginger root (pounds), harvested.
- Potatoes, excluding sweet potatoes (hundredweight), harvested.
- Ginseng (pounds), harvested.
- Sweet potatoes (hundredweight), harvested.
- Guar (pounds), harvested.
- Sugar beets for seed (pounds), harvested.
- Sesame (pounds).
- Sugar beets for sugar (tons), harvested.
- Herbs, dried (pounds), harvested.
- Sugarcane for seed (tons), harvested.
- Hops (pounds), harvested.
- Sugarcane for sugar (tons), harvested.
- Jojoba harvested (pounds), harvested.
- Peanuts for nuts (pounds), harvested.
- Mint for oil (pounds of oil), harvested.
- Alfalfa seed (pounds), harvested.
- Mint for tea.
- Austrian winter peas (hundredweight), harvested.
- Pineapples harvested (tons), harvested.
- Bahia grass seed (pounds), harvested.
- Sorghum for syrup (pounds), harvested.
- Bentgrass seed (pounds), harvested.
- Sweet corn for seed (pounds), harvested.
- Bermuda grass seed (pounds), harvested.
- Taro (pounds), harvested.
- Birdsfoot trefoil seed (pounds), harvested.
- Switchgrass.
- Bromegrass seed (pounds), harvested.
- Miscanthus.
- Crimson clover seed (pounds), harvested.
- Camelia.
- Fescue seed (pounds), harvested.
- Maple Syrup.
- Kentucky Bluegrass seed (pounds), harvested.
- Mushrooms.
- Ladino clover seed (pounds), harvested.

Standard Classification of Transported Goods 04

- Hay-alfal, other tame, small grain, wild, grass silage grass (tons).
- Haylage/Grass Silage/Greenchop (tons).
- Corn for silage or green chop (tons, green), harvested.
- Sorghum for silage or green chop (tons, green), harvested.
- Salt hay (tons), harvested.
- Sheep and lambs shorn (pounds of wool).
- Honey, sales (pounds).
- Mohair, sales (pounds).

Standard Classification of Transported Goods 07

- Milk and milk fat (million pounds).

Standard Classification of Transported Goods 09

- Tobacco.

APPENDIX B. TRIP LENGTH DISTRIBUTIONS BY COMMODITY AND ZONE

CORN

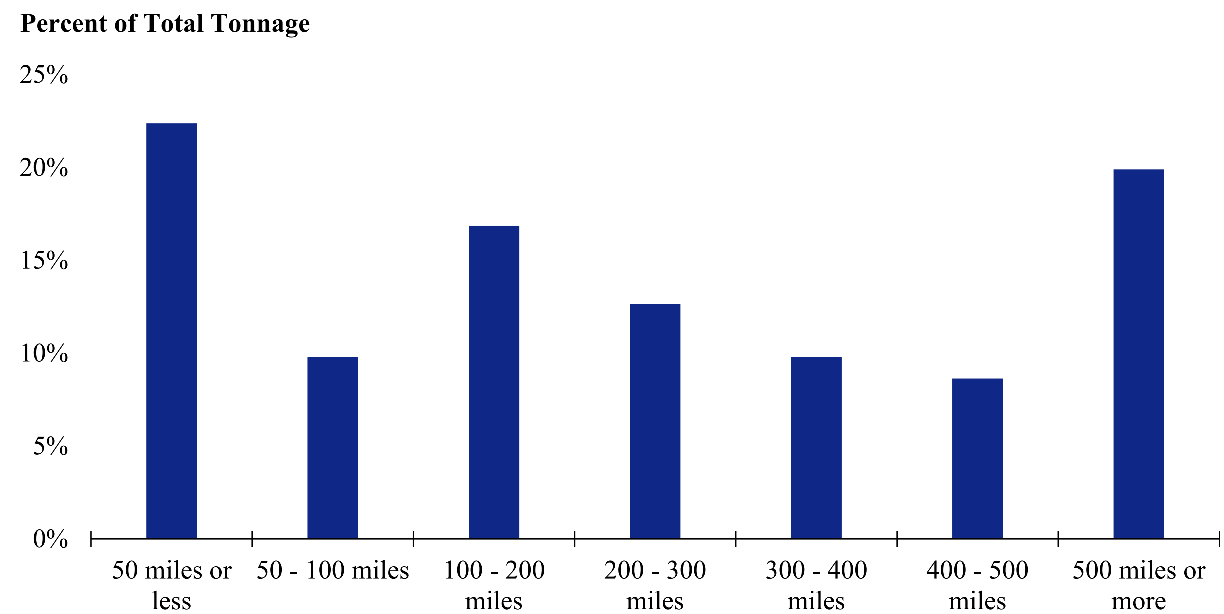

Figure 82. Bar graph. Distribution of shipment distances for farm-based shipments of corn for the Southeast production-consumption zone.
(Source: Federal Highway Administration.)

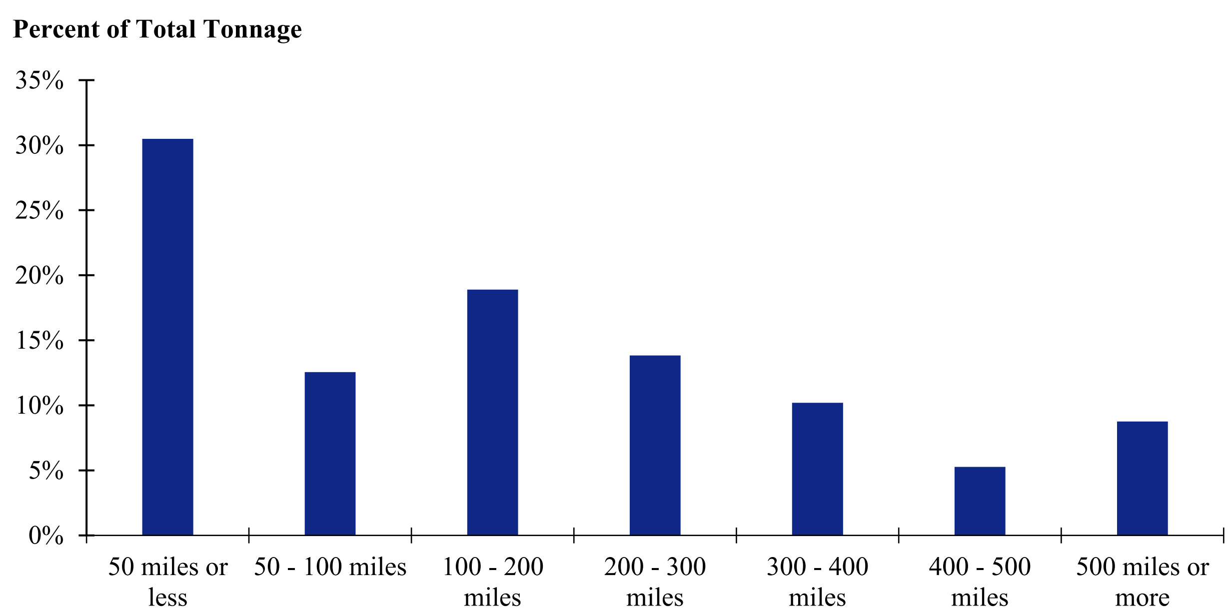

Figure 83. Bar chart. Distribution of shipment distances for farm-based shipments of corn for the Southwest production-consumption zone.
(Source: Federal Highway Administration.)

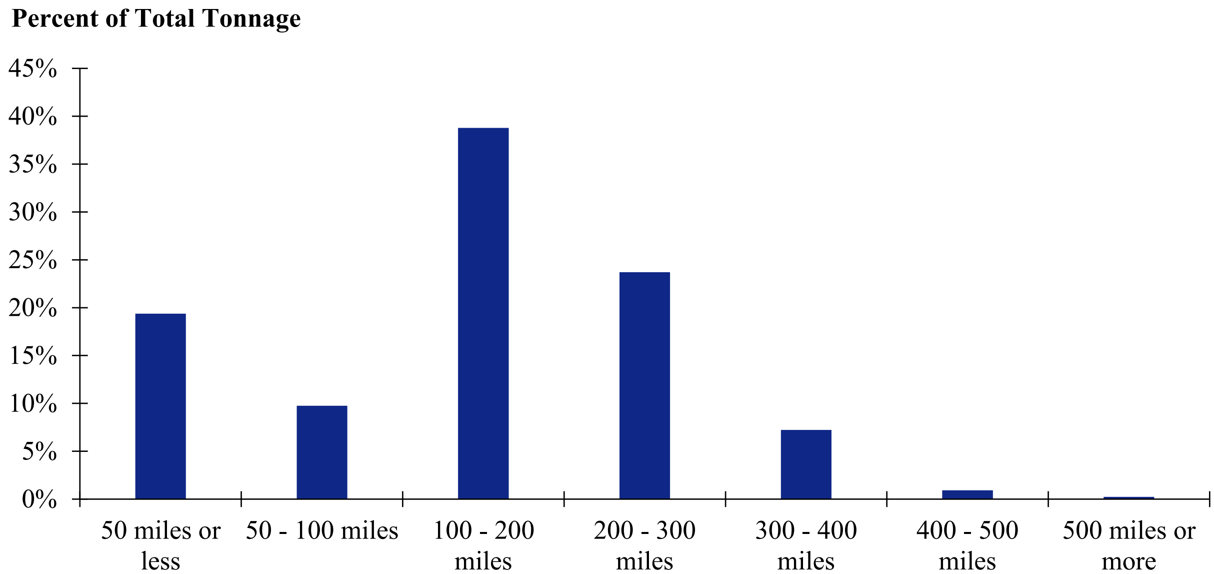

Figure 84. Bar chart. Distribution of shipment distances for farm-based shipments of corn for the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

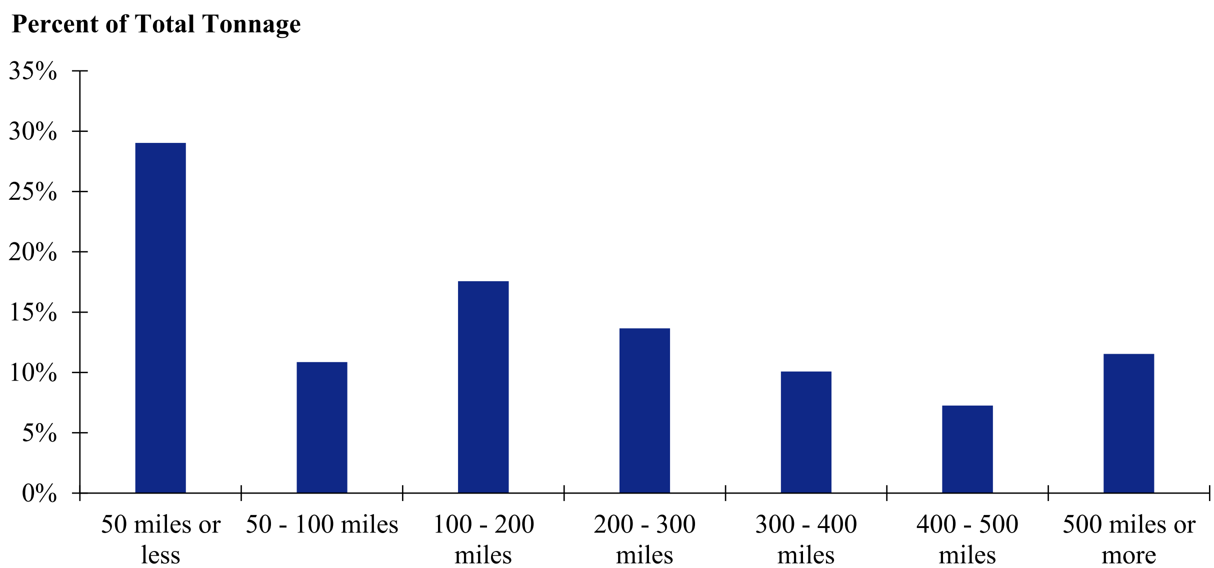

Figure 85. Bar chart. Distribution of shipment distances for farm-based shipments of corn for the Heartland production-consumption zone.
(Source: Federal Highway Administration.)

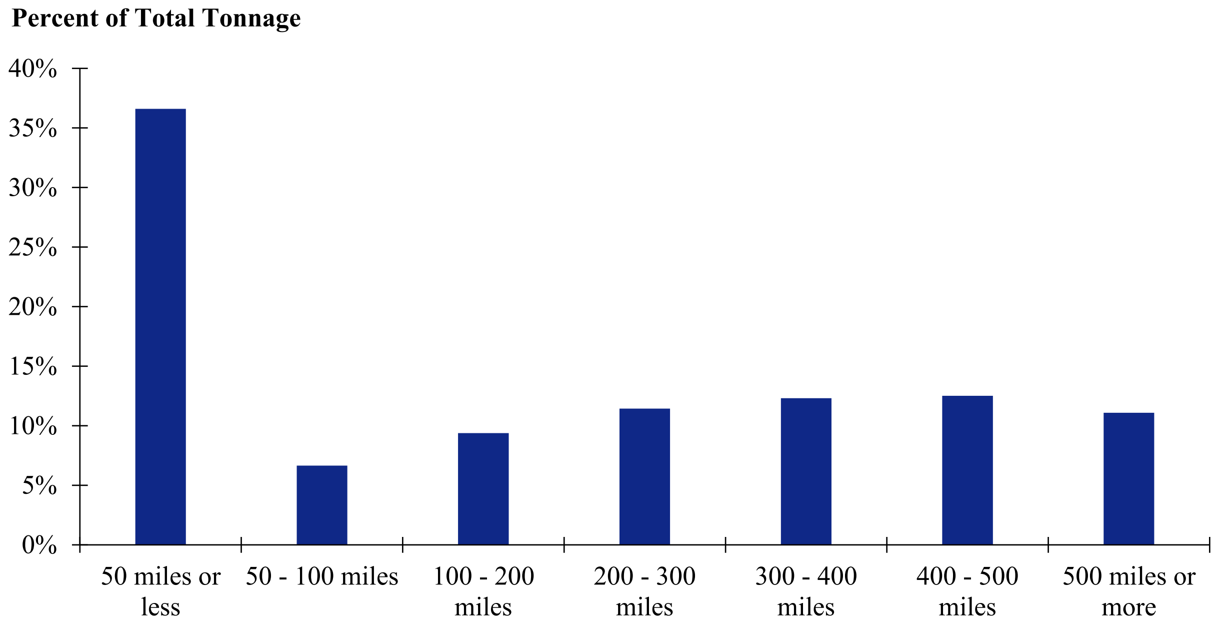

Figure 86. Bar chart. Distribution of shipment distances for farm-based shipments of corn for the Mountain production-consumption zone.
(Source: Federal Highway Administration.)

