Oklahoma Freight Flows

Prepared for

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Acronyms and Abbreviations

BNSF	BNSF Railway Company
BEA	Bureau of Economic Analysis
FAF	Freight Analysis Framework
FAF^3	Freight Analysis Framework, Third Generation
FHWA	Federal Highway Administration
MKARNS	McClellan-Kerr Arkansas River Navigation System
NAICS	North American Industry Classification System
ODOT	Oklahoma Department of Transportation
OKC	Oklahoma City
PCE	passenger-car equivalent
QRFM	Quick Response Freight Manual
SCTG	Standard Classification of Transported Goods
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Code
UP	Union Pacific Railroad
VIUS	Vehicle Inventory and Use Survey

Summary

Parsons Brinckerhoff has conducted an extensive analysis of freight flows in, through, and into and out of Oklahoma. That analysis, utilizing a variety of data sources as well as original analysis of the data by Parsons Brinckerhoff (truck and inland waterway data) and IHS Global Insight (freight rail data), is contained in this report. Freight flows reflect the most recent year for which consistent and comprehensive data could be found for each freight mode. Data were extrapolated as needed to produce all maps for a consistent year (2009).[1]

The report begins with this summary section, which pictures freight flows mapped to major freight corridors, including the freight rail network, major as well as secondary truck routes, and also the McClellan-Kerr Arkansas River Navigation System (MKARNS).[2]

The results of the data collection and analysis have been summarized in a series of freight flow maps (**Figure 1** through **Figure 7**).

Overview of freight flows

A summary of total freight flow volumes, by mode, is mapped on **Figure 1**. Key points highlighted on the map are as follows:

- The largest total freight volumes, for all modes combined, occur in the north-south corridor that includes the I-35 truck corridor and the BNSF Railway (BNSF) rail corridor. Those volumes are greatest between the Texas border and Oklahoma City (OKC), where some of the volumes are dispersed in east-west directions.
- Rail freight flows are predominantly in the north-south direction.
- An important question is whether some truck flows could be captured by rail if rail capacity was enhanced.
- As shown in **Table 1**, a total of 614 million tons, nearly 70 percent of all the state's freight traffic, flows *through* Oklahoma.
- Most of Oklahoma's freight, 68 percent of total tonnage, is transported by truck (**Table 2**).

[1] Most of the data for this report are based on (the 2007) version 3.1 of the Freight Analysis Framework (FAF[3]) database, the 2009 Surface Transportation Board rail waybill sample for Oklahoma, and 2009 Ports of Catoosa and Muskogee data. The Freight Analysis Framework (FAF) integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. As FAF[3] does not provide data specifically for 2009, data for 2007 and 2015 forecasts were used to interpolate truck freight flows for 2009 thus providing common base year data for this report. FAF[3] includes significant improvements and corrections over the 2002 version 2 Freight Analysis Framework (FAF[2]). Thus, comparisons between the magnitude of freight in this report, and that described in the 2012 Oklahoma Long Range Transportation Plan (based on FAF[2] data) are not recommended.
Source: http://faf.ornl.gov/fafweb/Highlights.aspx

[2] The MKARNS is 445 river miles long and has eighteen locks and dams, creating a staircase from the Mississippi River up to Catoosa in northeast Oklahoma. The Oklahoma portion includes two public ports, Catoosa and Muskogee, and several private ports.
http://digital.library.okstate.edu/encyclopedia/entries/M/MC009.html

Table 1. Directional flows and percentages—truck, rail, and waterway freight in Oklahoma in 2009

Flow	Million tons	Percent
Inbound	73.1	8.3
Outbound	65.5	7.4
Internal	129.7	14.7
Through	614.10	69.6
Total	882.4	100.0

Sources: FAF[3], 2009 Surface Transportation Board Rail Waybill Sample, Tulsa Port of Catoosa Tonnage Comparison Report–2012, Port of Muskogee—Two Year Barge Tonnage Report–2011.

Table 2. Oklahoma freight flow by mode and direction in 2009

Mode	Million Tons					Total (percent)
	Inbound	Outbound	Internal	Through	Total	
Truck	40.0	48.1	128.1	385.1	601.3	68.1
Rail	31.7	16.0	1.6	229.0	278.3	31.5
Waterway	1.4	1.4			2.8	0.3
Total	73.1	65.5	129.7	614.1	882.4	100.0

Sources: FAF3 , 2009 Surface Transportation Board Rail Waybill Sample, Tulsa Port of Catoosa Tonnage Comparison Report–2012, Port of Muskogee—Two Year Barge Tonnage Report–2011.

Truck flows

Total annual truck freight volumes are illustrated on **Figure 2** through **Figure 5**.

- The heaviest volume truck corridor attracts trips from several facilities and extends from central Oklahoma through Tulsa to the northeast along I-44.
- The largest single truck volume corridor occurs between OKC and Tulsa, with heaviest flows in and around OKC, where the three major interstates converge.
- Along the major Interstate truck corridors, external-to-external trips (i.e., trips passing through Oklahoma without a stop) are the largest flow component. Statewide, however, internal-to-internal truck trips (i.e., trips entirely within the state) comprise the majority of truck trips, which are generally shorter in length and occur in significant measure off the interstates.