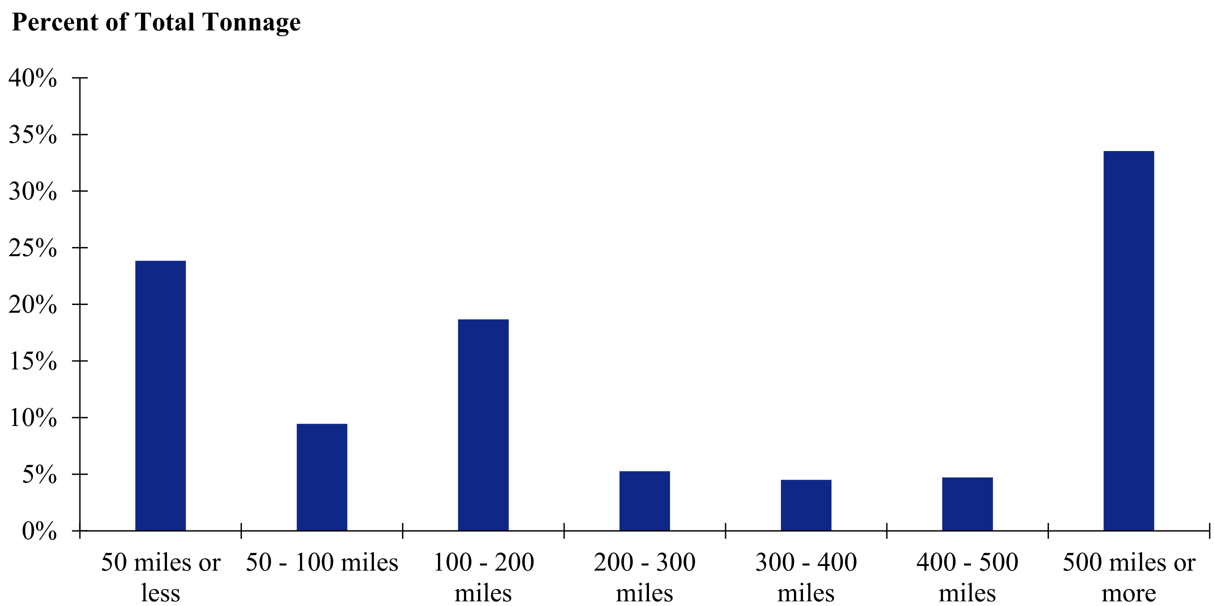

Figure 87. Bar chart. Distribution of shipment distances for farm-based shipments of corn for the West production-consumption zone.
(Source: Federal Highway Administration.)

FARM-BASED SHIPMENTS OF BROILERS

Hatchery-to-Farm Movements

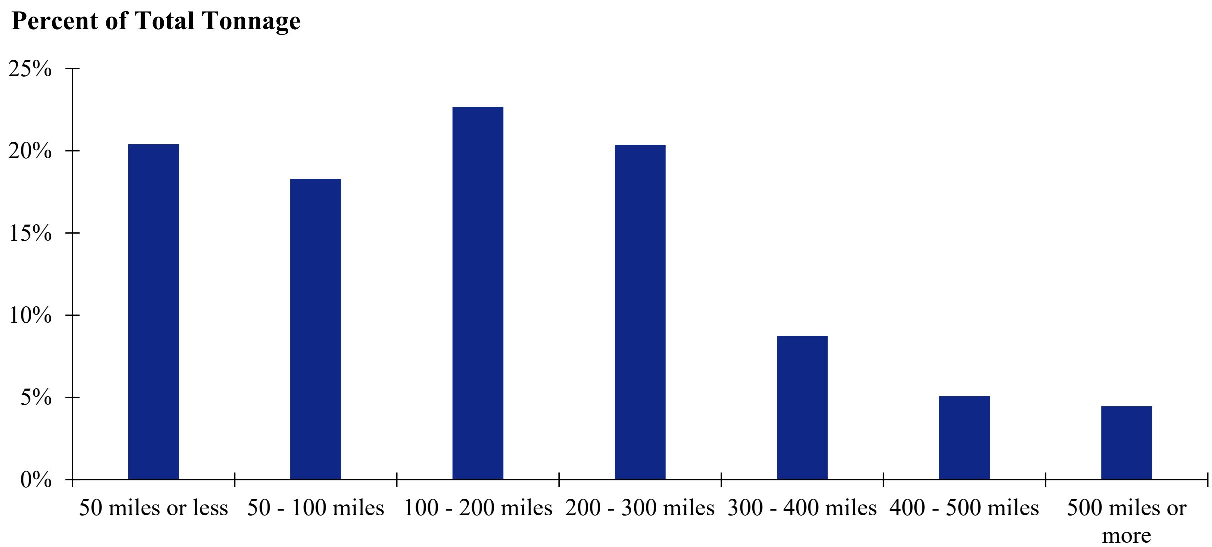

Figure 88. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the Southeast production-consumption zone. (Source: Federal Highway Administration.)

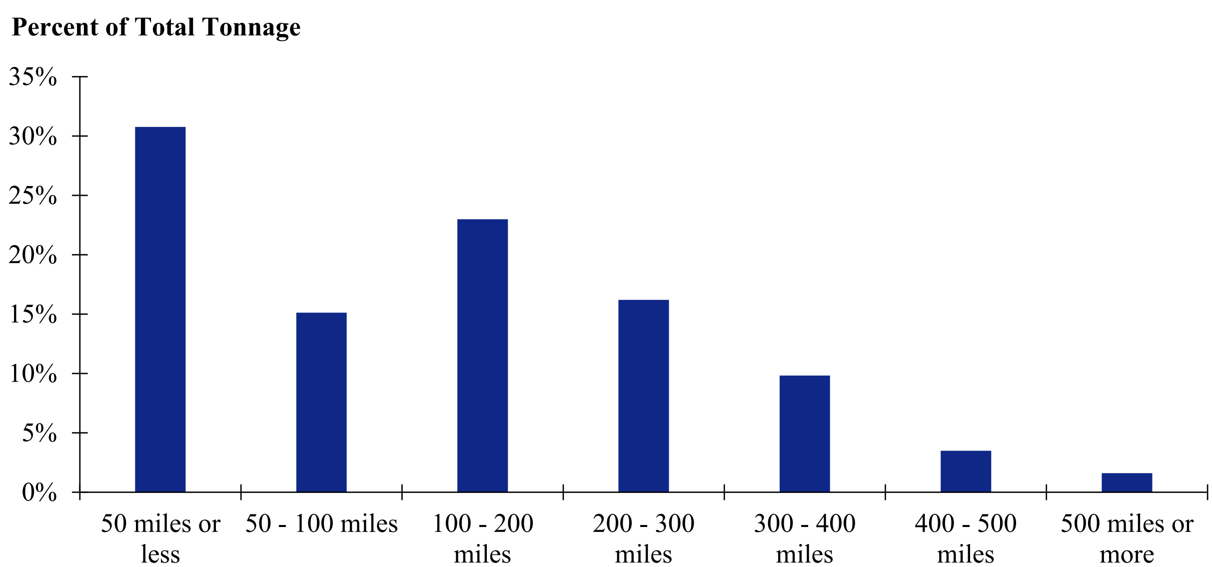

Figure 89. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the South Central production-consumption zone. (Source: Federal Highway Administration.)

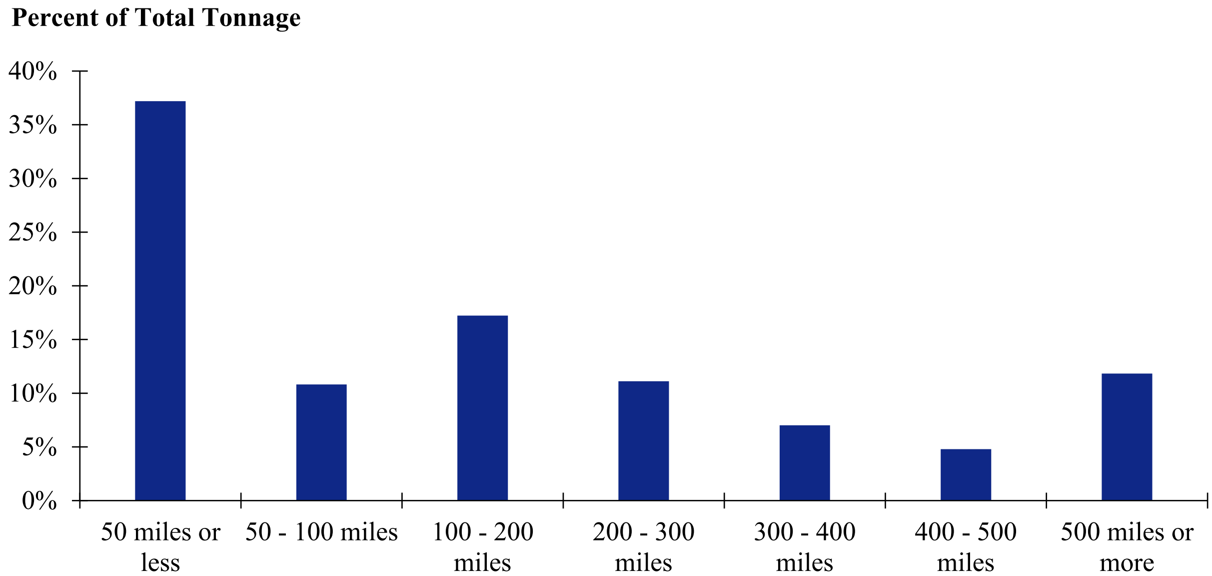

Figure 90. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

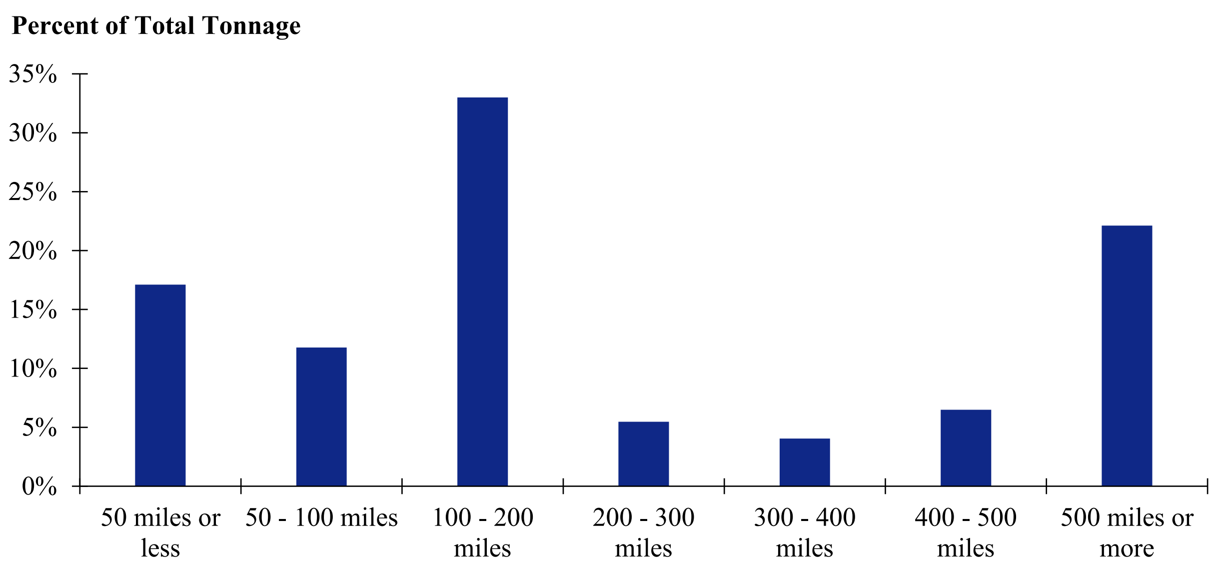

Figure 91. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the North Central production-consumption zone.
(Source: Federal Highway Administration.)

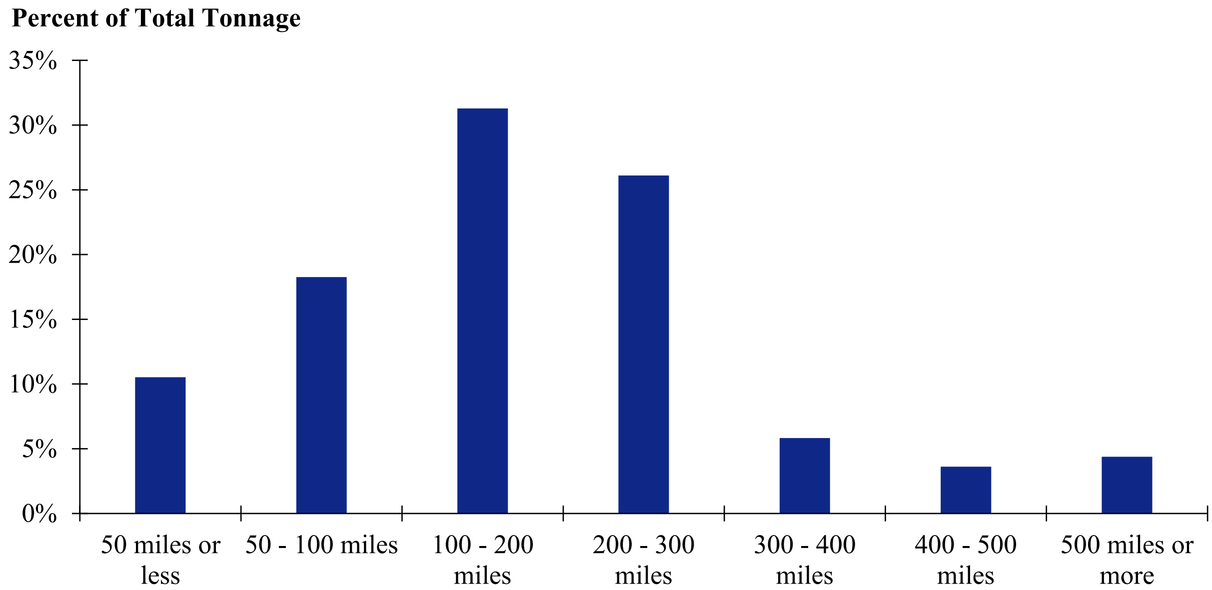

Figure 92. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the Great Plains production-consumption zone. (Source: Federal Highway Administration.)

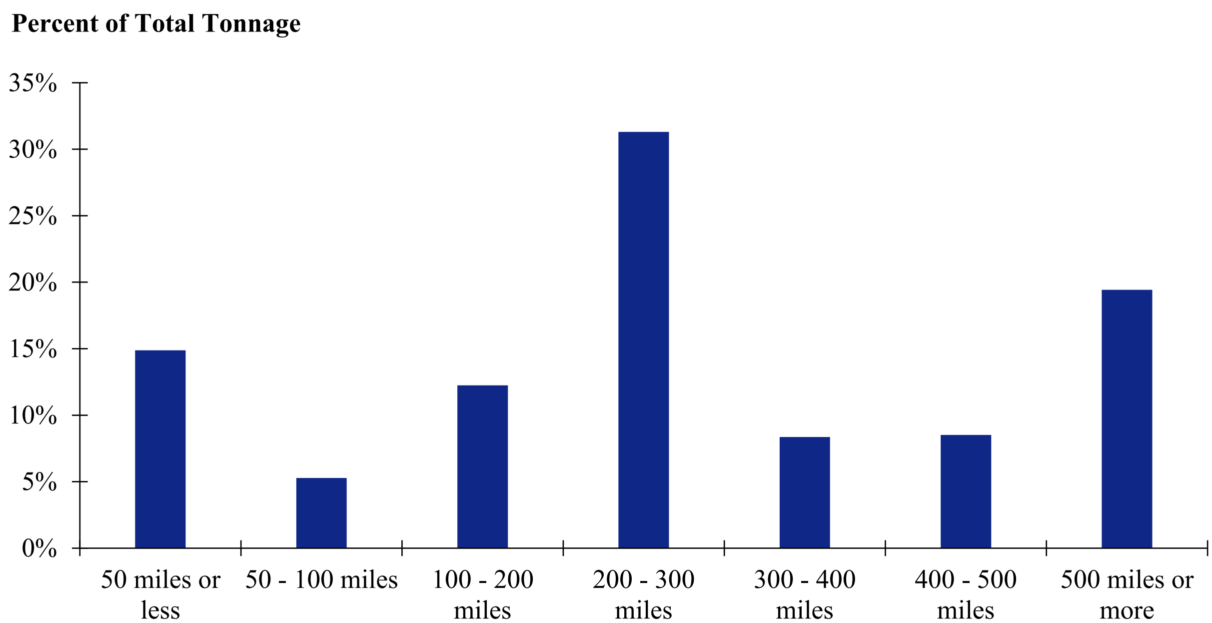

Figure 93. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the Intermountain production-consumption zone. (Source: Federal Highway Administration.)

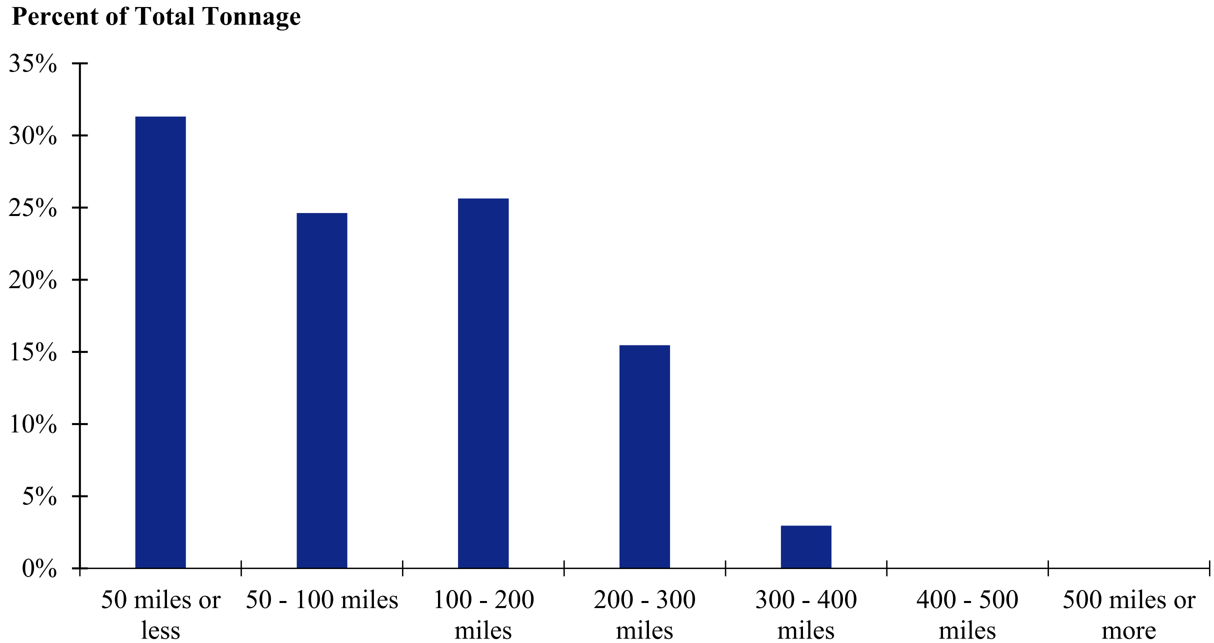

Figure 94. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the Pacific Northwest production-consumption zone. (Source: Federal Highway Administration.)

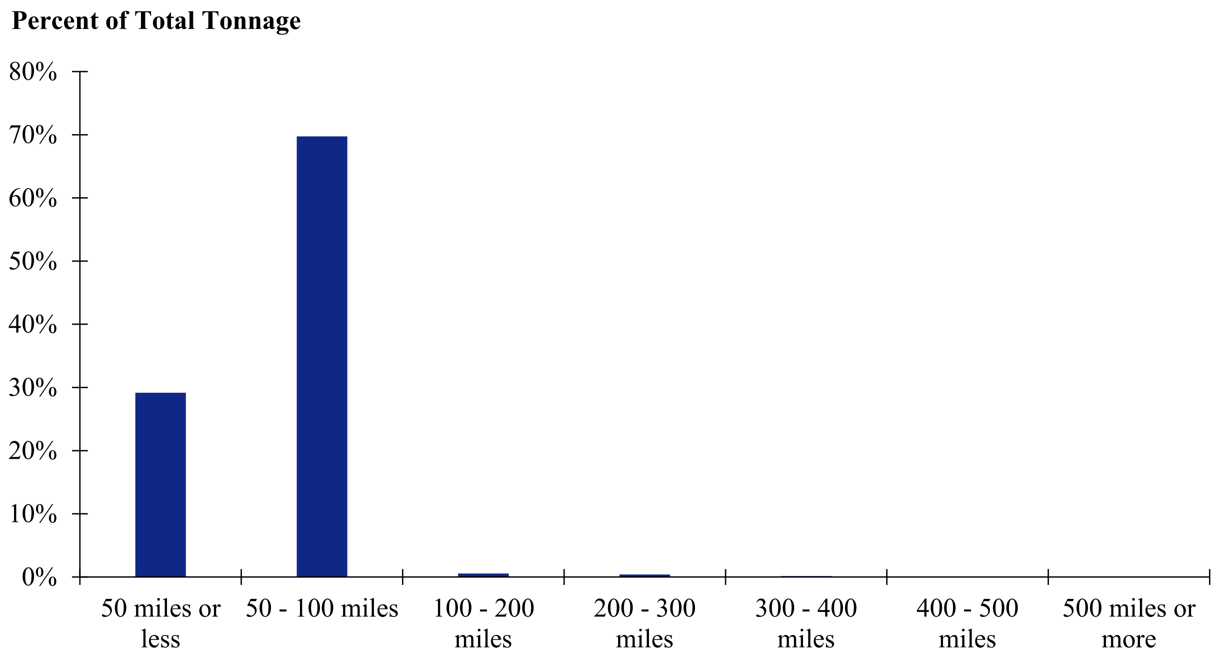

Figure 95. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of broilers for the California production-consumption zone. (Source: Federal Highway Administration.)

Farm-to-Processing Movements

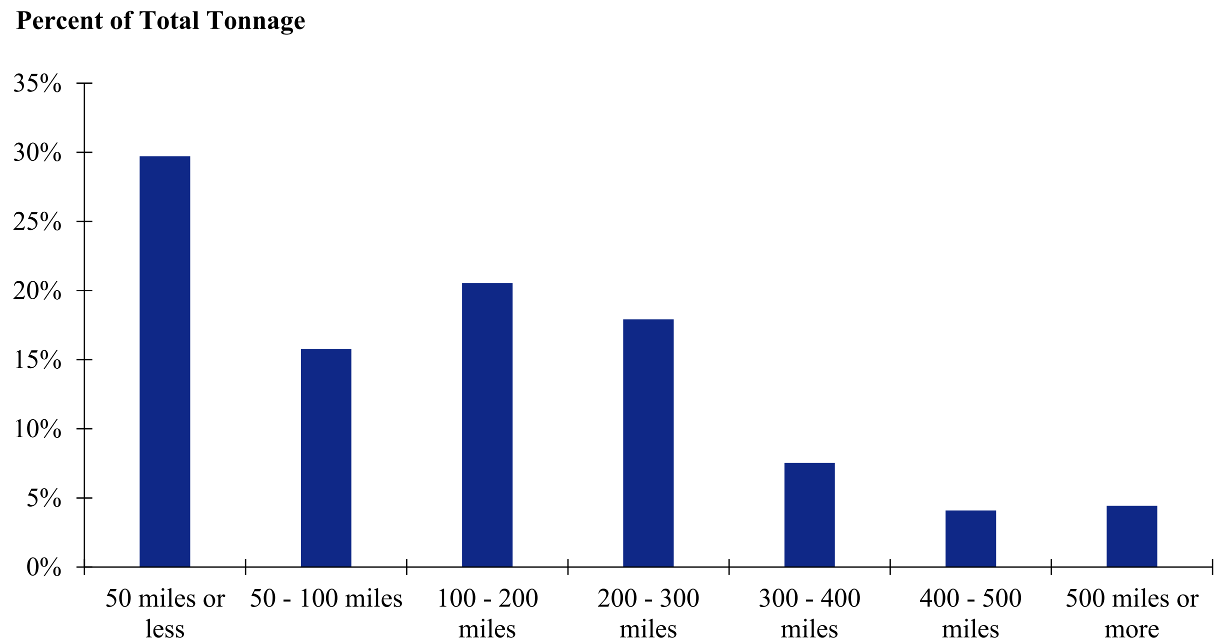

Figure 96. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Southeast production-consumption zone. (Source: Federal Highway Administration.)

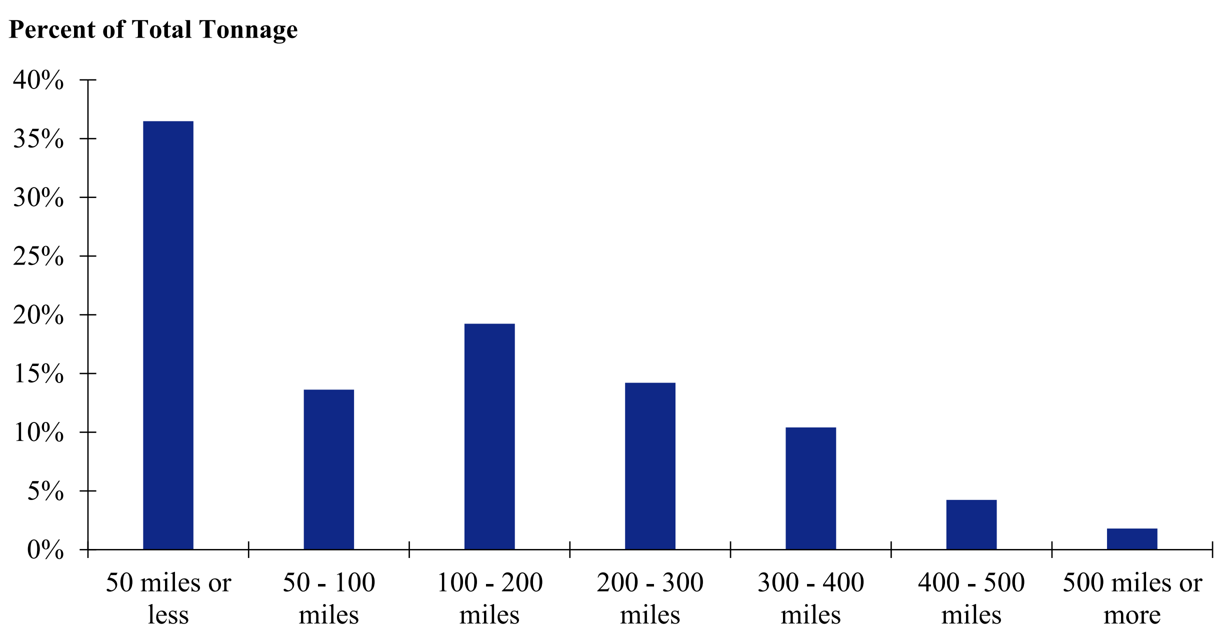

Figure 97. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the South Central production-consumption zone. (Source: Federal Highway Administration.)

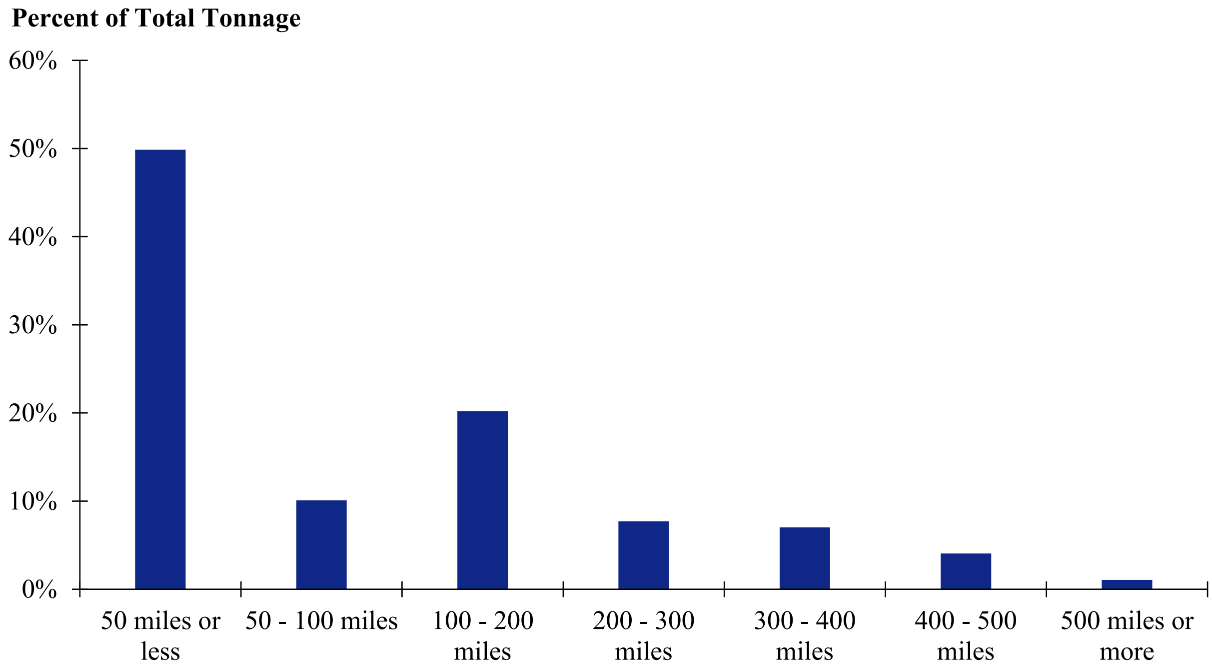

Figure 98. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Northeast production-consumption zone. (Source: Federal Highway Administration.)

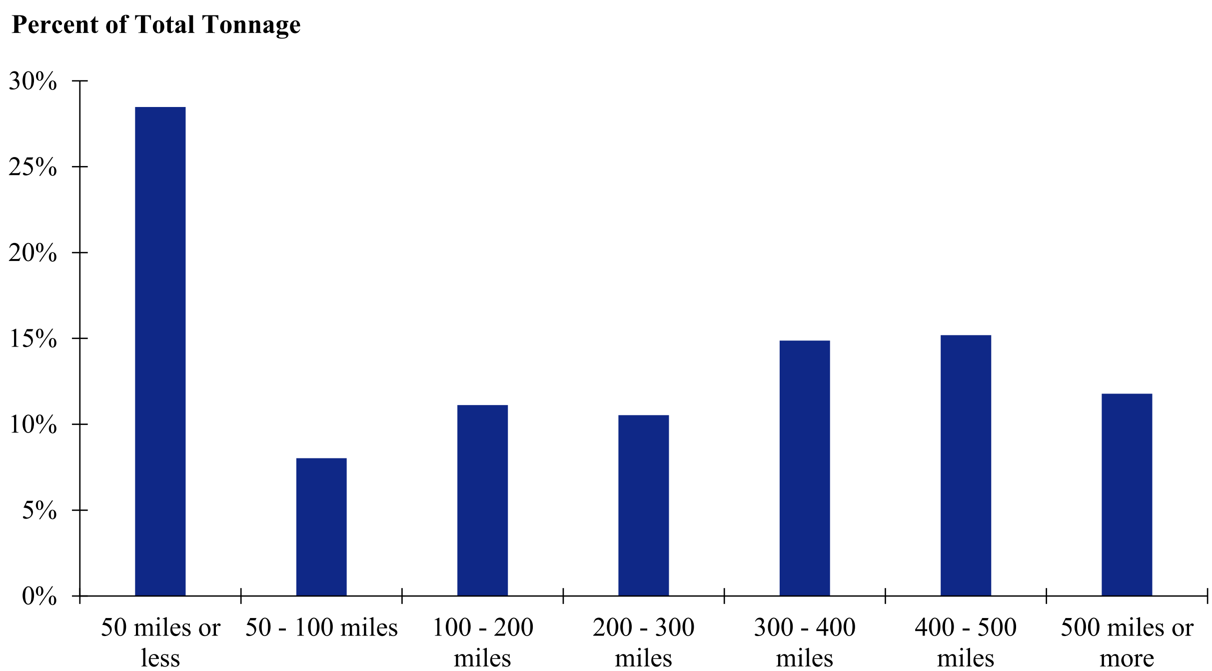

Figure 99. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the North Central production-consumption zone. (Source: Federal Highway Administration.)