Rail flows

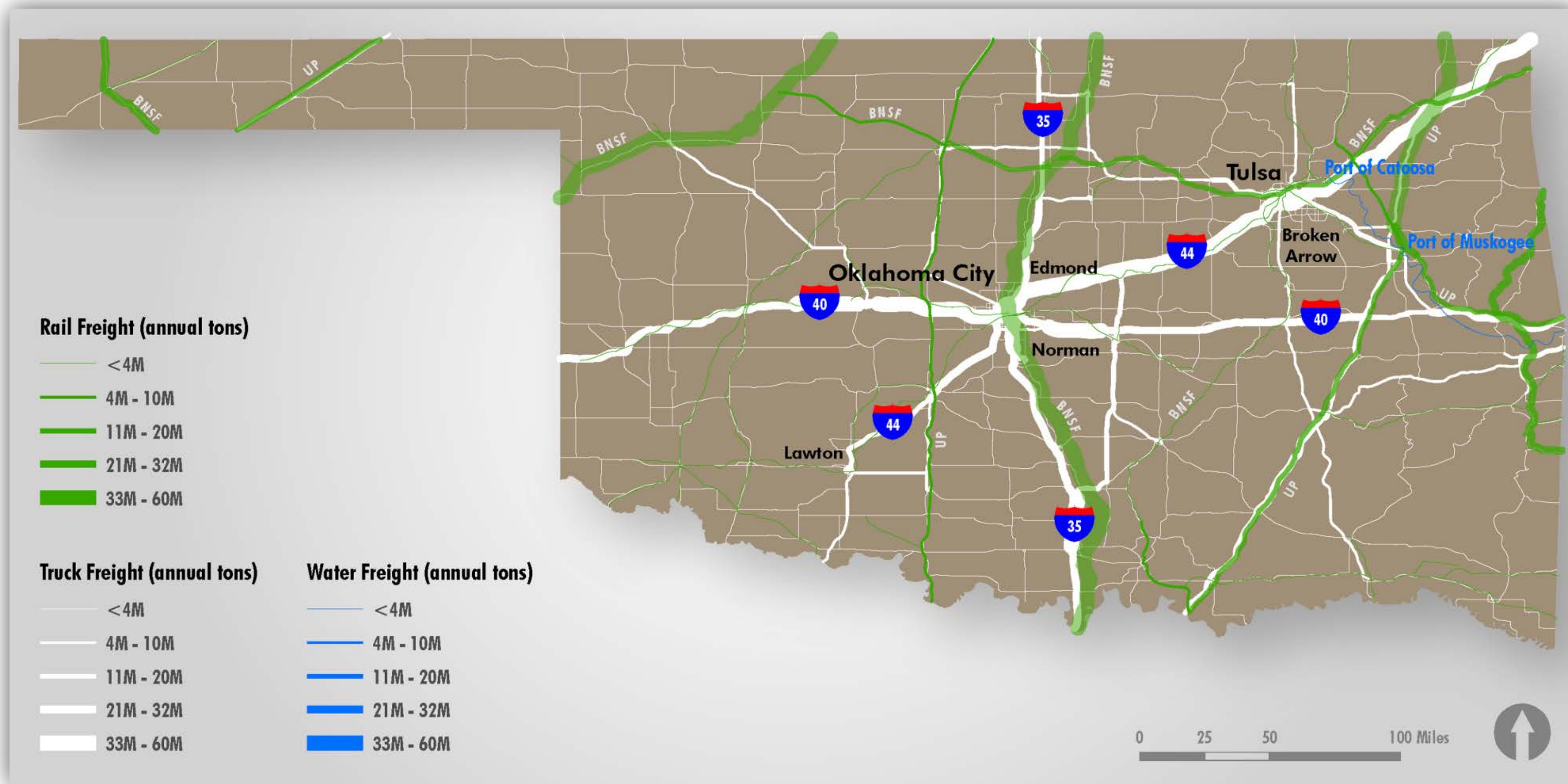
Total annual rail freight volumes are illustrated on **Figure 6**.

- Rail freight flows are predominantly in the north-south direction.
- An important question is whether some truck flows could be captured by rail if rail capacity was enhanced.

Waterway flows

Total annual waterway freight volumes are illustrated on **Figure 7**.

- MKARNS waterway volumes are small relative to other freight modes.
- Virtually all waterway flows are headed either from or to out-of-state locations; flows increase below the Port of Muskogee, the second of the two major Oklahoma ports along with the Port of Catoosa.
- Rail volumes via Union Pacific Railroad (UP) converge in substantial volumes near the Port of Muskogee, indicating some potential for rail-to-waterway intermodal activity that is currently not captured.



Sources: Truck—FHWA FAF[3]; Rail—Surface Transportation Board Waybill Data and IHS Global Insight; Water—Port of Catoosa and Port of Muskogee

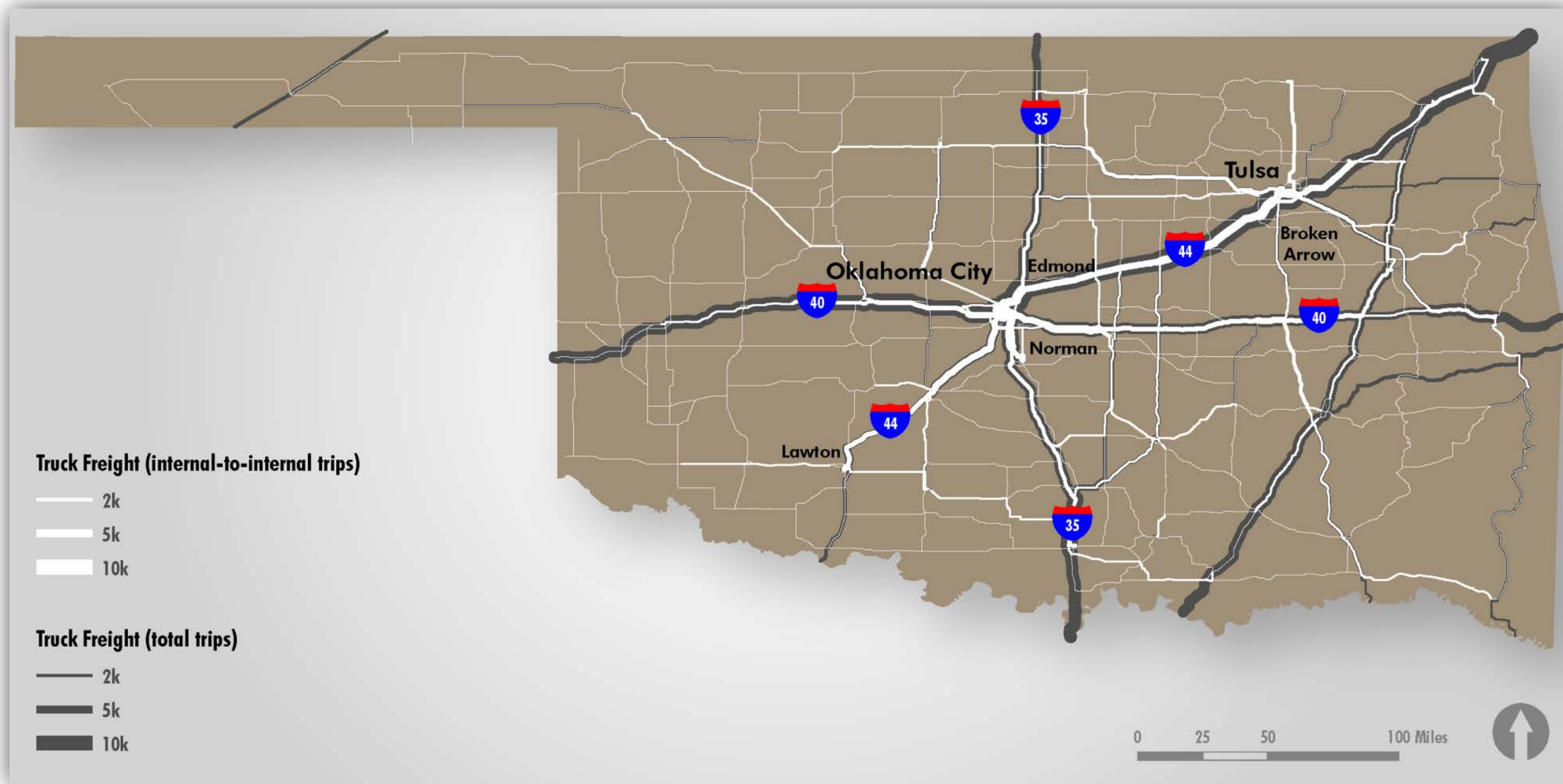
Figure 1. Total annual freight volumes, truck, rail, and waterway, 2009

Source: FHWA FAF[3]

Figure 2. Total annual freight volumes, truck, 2009

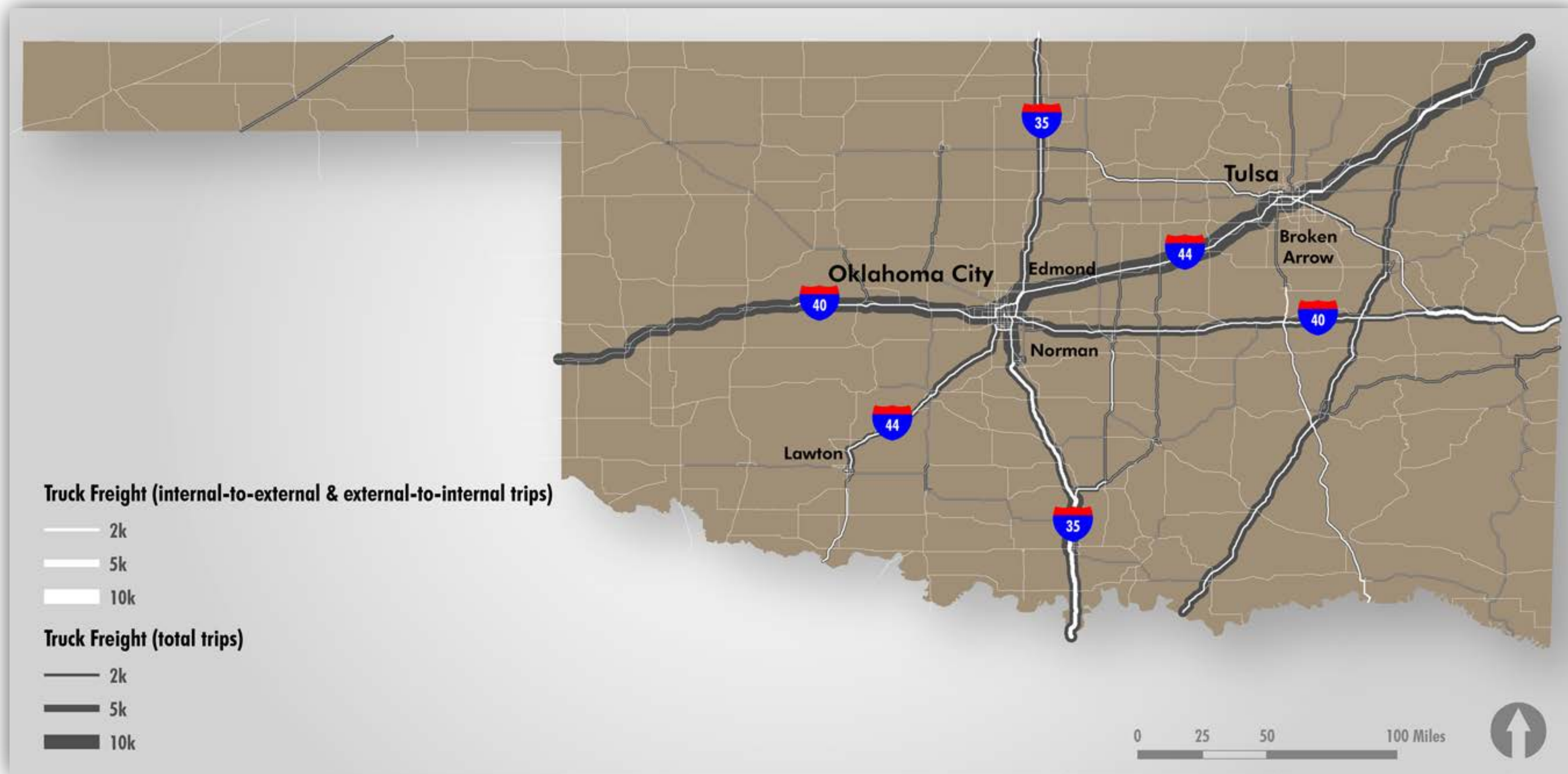
Source: FHWA FAF[3]

Figure 3. External-to-external (in white) relative to total truck trips in 2009



Source: FHWA FAF[3]

Figure 4. Internal-to-internal (in white) relative to total truck trips in 2009



Source: FHWA FAF[3]

Figure 5. Internal-to-external and external-to-internal (in white) relative to total truck trips in 2009

Sources: Surface Transportation Board Waybill Data and IHS Global Insight

Figure 6. Total annual freight volumes, rail, 2009

Sources: Port of Catoosa and Port of Muskogee

Figure 7. Total annual freight volumes, waterway, 2009

Truck Flows

Introduction

A model has been developed to analyze truck flows in and through Oklahoma. Given the geographic location of Oklahoma, a large number of external-to-external trips travel through the state (i.e., trips that have neither an origin nor a destination in Oklahoma). To capture the entire spectrum of truck traffic in Oklahoma, the model that was developed covers truck trips for the entire continental United States. The underlying basis for the analysis is commodity flow data processed in the Freight Analysis Framework (FAF). FAF is published by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation[3]. The data in this report include the truck freight flows data for 2009; truck flow forecasts are not included in this report. As FAF does not provide freight flows specifically for 2009, FAF data for 2007 and 2015 were interpolated to calculate flows for 2009.

Data

The third generation of the FAF data, called FAF^3, was released in summer 2010 and contains flow data between 123 domestic FAF regions and 8 international FAF regions. FAF flows are expressed on a ton and value basis, and are broken down into their major mode of travel. **Figure 8** shows the FAF zones in the continental United States. Oklahoma has three FAF zones that are highlighted in Figure 8: Oklahoma City Region, Tulsa Region, and Oklahoma Remainder.