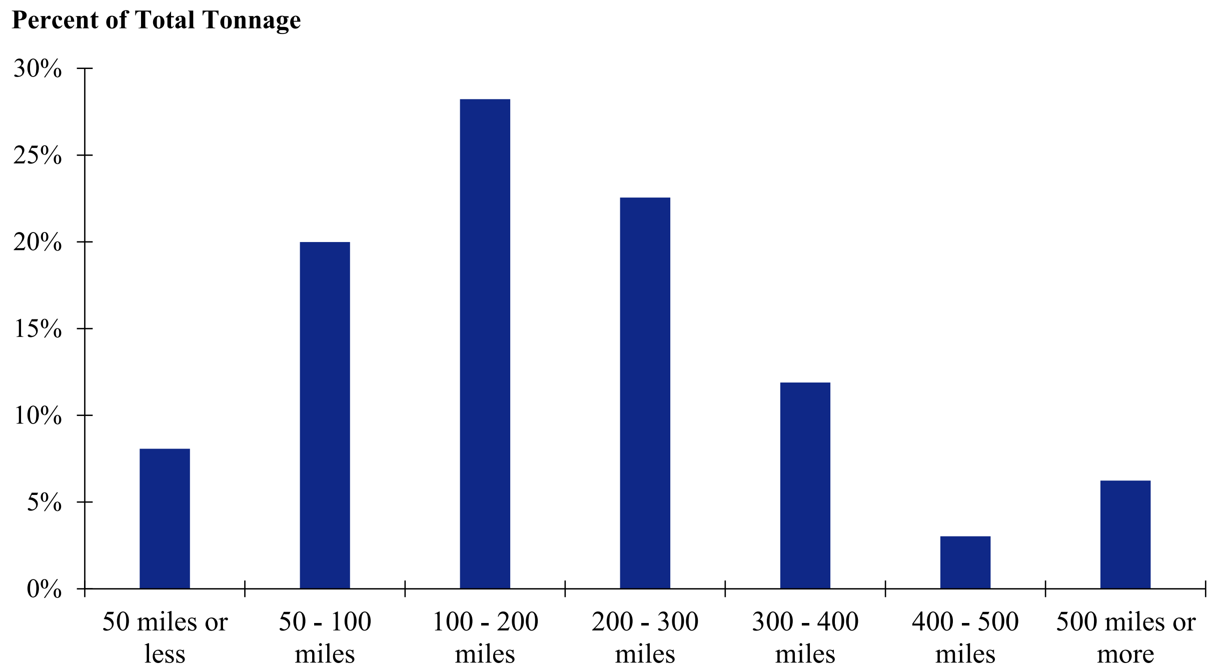

Figure 100. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Great Plains production-consumption zone. (Source: Federal Highway Administration.)

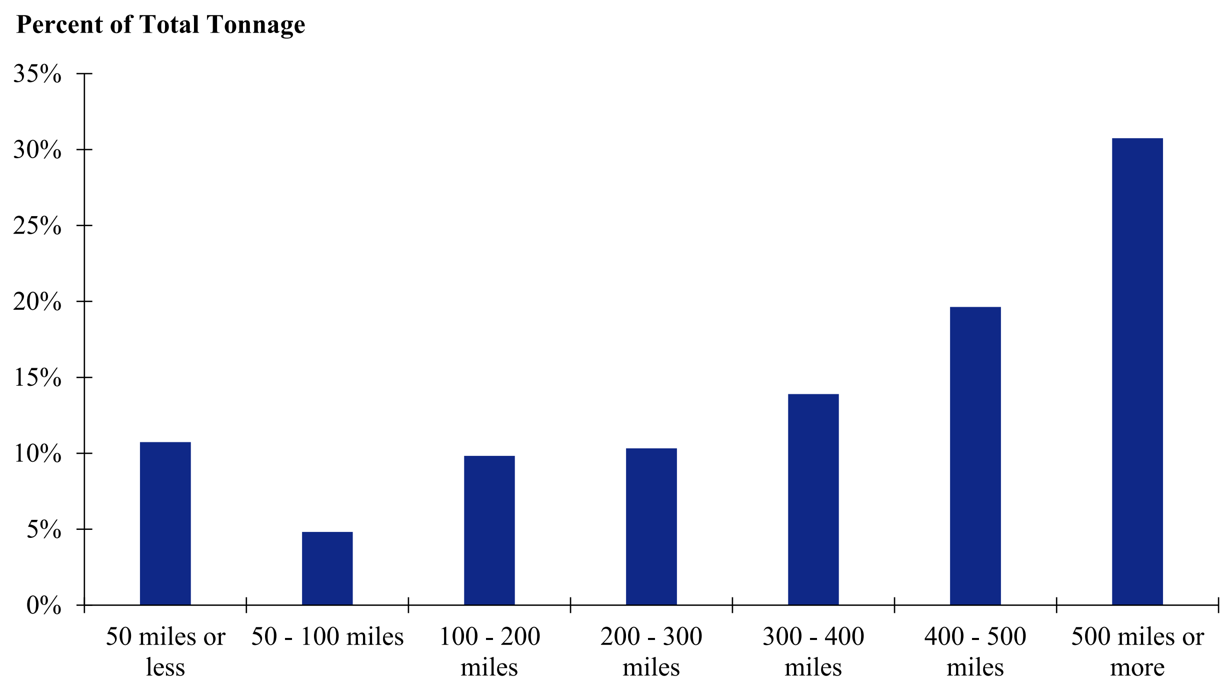

Figure 101. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Intermountain production-consumption zone. (Source: Federal Highway Administration.)

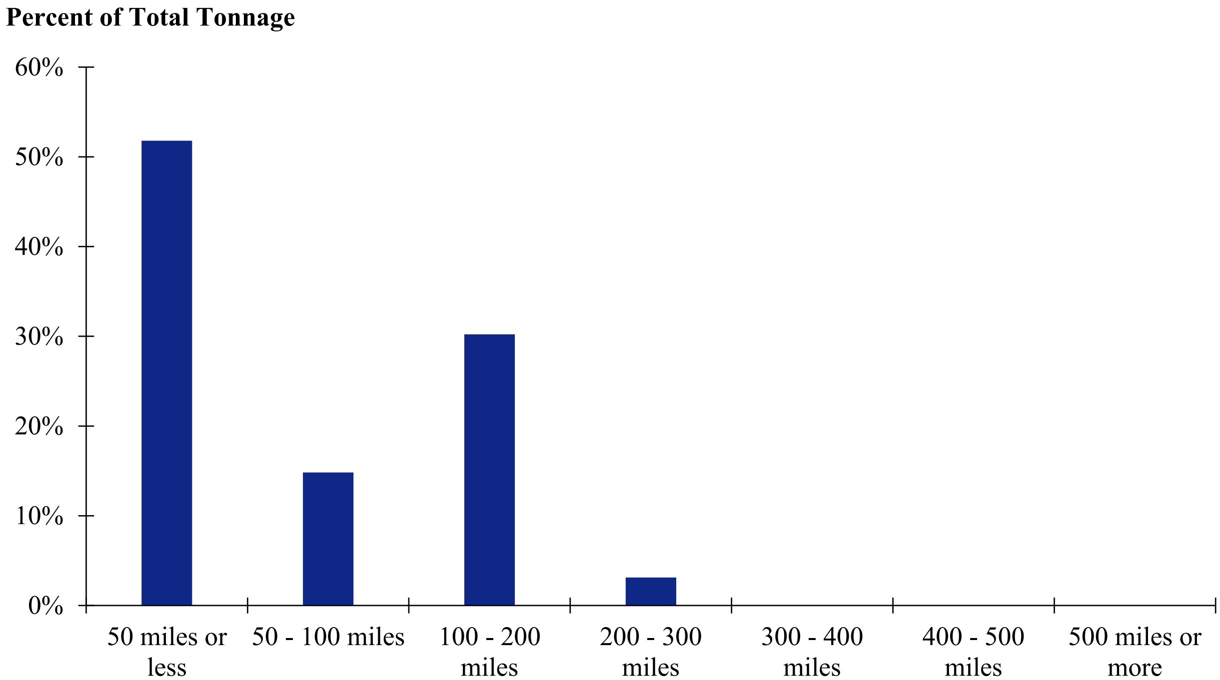

Figure 102. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the Pacific Northwest production-consumption zone. (Source: Federal Highway Administration.)

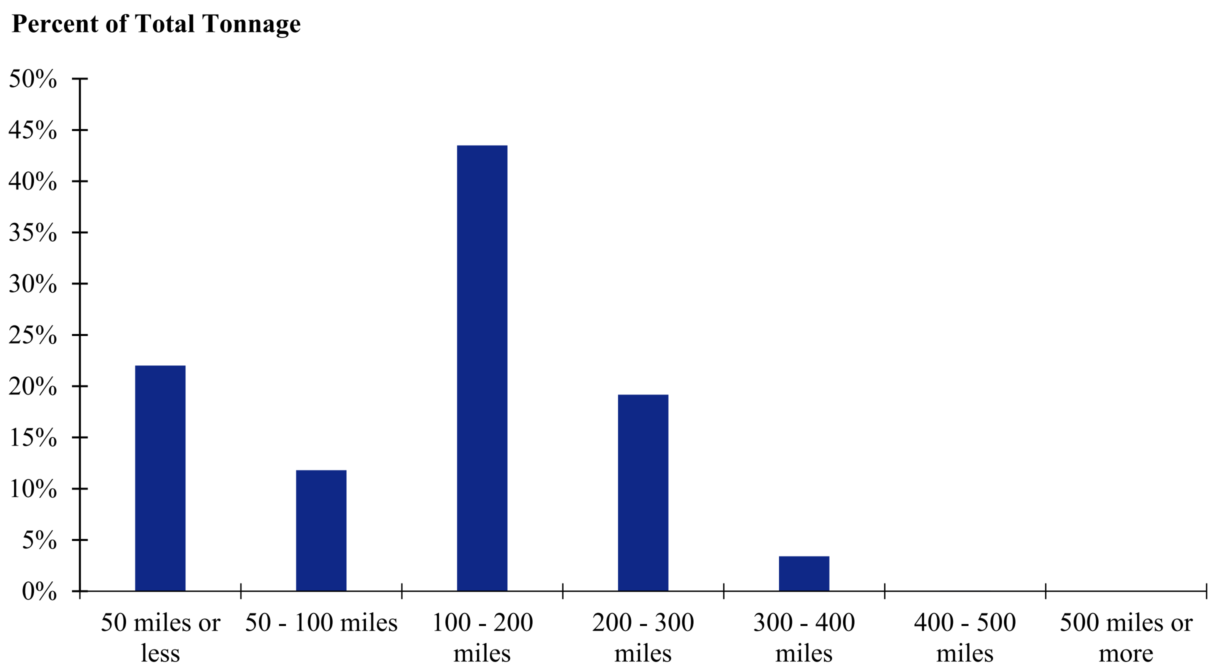

Figure 103. Bar chart. Distribution of shipment distances for farm-to-processing farm-based shipments of broilers for the California production-consumption zone. (Source: Federal Highway Administration.)

FARM-BASED SHIPMENTS OF PULLETS

Hatchery-to-Farm Movements

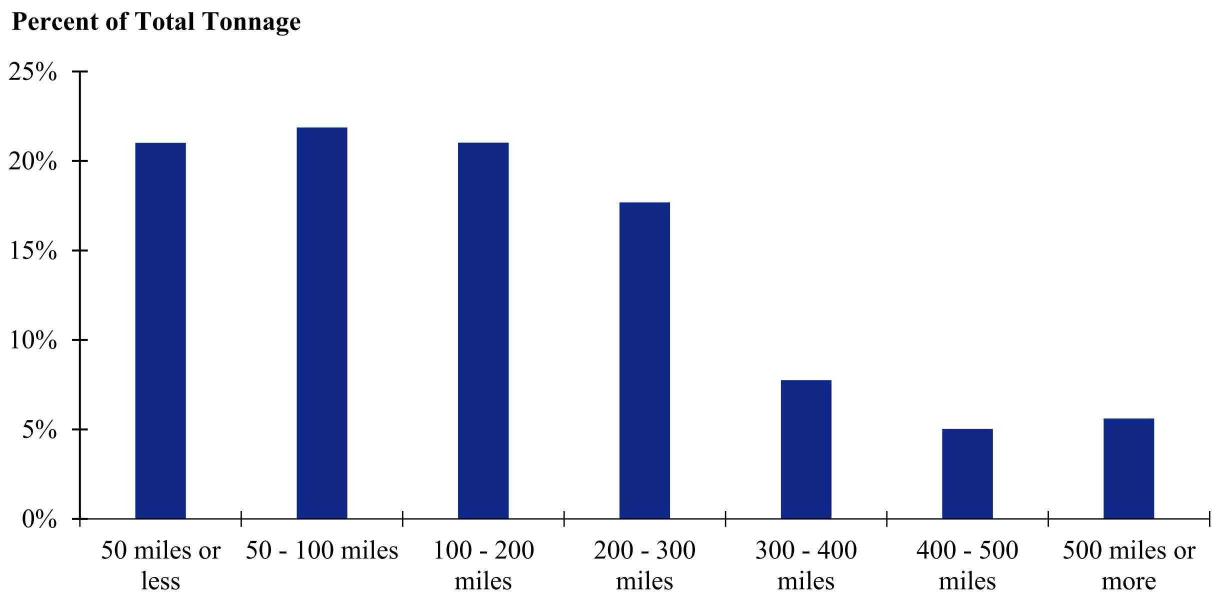

Figure 104. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the Southeast production-consumption zone. (Source: Federal Highway Administration.)