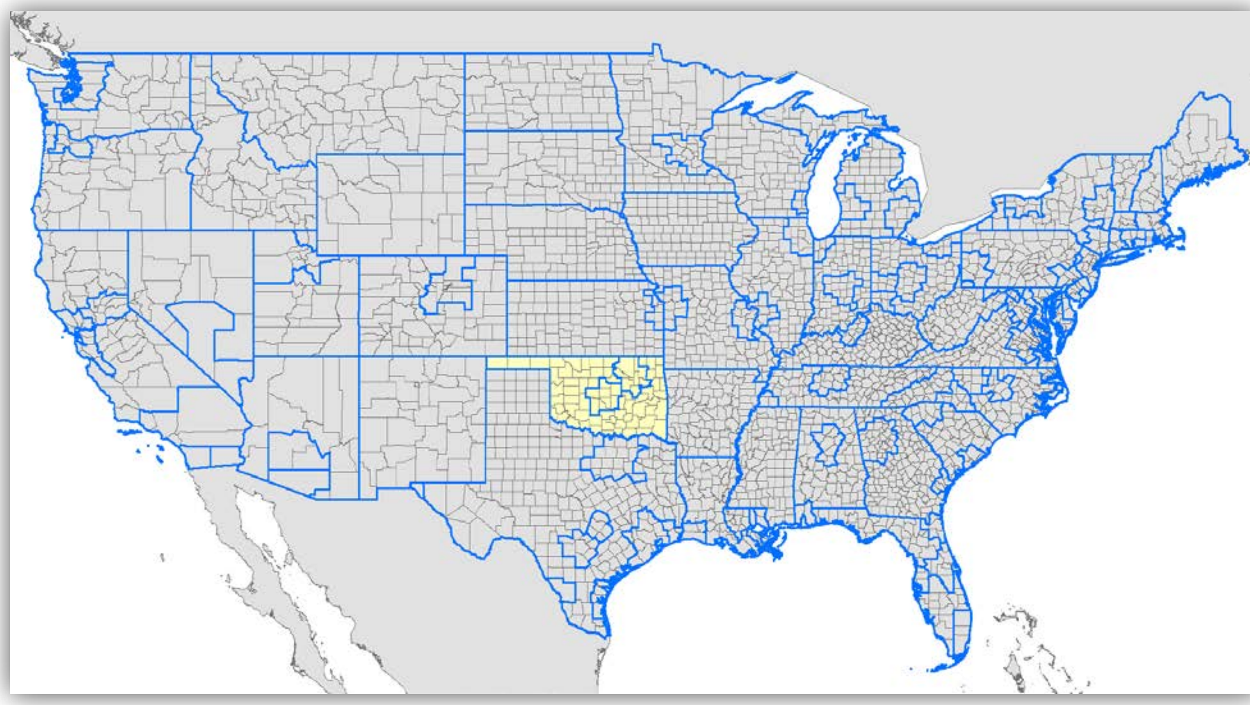


Figure 8. Oklahoma and U.S. FAF zones

[3] FAF data are available for download from the FHWA website at http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm.

FAF[3] data provide commodity flows in tons and dollars by

- FAF zones (123 domestic + 8 international global zones)
- Mode (7 types)
- Standard Classification of Transported Goods (SCTG) commodity (43 types)
- Port of entry/exit for international flows (i.e., border crossing, seaport, or airport)

The base year is 2007, and freight flow forecasts are provided for the years 2015 to 2040 in five-year intervals.

Table 3 summarizes the FAF[3] commodity flows (to, from, and within the state) by truck for Oklahoma. Flows in 1000's of tons for the year 2009 are shown. As FAF[3] does not provide data for 2009, available FAF data for 2007 and 2015 have been interpolated to derive data for the year 2009. The three parts of this table distinguish flows into Oklahoma (from all other 128 FAF zones), internal flows, and flows from Oklahoma (to all other 128 FAF zones). For convenience, flows out of Oklahoma will be called "exports," and flows into Oklahoma will be call "imports." For each of these three flow types, SCTG commodities were sorted by their relative share of all flows in that direction.

According to FAF[3], the largest import commodities, with 11 percent of all tons imported, is cereal grains (SCTG02). The most important commodity for internal flows and exports is gravel (SCTG12), a product that commonly appears as an important good when analyzing commodities by weight.

Table 3 does not show flows traveling *through* the State of Oklahoma. The FAF data only know the origin and destination of commodity flows, but not the route traveled. (The truck model described in the following section assigns flow to a network, and therefore is able to include through flows.)

The FAF data contain different modes and mode combinations. For this project, the mode "Truck" was extracted for highway assignment. In addition, multi-modal international flows were included if the domestic segment was by truck. For example, a flow from Asia to L.A./Long Beach by vessel and from L.A./Long Beach to Oklahoma City by truck is included with the domestic portion of the trip.

Further data required for the truck model include the Vehicle Inventory and Use Survey (VIUS) conducted in 2002. The U.S. Census Bureau publishes the data with survey records of trucks and their usage[4]. County-level data on population and employment by type were used for FAF[3] data disaggregation, and Oklahoma Department of Transportation (ODOT) 2009 truck counts[5] were used to validate the model.

[4] www.census.gov/svsd/www/vius/products.html
[5] Oklahoma Department of Transportation (2010): *Freight and Goods Movement Report.* December 2010.

Table 3. Summary of FAF^3 commodity flows by truck to/from/within Oklahoma in 2009

Imports to Oklahoma				Internal Flows				Exports from Oklahoma			
SCTG	Commodity	Tons (thousands)	%	SCTG	Commodity	Tons (thousands)	%	SCTG	Commodity	Tons (thousands)	%
2	Cereal grains	4,571	11	12	Gravel	25,478	20	12	Gravel	5,071	11
17	Gasoline	2,801	7	17	Gasoline	13,519	11	31	Nonmetal min. prods.	3,612	8
7	Other foodstuffs	2,705	7	2	Cereal grains	12,525	10	19	Coal not elsewhere classified	3,546	7
32	Base metals	2,315	6	31	Nonmetal min. prods.	11,490	9	2	Cereal grains	3,006	6
31	Nonmetal min. prods.	2,167	5	41	Waste/scrap	9,556	7	18	Fuel oils	2,883	6
11	Natural sands	1,881	5	18	Fuel oils	7,958	6	4	Animal feed	2,870	6
43	Mixed freight	1,856	5	19	Coal not elsewhere classified	7,541	6	5	Meat/seafood	2,237	5
41	Waste/scrap	1,815	5	11	Natural sands	5,967	5	22	Fertilizers	2,237	5
4	Animal feed	1,762	4	13	Nonmetallic minerals	5,433	4	43	Mixed freight	2,144	4
20	Basic chemicals	1,246	3	1	Live animals/fish	2,946	2	13	Nonmetallic minerals	1,885	4
33	Articles-base metal	1,224	3	7	Other foodstuffs	2,447	2	17	Gasoline	1,775	4
18	Fuel oils	1,222	3	99	Unknown	2,213	2	27	Newsprint/paper	1,372	3
1	Live animals/fish	1,068	3	4	Animal feed	2,087	2	33	Articles-base metal	1,366	3
12	Gravel	1,027	3	43	Mixed freight	2,070	2	11	Natural sands	1,289	3
19	Coal not elsewhere classified	950	2	32	Base metals	1,993	2	1	Live animals/fish	1,263	3
	Other commodities	11,405	29		Other commodities	14,865	12		Other commodities	11,498	24
	Total Imports	40,015	100		Total Internal	128,089	100		Total Exports	48,053	100
									Grand Total	216,157	

Source: FAF^3, version 3.1

Truck model design

The resolution of the FAF[3] data with 123 zones within the U.S. is too coarse to analyze freight flows for Oklahoma. Some of these zones cover entire states, such as two of Oklahoma's neighboring states, Arkansas and New Mexico. Assigning all truck flows from and to these states to a single point in these states would lead to unrealistic truck travel patterns. Therefore, a method has been developed to disaggregate freight flows from 123 FAF zones to 3,241 U.S. counties (**Figure 9**). This disaggregation process uses make/use coefficients, also called input/output coefficients, and employment data by 11 employment types. For example, SCTG25 (logs and other wood in the rough) is produced in those zones that have agriculture employment (as a proxy for forestry); this commodity is shipped to those zones that have employment in industries consuming this commodity, particularly manufacturing. The coefficients used are derived from input/output coefficients published by the Bureau of Economic Analysis (BEA).[6]

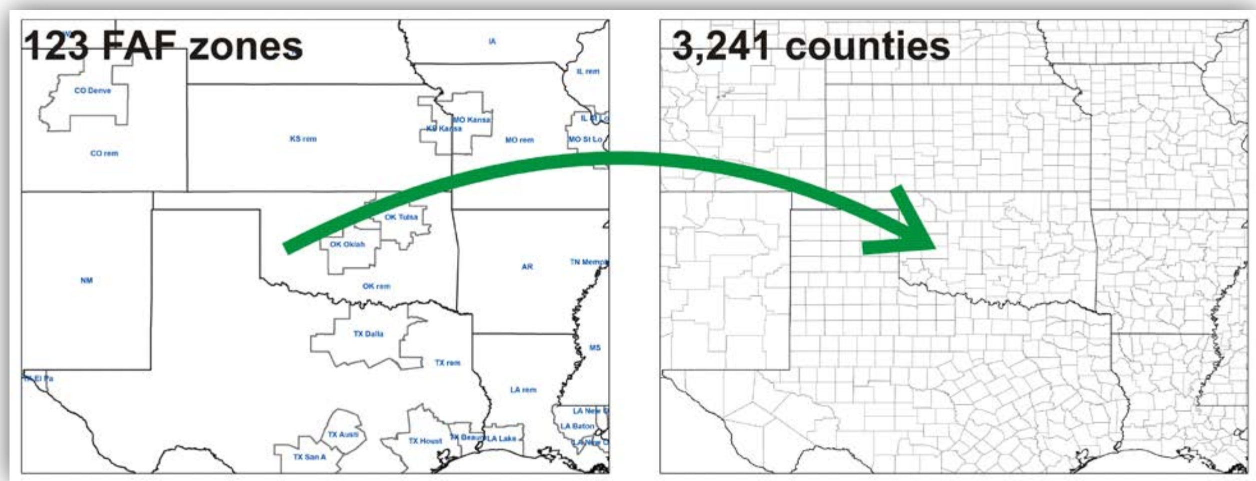


Figure 9. Disaggregation of freight flows from FAF zones to counties

[6] www.bea.gov/industry/index.htm

An overview of the truck model design is shown in **Figure 10**. (The truck model is described in detail in Appendix A) First, the FAF^3 data are disaggregated to counties across the entire United States using employment by two-digit-level North American Industry Classification System (NAICS) industry types in each county. Then, commodity flows in tons are converted into truck trips using average payload factors. Such factors describe how many goods of a certain commodity are carried by a single truck on average. As FAF data only describe the flow of goods, empty truck trips need to be added. Based on U.S. Census Bureau data, an empty-truck rate of 19 percent is added to all flows. Finally, the truck trips are assigned to a national network to analyze truck flows through Oklahoma.

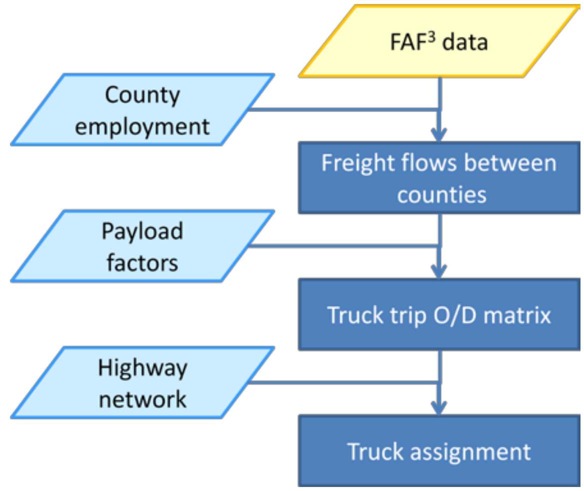


Figure 10. Model design of the regional truck model

Two truck types are distinguished for the Oklahoma truck flow analysis: single-unit trucks (FHWA vehicle classes 5 to 7) and multi-unit trucks (FHWA vehicle classes 8 to 14). While single-unit trucks tend to serve shorter distances, multi-unit trucks are predominately used for long-distance trucks. Both truck types tend to serve different origins and destinations. Finally, this distinction is relevant for the assignment. Multi-unit trucks take up more space on the highway system, and they need more time to accelerate. The assignment accounts for these differences between single-unit and multi-unit trucks by using different passenger-car equivalent (PCE) factors. Commonly, single-unit trucks are assigned with a PCE factor of 2, meaning that a truck of this type in contributing twice as much to congestion as a passenger car. Multi-unit trucks often are assigned a PCE factor of 2.5.

A comprehensive description of the truck model specification is provided in Appendix A.

Results

Total corridor truck flows

Figure 11 shows the assigned truck volumes on the U.S. network. Major freight axes, such as the San Francisco Bay Area to the L.A. Basin, Dallas/Fort Worth to New York, or Chicago to Atlanta, are noticeable. Trucks traveling through Oklahoma on I-35, I-40, and I-44 are modeled with their true origins and destinations outside of the state.