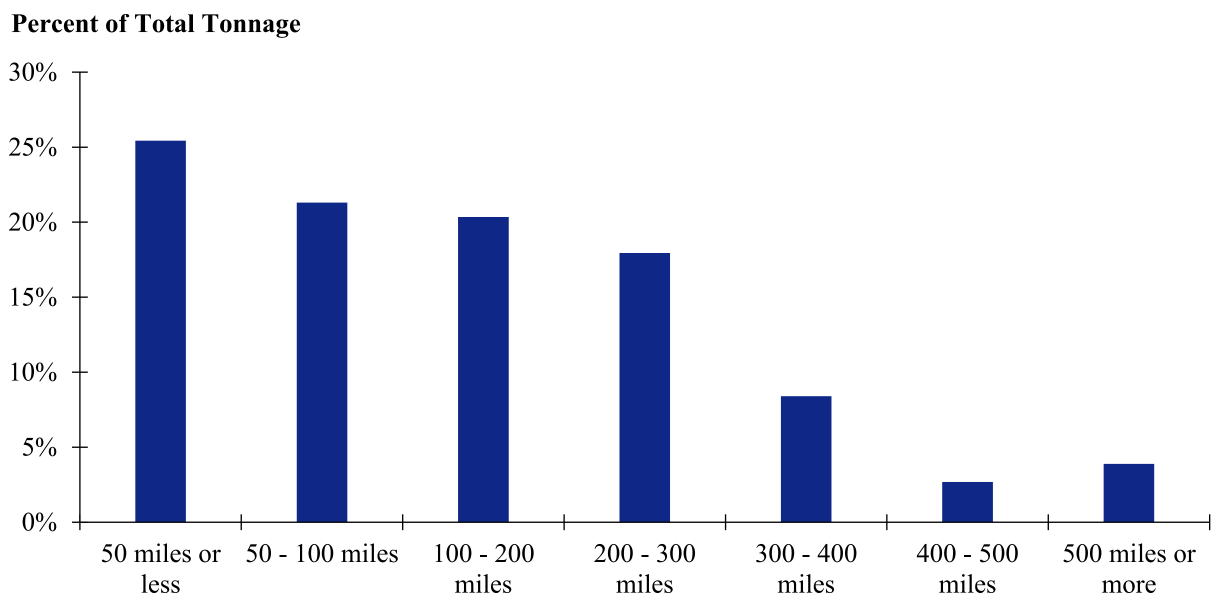

Figure 105. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the South Central production-consumption zone. (Source: Federal Highway Administration.)

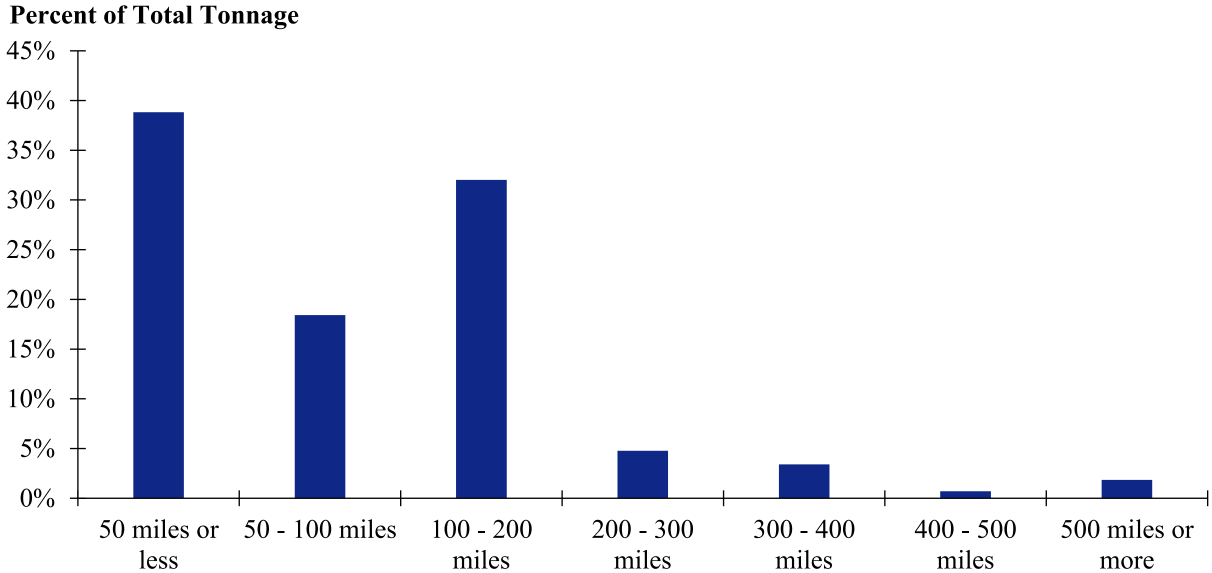

Figure 106. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

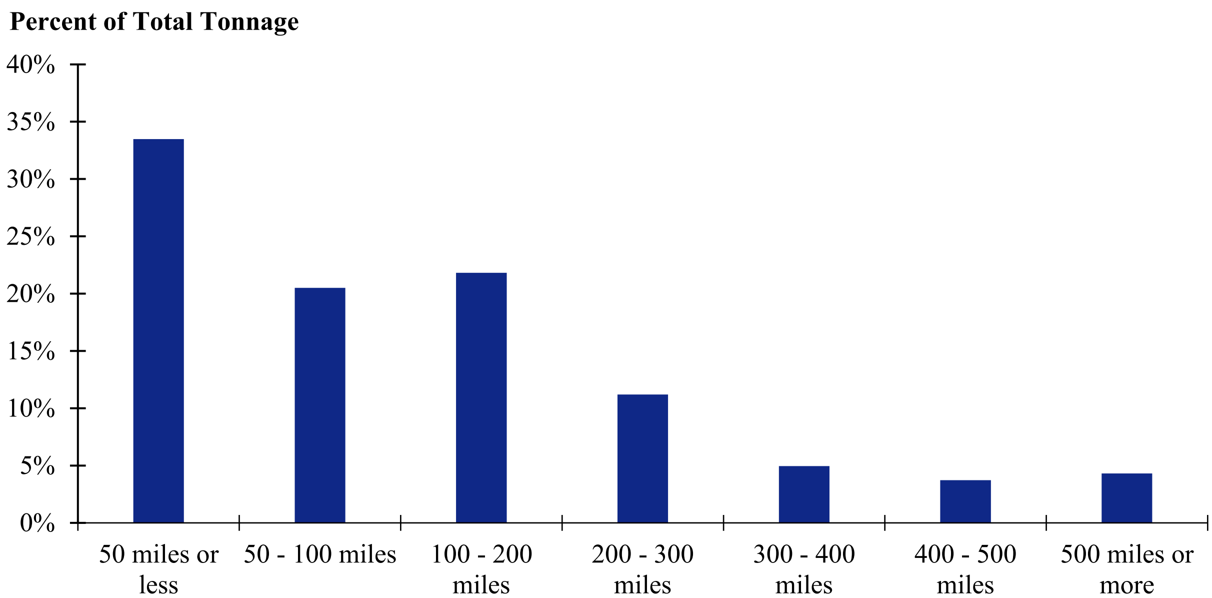

Figure 107. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the North Central production-consumption zone.
(Source: Federal Highway Administration.)

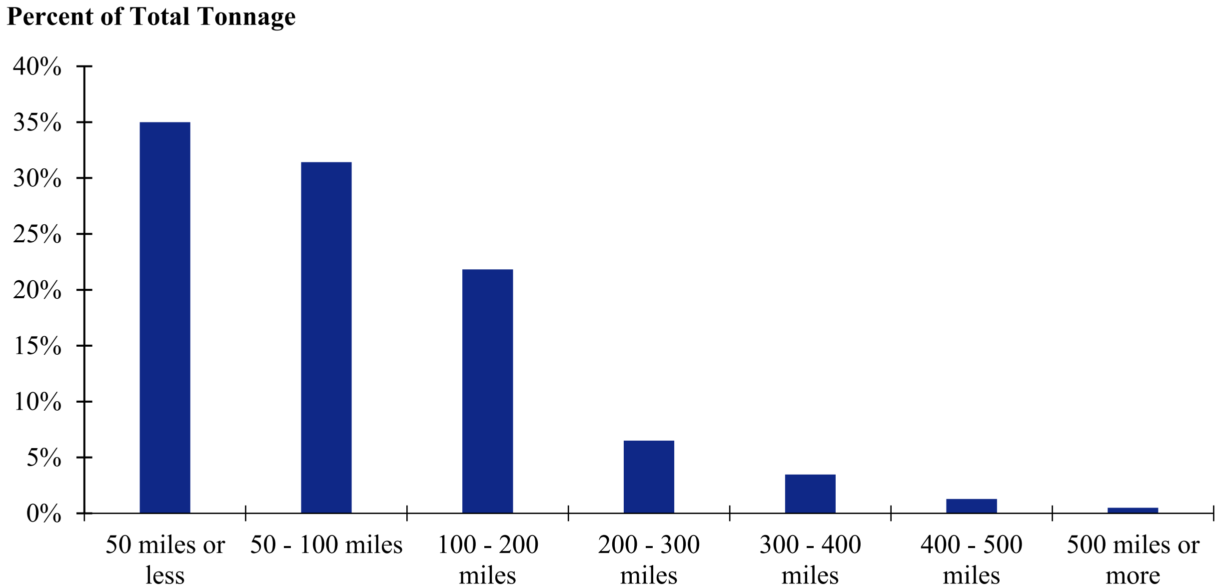

Figure 108. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the Great Plains production-consumption zone. (Source: Federal Highway Administration.)

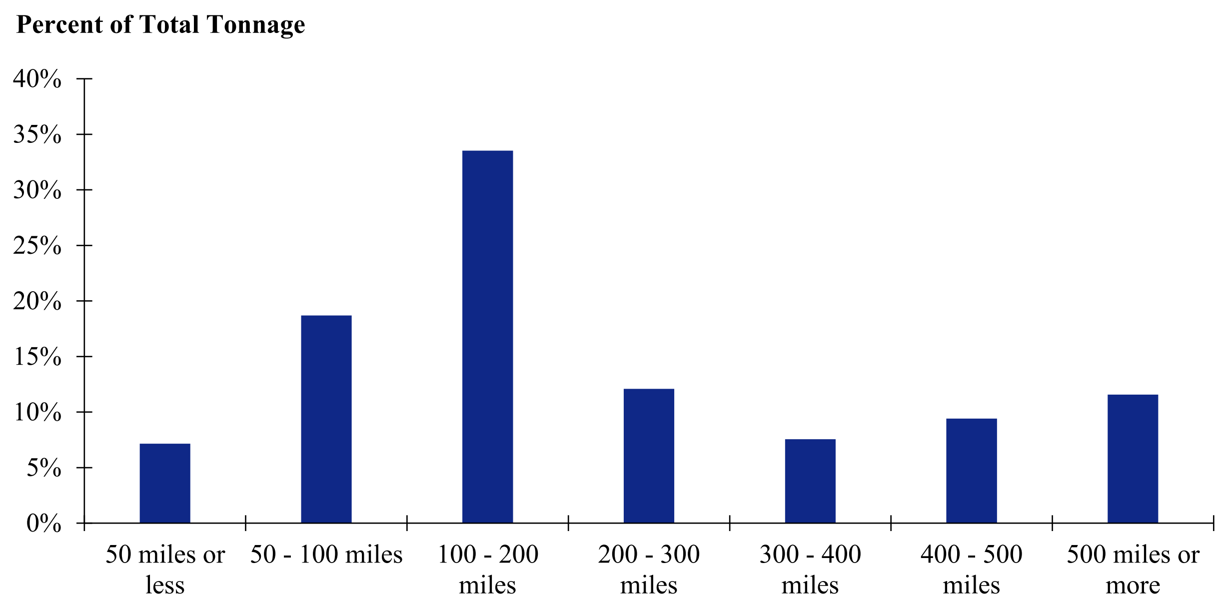

Figure 109. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the Intermountain production-consumption zone. (Source: Federal Highway Administration.)

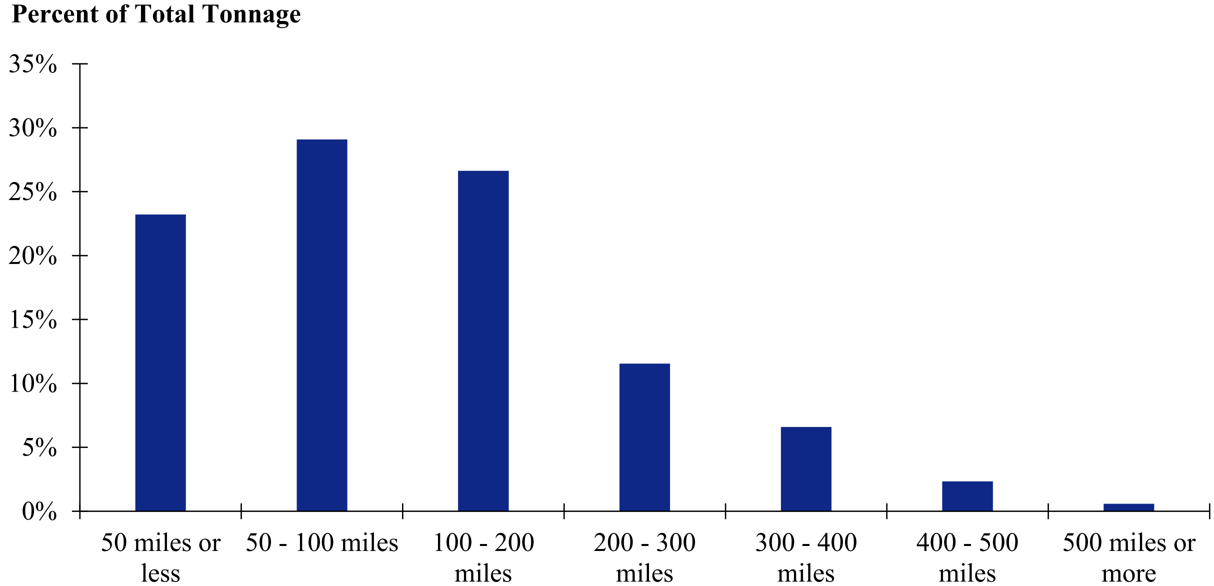

Figure 110. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the Pacific Northwest production-consumption zone. (Source: Federal Highway Administration.)

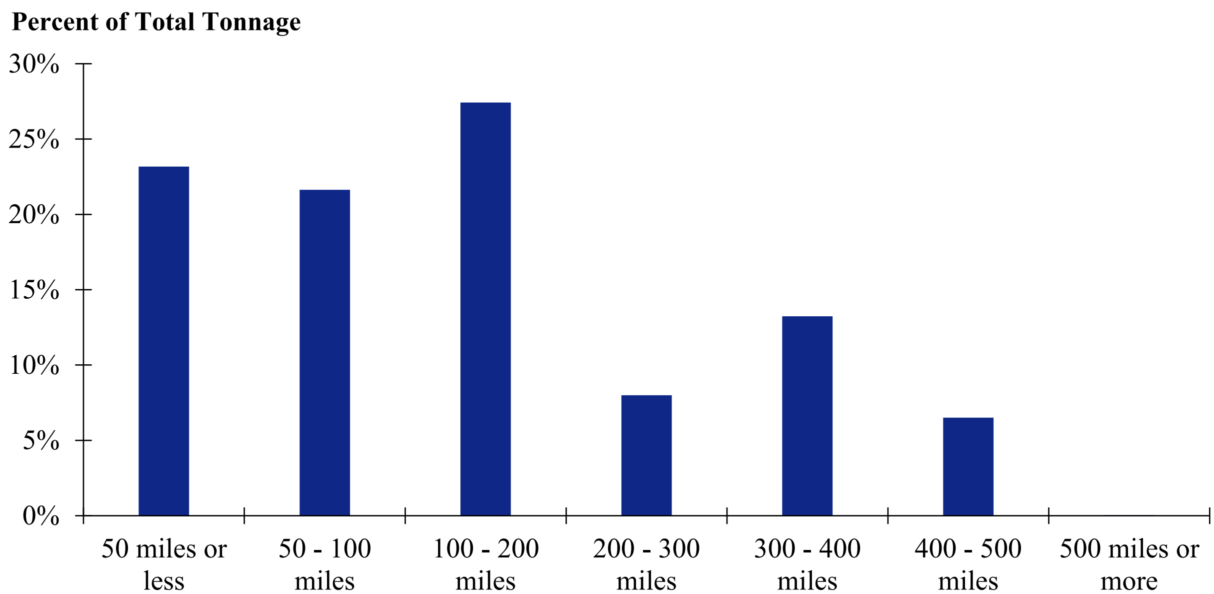

Figure 111. Bar chart. Distribution of shipment distances for hatchery-to-farm farm-based shipments of pullets for the California production-consumption zone. (Source: Federal Highway Administration.)