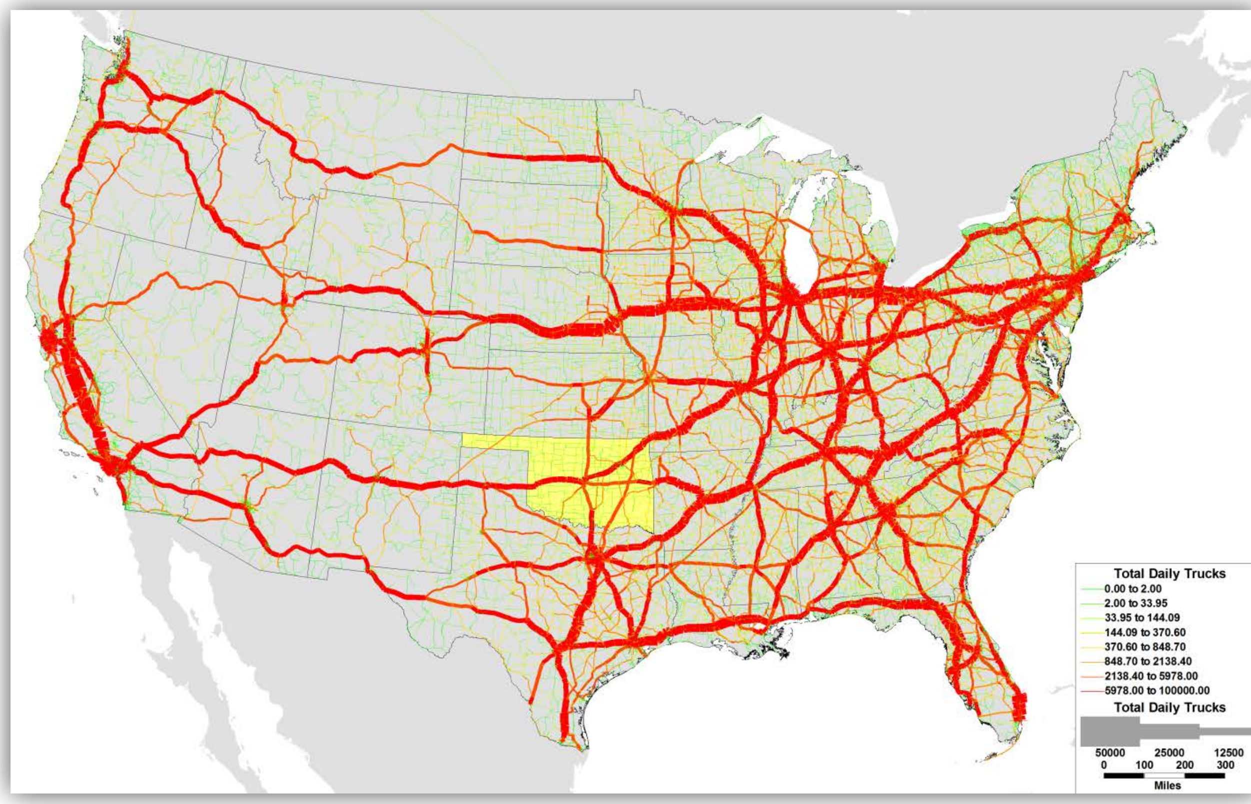


Figure 11. Daily long-distance truck flows on the U.S. network in 2009

Figure 12 shows the State of Oklahoma in greater detail. In addition to the interstate highways in Oklahoma, US 69, US 54, and US 412 are shown to carry large truck volumes.

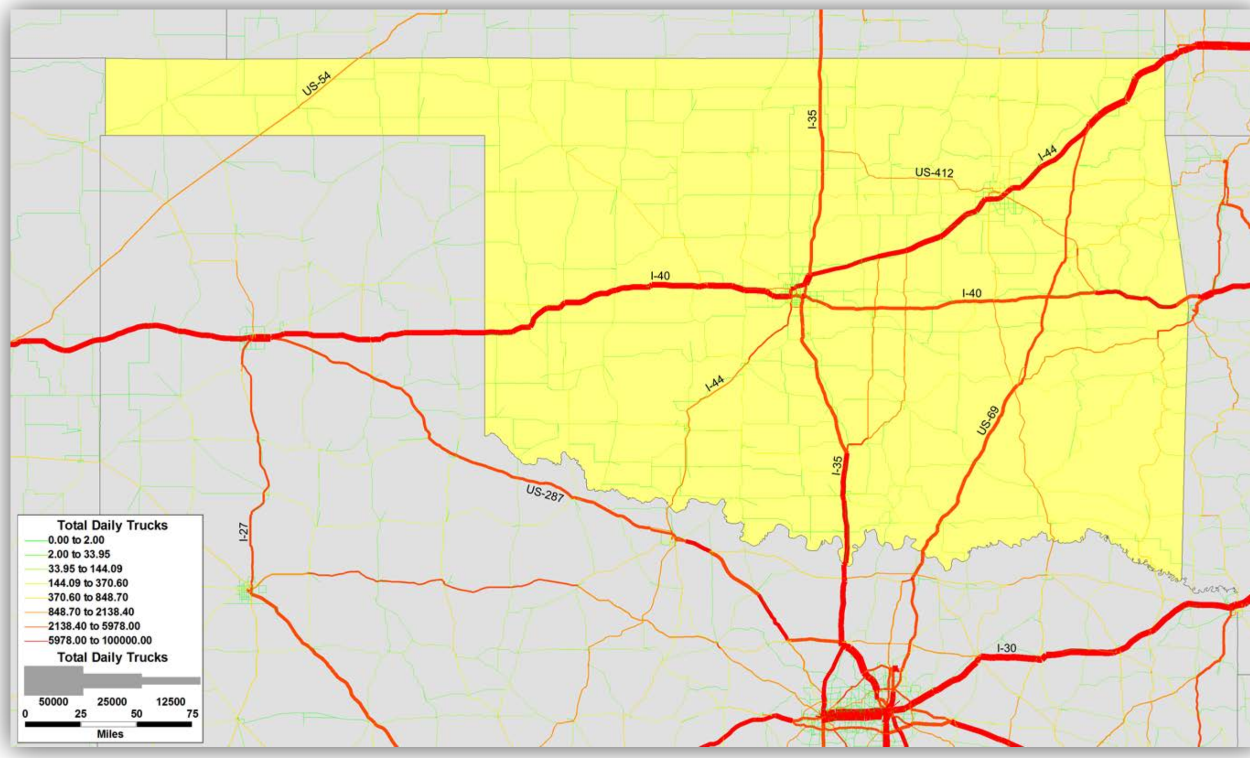


Figure 12. Daily long-distance truck flows in Oklahoma in 2009

Regional flows

Results of the Oklahoma Truck Model have been summarized at the regional level[7] to show the bigger picture and at the state level to identify major flows within Oklahoma. The commodity flows were first summarized by regions to obtain a broader picture of truck flows. A halo region around the State of Oklahoma was defined to capture medium-distance flows. This region includes the states of Colorado, Kansas, Missouri, Arkansas, Texas, and New Mexico. Long-haul truck trips traveling beyond the halo are summarized by five national regions, which have been defined mostly in line with BEA economic regions (**Figure 13**).

The state of Oklahoma was subdivided into three regions: Oklahoma City, Tulsa, and the remainder of the state. The definitions of these internal regions reflect the FAF regions in Oklahoma. Although it was not required to adhere to FAF regions after disaggregating FAF-region-to-FAF-region flows into county-to-county flows, it is assumed that FAF regions represent regions of economic activity reasonably well. **Figure 14** shows the definition of the three Oklahoma regions.

[7] For the purposes of this report, a region is a group of states or (in the State of Oklahoma) a part of a state.

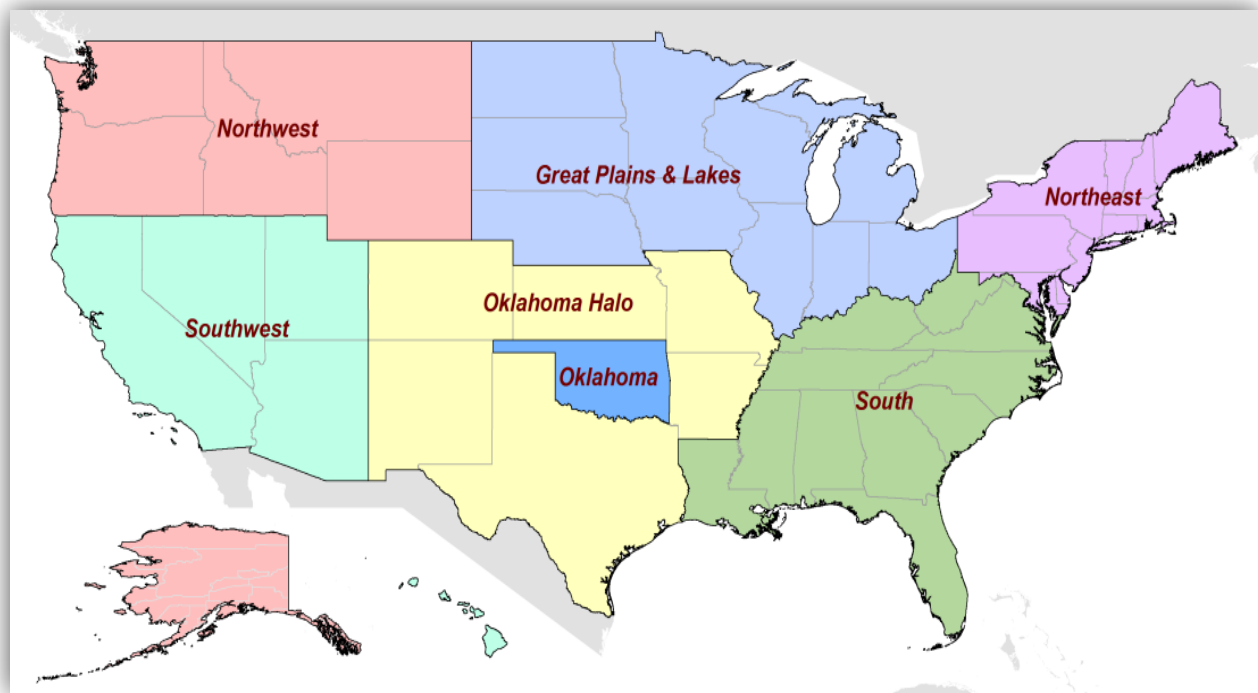


Figure 13. U.S. regions for commodity flow summary

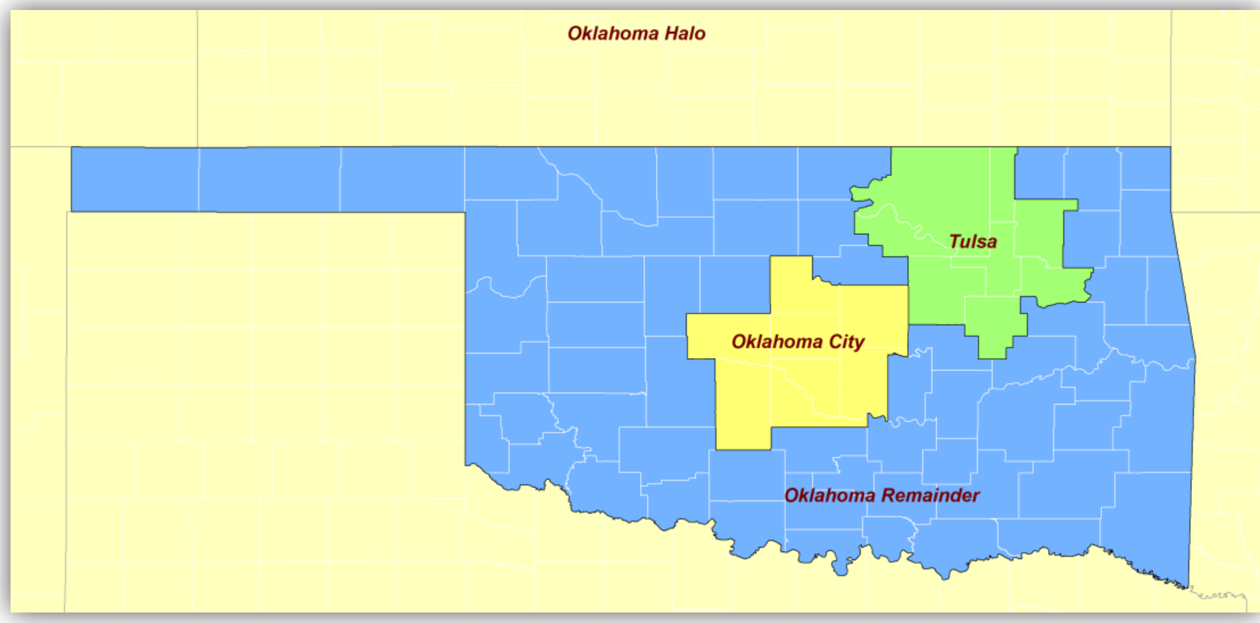


Figure 14. Summary of commodity flow for Oklahoma regions

Table 4 summarizes daily truck flows by region for 2009. Only flows that travel at least partly through Oklahoma are shown. For example, the field from Southwest region to Northwest region is empty as there are no truck trips from the Southwest region to the Northwest region that would travel through Oklahoma. Yellow cells show internal-to-internal trips for the State of Oklahoma. As expected, the largest volumes are within Oklahoma City and Tulsa. Green cells show internal-to-external or external-to-internal flows. Blue cells show through truck trips.