LOGS

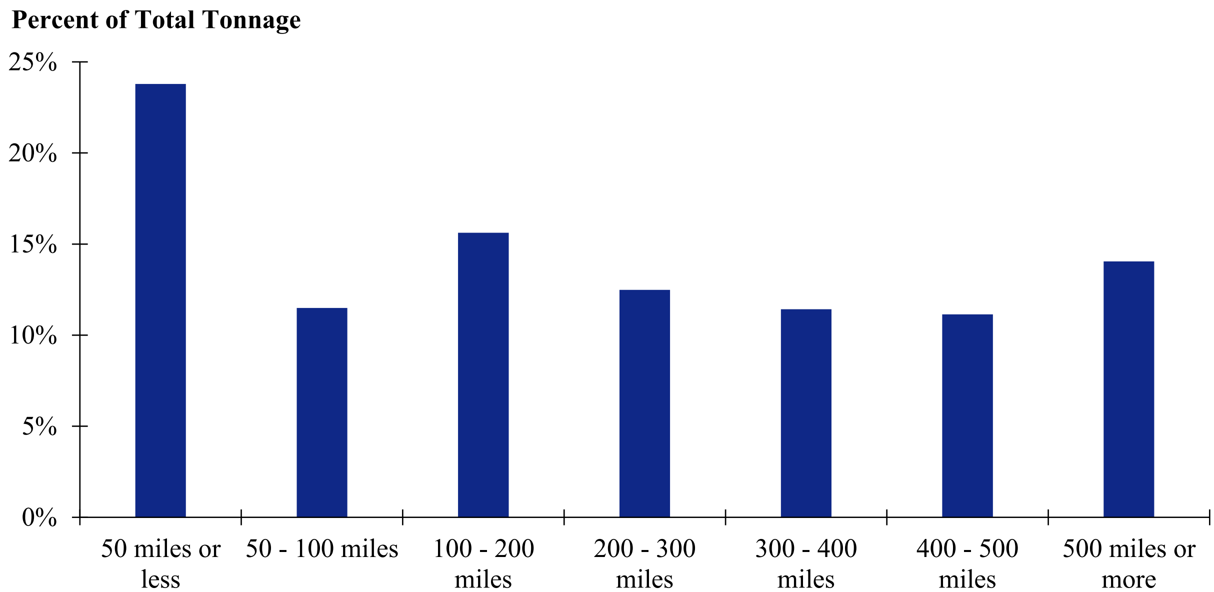

Figure 112. Bar chart. Distribution of shipment distances for logs for the Southeast production-consumption zone.
(Source: Federal Highway Administration.)

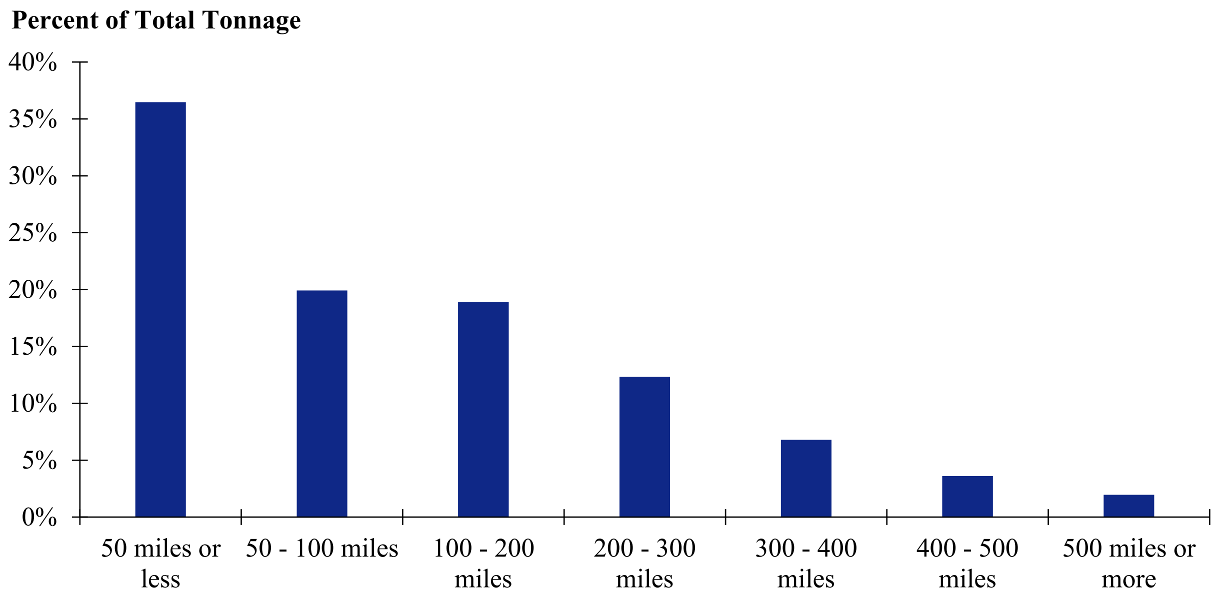

Figure 113. Bar chart. Distribution of shipment distances for logs for the South Central production-consumption zone.
(Source: Federal Highway Administration.)

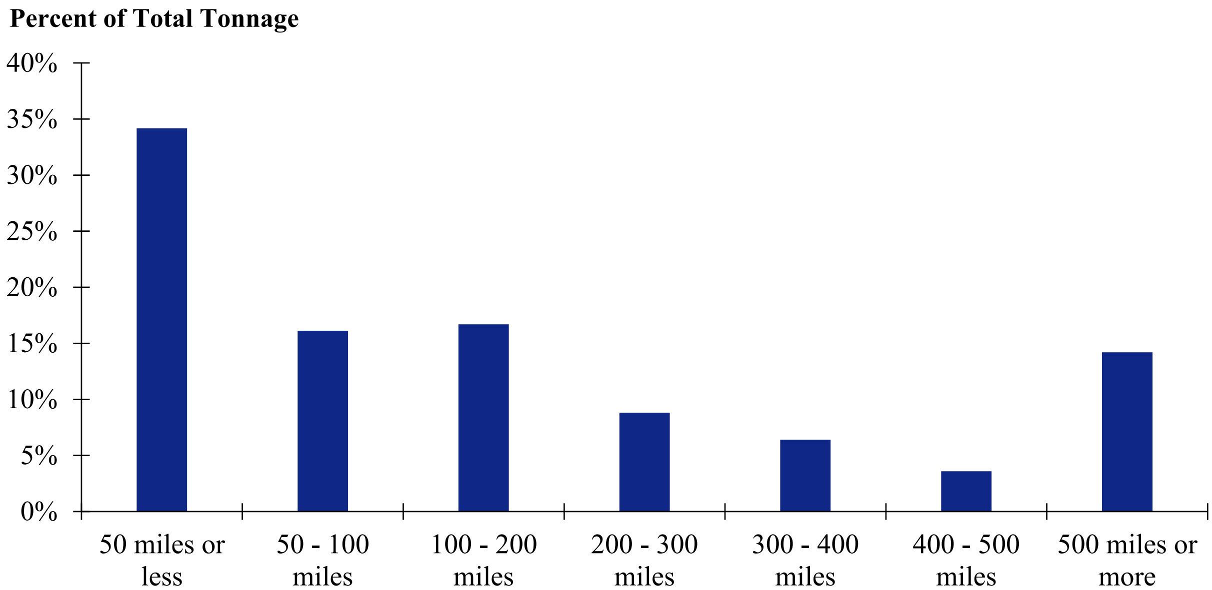

Figure 114. Bar chart. Distribution of shipment distances for logs for the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

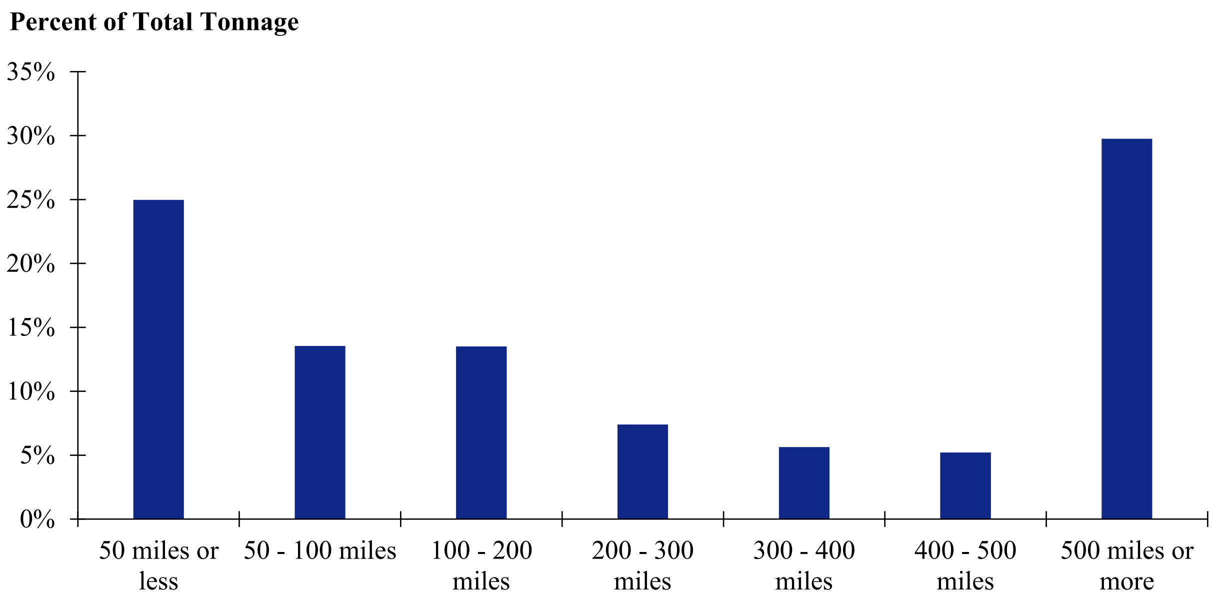

Figure 115. Bar chart. Distribution of shipment distances for logs for the North Central production-consumption zone.
(Source: Federal Highway Administration.)

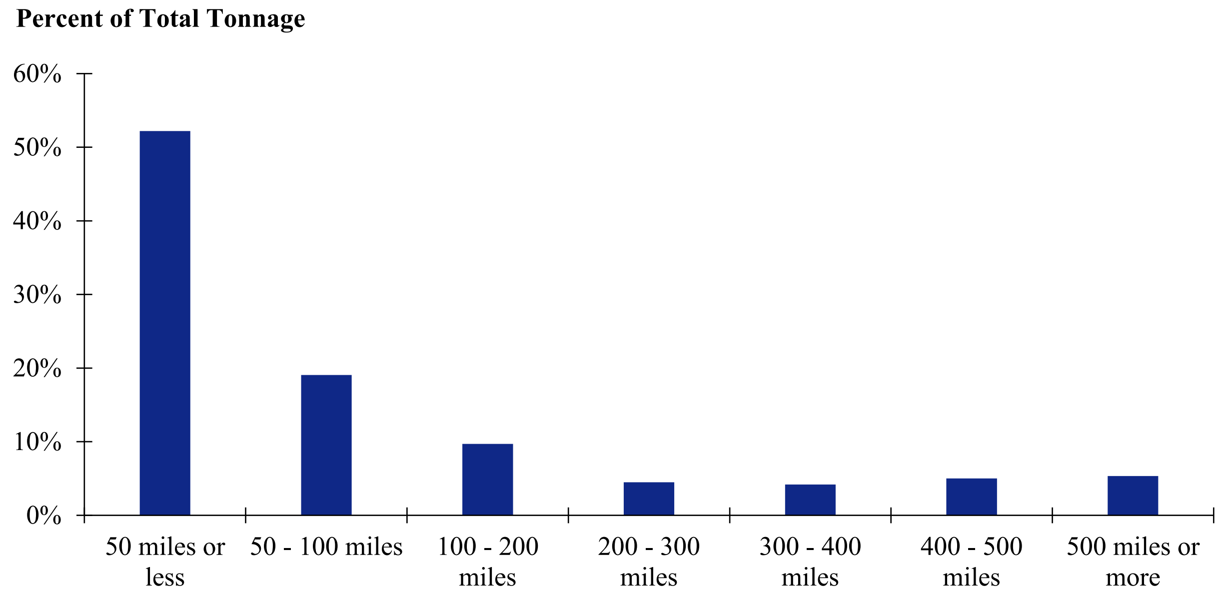

Figure 116. Bar chart. Distribution of shipment distances for logs for the Great Plains production-consumption zone.
(Source: Federal Highway Administration.)

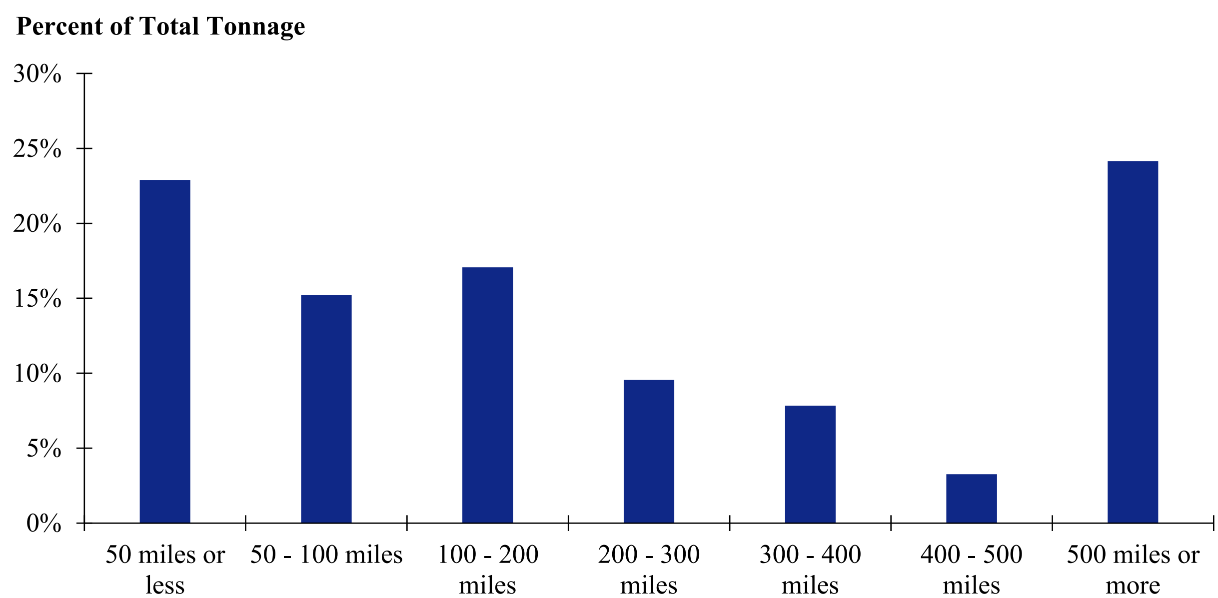

Figure 117. Bar chart. Distribution of shipment distances for logs for the Intermountain production-consumption zone.
(Source: Federal Highway Administration.)

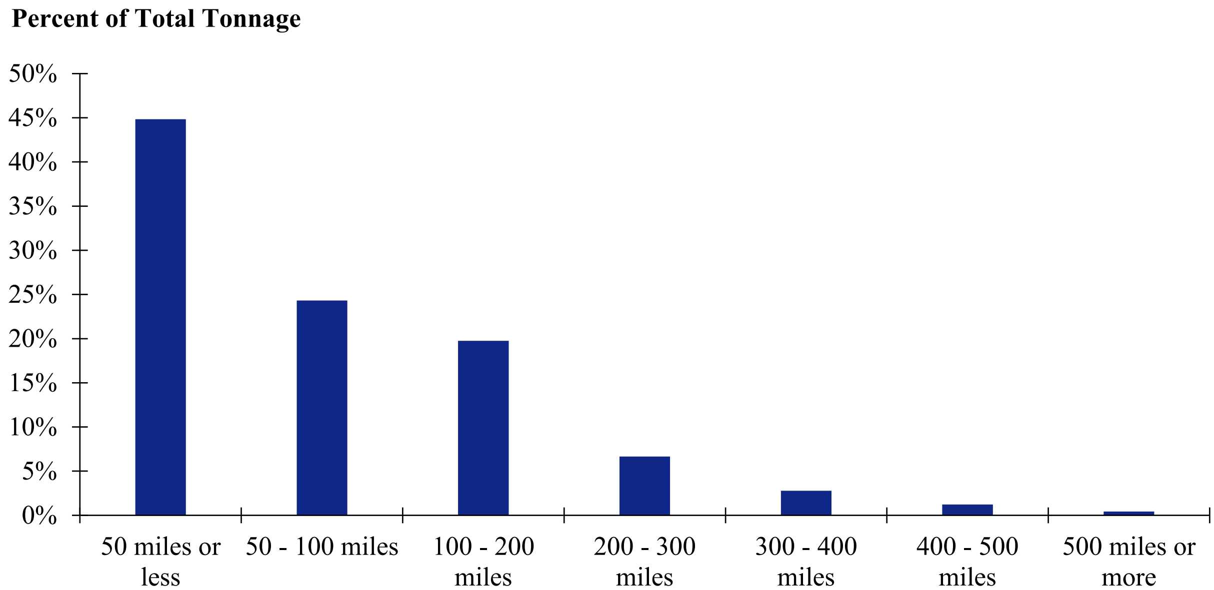

Figure 118. Bar chart. Distribution of shipment distances for logs for the Pacific Northwest production-consumption zone.
(Source: Federal Highway Administration.)

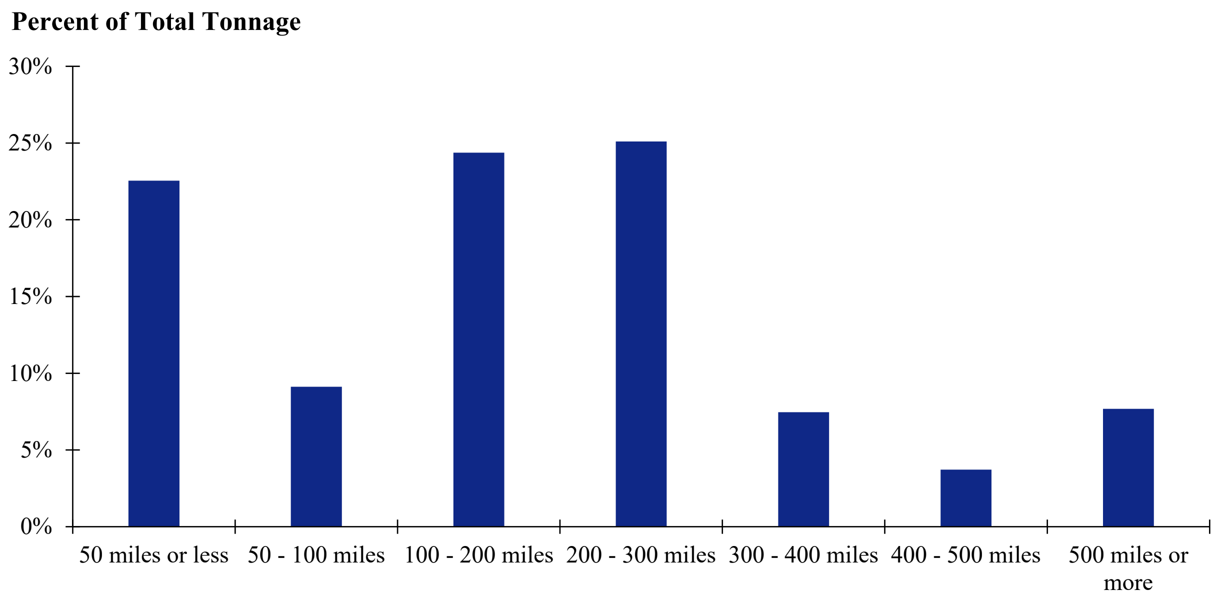

Figure 119. Bar chart. Distribution of shipment distances for logs for the California production-consumption zone.
(Source: Federal Highway Administration.)

FISH

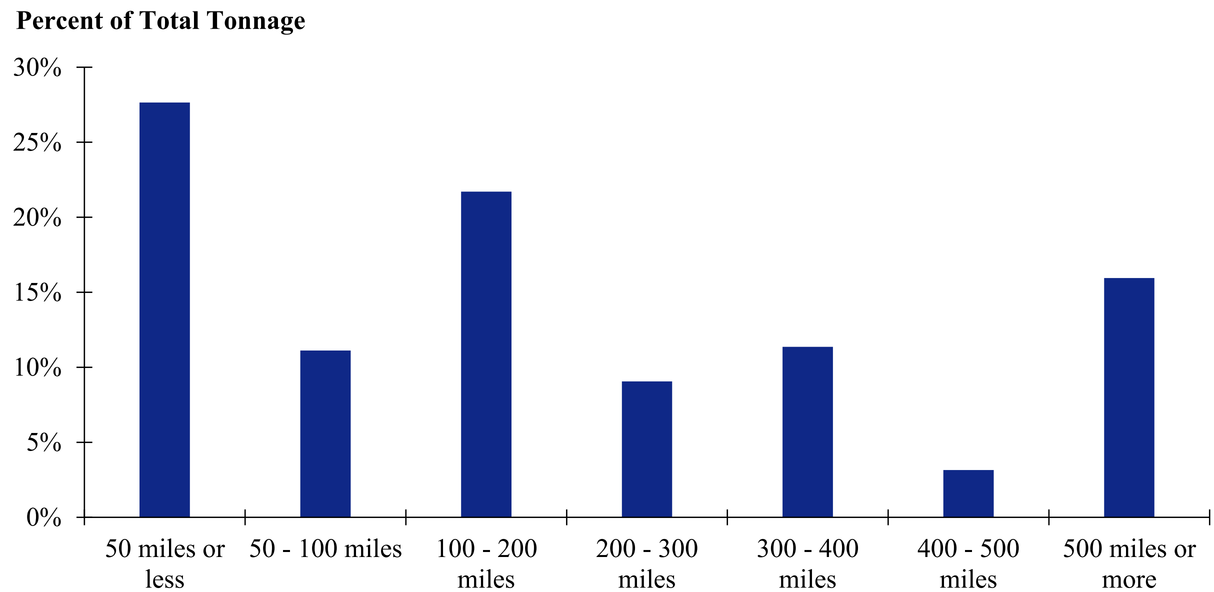

Figure 120. Bar chart. Distribution of shipment distances for fish in the Coastal Southeast production-consumption zone.
(Source: Federal Highway Administration.)

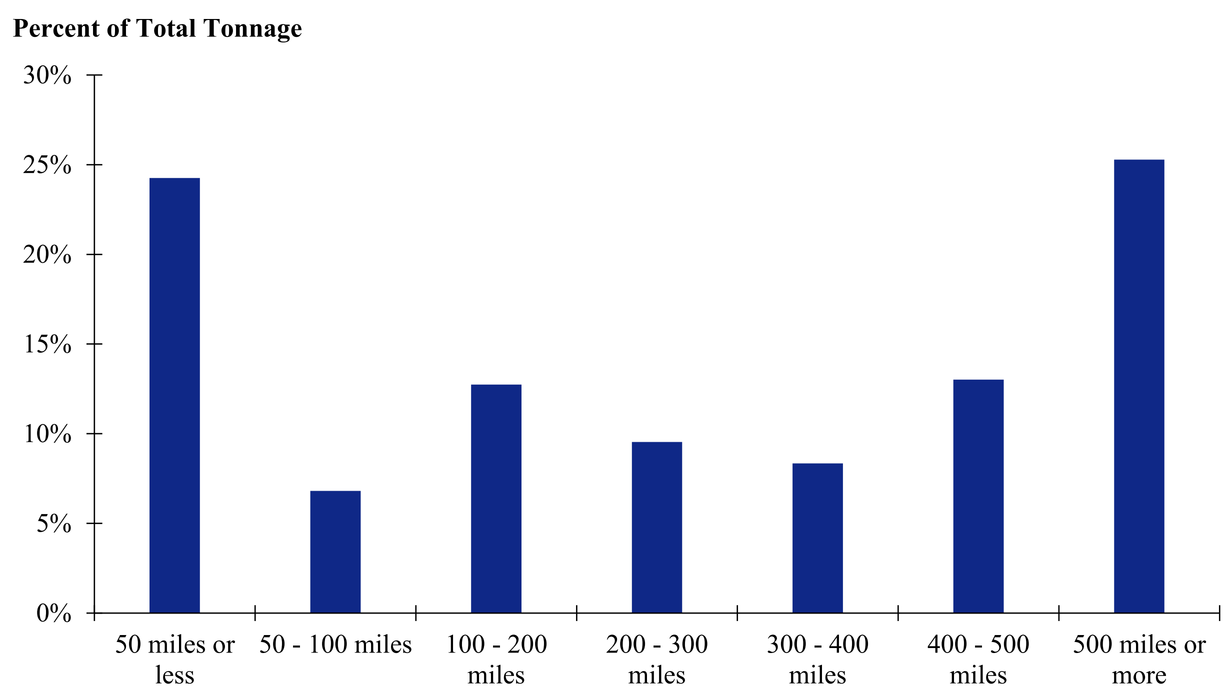

Figure 121. Bar chart. Distribution of shipment distances for fish in the Gulf Coast production-consumption zone.
(Source: Federal Highway Administration.)

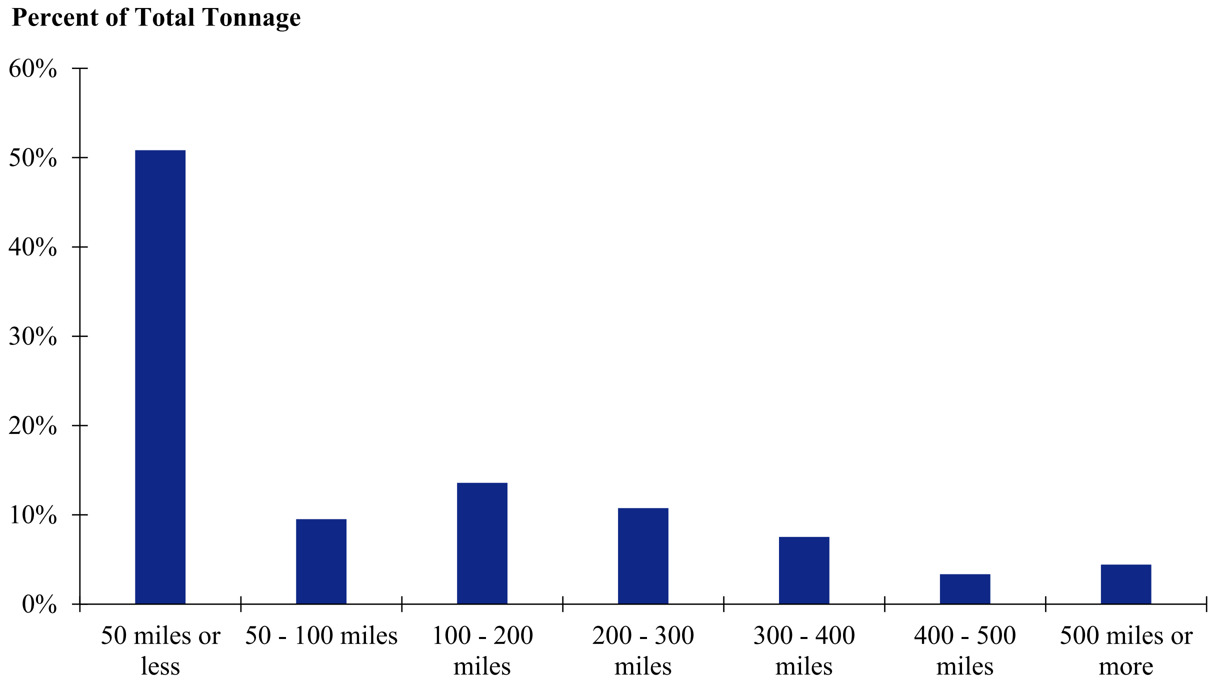

Figure 122. Bar chart. Distribution of shipment distances for fish in the Northeast production-consumption zone.
(Source: Federal Highway Administration.)

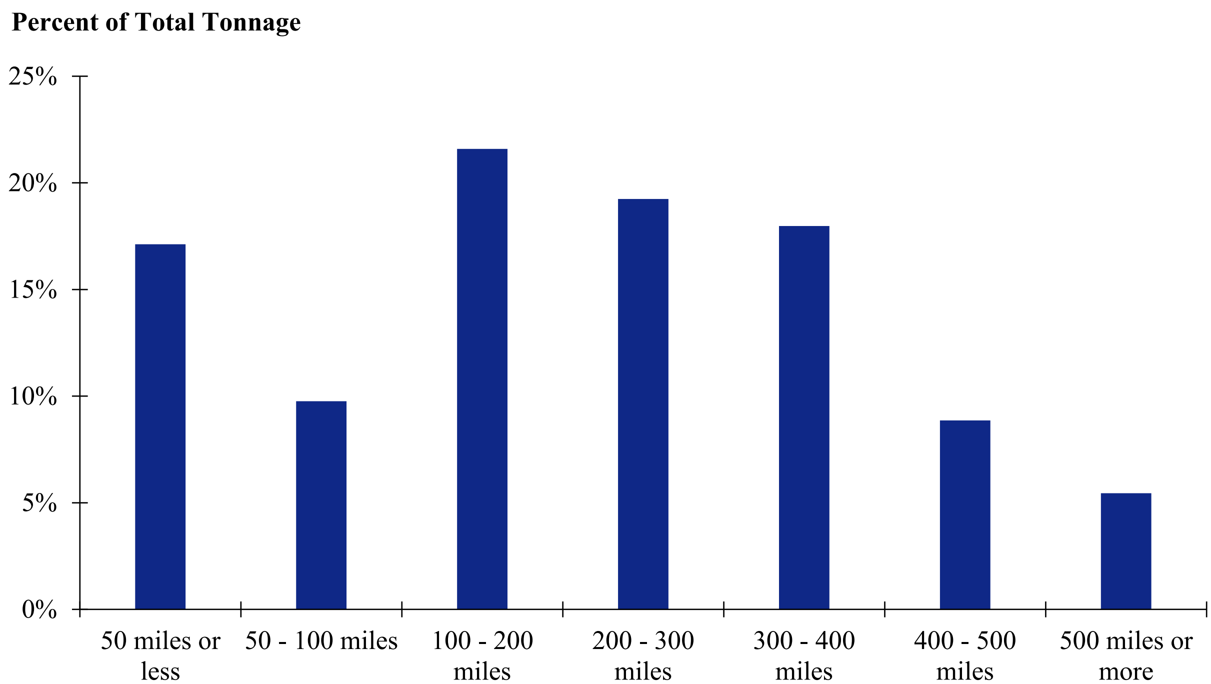

Figure 123. Bar chart. Distribution of shipment distances for fish in the Great Lakes production-consumption zone.
(Source: Federal Highway Administration.)

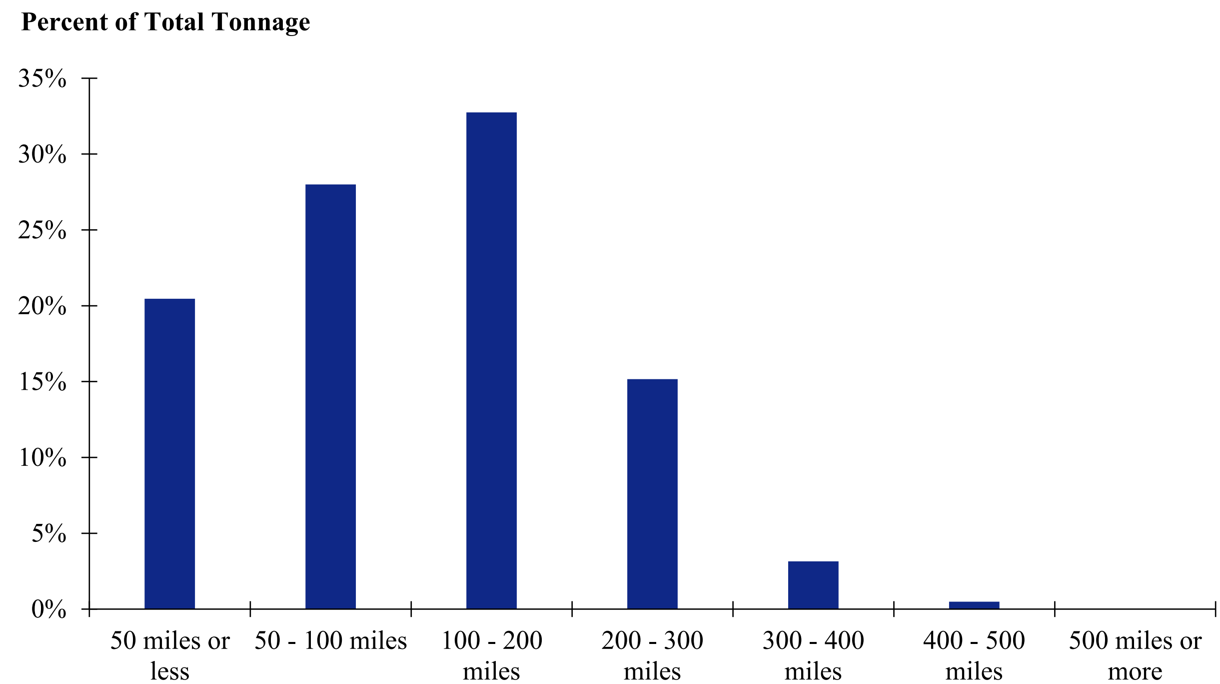

Figure 124. Bar chart. Distribution of shipment distances for fish in the Pacific Northwest production-consumption zone.
(Source: Federal Highway Administration.)

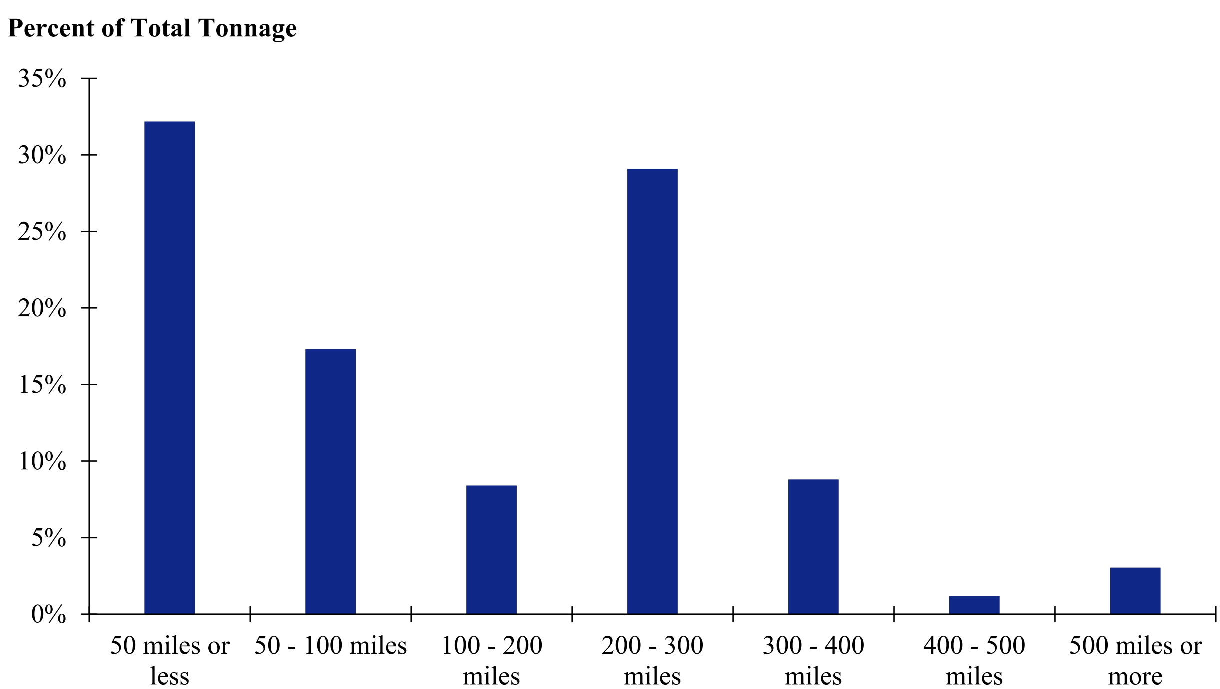

Figure 125. Bar chart. Distribution of shipment distances for fish in the California production-consumption zone.
(Source: Federal Highway Administration.)

APPENDIX C. CROSSWALK BETWEEN VEHICLE INVENTORY AND USE SURVEY COMMODITY CODES AND STANDARD CLASSIFICATION OF TRANSPORTED GOODS 2 COMMODITIES

Table 54. Crosswalk between vehicle inventory and use survey and standard classification of transported goods.

VIUS Commodity Code	VIUS Commodity Description	SCTG2
1	Live animals and fish	01
2	Animal feed or products of animal origin	04
3	Cereal grains	02
4	All other agricultural products	03
5	Basic chemicals	20
6	Fertilizers and fertilizer materials	22
7	Pharmaceutical products	21
8	All other chemical products and preparations	23
9	Alcoholic beverages	08
10	Bakery and milled grain products	06
11	Meat, seafood, and their preparations	05
12	Tobacco products	09
13	All other prepared foodstuffs	07
14	Logs and other wood in the rough	25
15	Paper or paperboard articles	28
16	Printed products	29
17	Pulp, newsprint, paper, or paperboard	27
18	Wood products	26
19	Articles of base metal	33
20	Base metal in primary or semi-finished forms	32
21	Nonmetallic mineral products	31
22	Nonpowered tools	Service, Not in FAF
23	Powered tools	Service, Not in FAF
24	Electronic and other electrical equipment	35
25	Furniture, mattresses, lamps, etc.	39
26	Machinery	34
27	Miscellaneous manufactured products	40
28	Precision instruments and apparatus	38
29	Textile, leather, and related articles	30
30	Vehicles, including parts	36
31	All other transportation equipment	37
32	Coal	15
33	Crude petroleum	16
34	Gravel or crushed stone	12
35	Metallic ores and concentrates	14
36	Monumental or building stone	10

Table 54. Crosswalk between vehicle inventory and use survey and standard classification of transported goods (continuation).

VIUS Commodity Code	**VIUS Commodity Description**	**SCTG2**
37	Natural sands	11
38	All other nonmetallic minerals	13
39	Fuel oils	18
40	Gasoline and aviation turbine fuel	17
41	Plastics and rubber	24
42	All other coal and refined petroleum products	19
43	Hazardous waste	Not in FAF
44	All other waste and scrap	41
45	Recyclable products	41
46	Mail and courier parcels	42
47	Empty shipping containers	Not in FAF
48	Passengers	Personal, Not in FAF
49	Mixed freight (for-hire carriers only)	43
50	Multiple categories	[1]
99	Products, equipment, and materials not elsewhere classified	99

(Source: Federal Highway Administration.)

[1] Multiple categories are only used as a response to the Principal Product Carried question. Tons and ton-miles are only reported for specific commodities. The Principal Product Carried limits the use of survey records.

APPENDIX D. EXAMPLE CALCULATION OF REVISED PAYLOAD FACTORS

This appendix works through, using SCTG 20, Basic Chemicals, which is Vehicle Inventory and Use Survey (VIUS) Commodity 5 as an example, the steps in chapter 12.

In the 2002 VIUS Microdata, there is a record for a tractor trailer, i.e., Combination Unit truck, where the Principal Product Carried is reported as Powered Tools, which are carried in 60 percent of its miles, but 25 percent of the miles are reported to be carrying Basic Chemicals. The weighted expanded annual miles reported for this record is 8,758,553 which means that 2,189,638.25 miles would be carrying Basic Chemicals.

For the previous payload factors, this record would NOT have contributed to the payload factors because these values were only computed for the Principal Product Carried.

That 2002 VIUS record reports an average loaded weight of 78,000 lbs. and an empty weight of 33,500 lbs. which implies that the average payload is 44,500 lbs. This also means that the annual ton-miles carrying Basic Chemicals is 48,719,451.

These are figure 70 and figure 71 in the main body of the report. For that record, the original payload factor for SCTG 20 would be 22.25 tons per truck.

By summing all records by truck size and commodity in the 2002 VIUS microdata the sum of the miles and ton-miles are as shown in table 55. Single unit (SU) trucks are Strata 3 and 4 in VIUS. Combination unit (CU) trucks are stratum 5 in VIUS. The Combination of SU and CU trucks is the sum of these three strata. Also shown in the table is the standard error for each calculation, from the standard deviation, count and means of the records. The results also can be used to compute the share of the ton-miles for SU and CU trucks.

Table 55. 2002 vehicle inventory and use survey results for standard classification of transported goods 20.

	Annual (Billions)	Standard Error
Ton-miles SU, 2002	1.19	17.6%
Miles SU, 2002	0.29	13.0%
Truck Payload Factors (TPF) SU, 2002 (tons per truck)	4.10	21.9%
Ton-miles CU, 2002	10.48	6.7%
Miles CU, 2002	0.53	10.0%
TPF CU, 2002 (tons per truck)	19.77	12.0%
Ton-miles SU and CU, 2002	11.67	12.3%
Miles SU and CU, 2002	0.83	16.0%
TPF SU and CU, 2002 (tons per truck)	14.06	20.2%
SU Share of Ton-miles, 2002	10.2%	
CU Share of Ton-miles, 2002	89.8%	

(Source: Federal Highway Administration.)

From Highway Statistics table VM-1, it is possible to determine the ratio of TOTAL annual Miles for SU and CU trucks from 2012 to 2002. By summarizing the results from Vehicle Travel Information System (VTRIS) table W-3, it is possible to determine the ratios of payload weights from 2012 to 2002. There is no source to show how these values have changed by commodity. By assuming that the ratios can be applied to every SCTG2 value, the 2012 VIUS for SCTG 20 values can be computed. The ratios from VM-1 and W-3 are shown in table 56.

Table 56. Ratio of miles and weights 2012 to 2002.

a= Ratio SU miles 2012 to 2002	1.39
b= Ratio CU miles 2012 to 2002	1.18
c= Ratio SU payload weights 2012 to 2002	1.199
d= Ratio CU payload weights 2012 to 2002	1.011

(Source: Federal Highway Administration.)

The 2012 ton-miles would be the 2002 ton-miles multiplied by the change in weight, *c* for SU trucks and *d* for CU trucks, multiplied by the change in miles, *a* for SU truck and *b* for CU trucks, where *a, b, c*, and *d*, are from table 56 and the 2002 ton-miles are from table 55. The 2012 miles would be the 2002 miles multiplied by the change in miles, *a* for SU truck and *b* for CU trucks, where *a* and *b*, are from table 56 and the 2002 miles are from table 55. The 2012 tons and ton miles are shown in table 57. The 2012 miles for SU trucks are according to figure 73. The 2012 miles for CU trucks are according to figure 74. The 2012 ton-miles for SU trucks are according to figure 75. The 2012 miles for CU trucks are according to figure 76. Also shown in table 57 is the share of ton-miles in 2012.

Table 57. 2012 ton-miles, mile and share of ton-miles.

	Result	**Calculation**
Ton-miles SU, 2012	1.94	1.39*1.18*1.19
Miles SU, 2012	0.40	1.39*0.29
Ton-miles CU, 2012	12.70	1.199*1.011*10.48
Miles CU, 2012	0.63	1.18*0.53
SU Share of Ton-miles, 2012	14%	1.94/(1.94+12.7)
CU Share of Ton-miles, 2012	86%	12.7/(1.94+12.7)
SU Share of Miles, 2012	39.2%	0.40/(0.40+0.63)
CU Share of Miles, 2012	60.8%	0.63/(0.40+ 0.63)

(Source: Federal Highway Administration.)

The payload factors for 2012 for SCTG20 would be the 2012 Ton-miles divided by the 2012 Miles. This is figure 77 for SU truck and figure 78 for CU trucks. The Combined TPF for SU and CU trucks weighted by their respective share of ton miles, is according to figure 79. Those values are shown in table 58.

Table 58. Standard classification of transported goods 20 2012 truck payload factor for single unit, combination unit and combined combination unit and single unit trucks.

Payload Factor	Result	Calculation
TPF SU,2012	4.92	1.199*4.10
TPF CU,2012	19.99	1.011*19.77
Combined CU and SU TPF,2012	14.08	0.392*1.199*4.10+0.608*1.011*19.77

(Source: Federal Highway Administration.)

APPENDIX E. QUERY FOR CONSUMER DURABLE GOODS TABLE

This appendix outlines the query entered to generate the current cost net stock of consumer durable goods results in table 5 of chapter 2. The following steps were followed after navigating to the following page on the U.S. Bureau of Economic Analysis website: https://apps.bea.gov/iTable/iTable.cfm?ReqID=10&step=1#reqid=10&step=1&isuri=1.

1. Select "View Fixed Assets interactive tables" and press the "Next Step" button.
2. Select the "SECTION 8—CONSUMER DURABLE GOODS" option.
3. From the drop-down menu, select the "Table 8.1. Current-Cost Net Stock of Consumer Durable Goods (A)" option.
4. Press the "Modify" button. On the menu that appears, select "2010 A" as the first year and "2017 A" as the last year. Then, click the "Refresh Table" button.

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