Table 4. Daily truck flows through Oklahoma by region in 2009

from \ to		Internal destination			External destination					
		Oklahoma City	Tulsa	Oklahoma Remainder	Oklahoma Halo	Southwest	Northwest	Great Plains and Lakes	Northeast	South
Internal origin	Oklahoma City	18,204	672	2,008	626	13	8	97	23	219
	Tulsa	1,237	17,166	3,728	1,053	46	17	118	53	232
	Oklahoma Remainder	5,663	1,267	15,758	3,584	30	15	144	65	581
External origin	Oklahoma Halo	683	1,054	1,980	9,040	618	236	2,106	106	257
	Southwest	13	12	21	470			734	1,508	1,161
	Northwest	12	17	14	178					113
	Great Plains and Lakes	154	120	163	4,503	826				1
	Northeast	71	48	111	83	731				
	South	242	315	325	271	940	75	4		

yellow = internal-to-internal trips green = internal-to-external or external-to-internal trips blue = through truck trips

Source: Oklahoma Truck Model Output, based on FAF^3, version 3.1

Oklahoma's largest trading partner is the Oklahoma Halo, mostly due to its proximity. For external-to-external flows, which are colored in blue in Table 4, Halo-to-Halo is the most important truck flow. Note that only truck trips that travel through Oklahoma are included in the blue-colored cells. There are many more truck trips that travel in the Oklahoma Halo, but only 9,040 of those use Oklahoma roads for some portion of their trip. The other larger contributor of through trips through Oklahoma is truck trips from the Great Plains and Lakes to the Oklahoma Halo and vice versa. To a large degree, these are trips from the Chicago area to Texas.

Table 5 summarizes the data provided in Table 4 and shows truck trips into Oklahoma and out of Oklahoma as well as internal and through truck trips (the percent share of this flow direction is given in parentheses). Almost two-thirds of all trucks traveling on the Oklahoma highway network have their origin and their destination within the state. Nearly one quarter (24 percent) of all trucks traveling in Oklahoma are involved in through trips.

Table 5. Daily truck flows through Oklahoma by state in 2009

to / from	Internal Oklahoma destination		External Oklahoma destination		Total destinations	
Internal OK origin	65,703	(64%)	6,924	(7%)	72,627	(71%)
External OK origin	5,356	(5%)	23,961	(24%)	29,317	(29%)
Total origins	71,059	(70%)	30,885	(30%)	101,944	(100%)

Percents do not necessarily sum to totals due to rounding.
yellow = internal-to-internal trips
green = internal-to-external or external-to-internal trips
blue = through truck trips
Source: Oklahoma Truck Model Output, based on FAF[3], Version 3.1

In-state flows

The Oklahoma Department of Transportation has eight field divisions (**Figure 15**). The daily truck flows within and among these field divisions and the rest of the world are shown in **Table 6**. The Oklahoma truck flows were derived from the more detailed county-level truck assignments. Flows in Table 6 exclude through trucks, but are otherwise equal to the flows shown in Table 4 and Table 5.

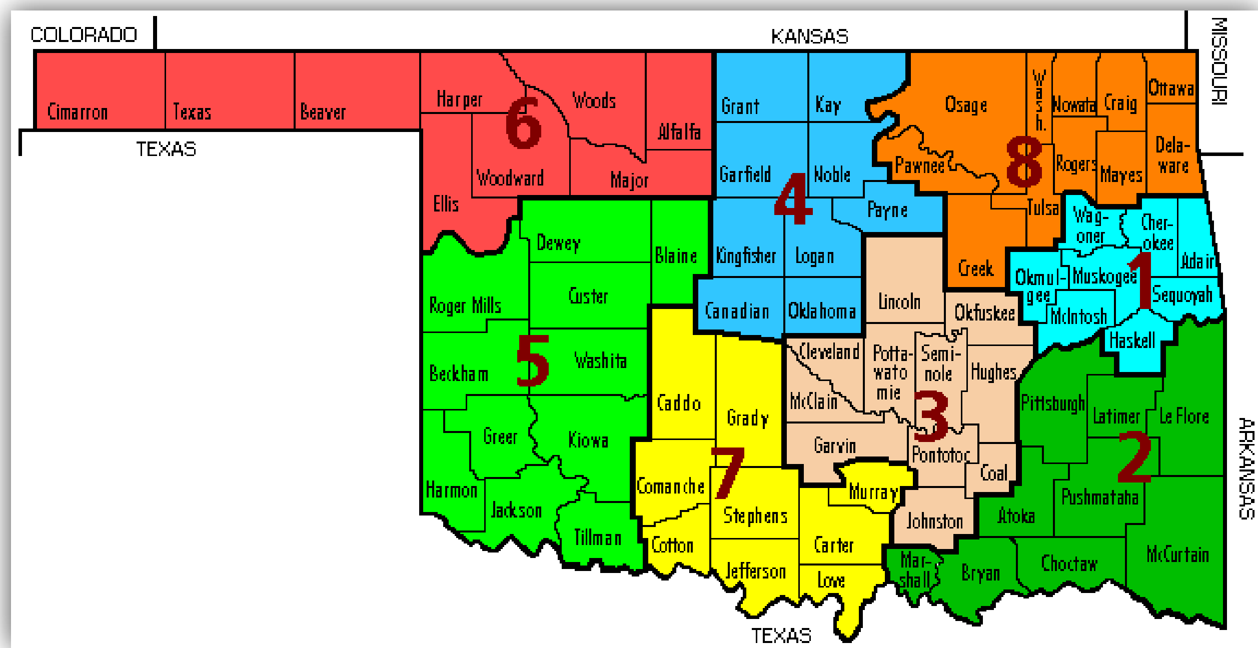


Figure 15. ODOT field divisions and counties

Table 6. Daily truck flows between Oklahoma field divisions in 2009

from \ to		Field Division 1	2	3	4	5	6	7	8	Outside Oklahoma	Total truck trip attraction
Field Division	1	508	358	311	958	164	101	394	1,026	648	**4,468**
	2	345	446	360	965	176	107	462	345	687	**3,893**
	3	225	277	864	3,276	146	82	472	348	565	**6,255**
	4	581	587	3,105	14,043	400	246	1,284	1,117	1,617	**22,980**
	5	158	176	200	667	190	84	315	189	395	**2,374**
	6	97	107	112	387	84	65	161	116	243	**1,372**
	7	370	452	603	1,946	307	157	999	450	925	**6,209**
	8	1,437	670	688	2,245	364	222	881	16,728	1,846	**25,081**
Outside Oklahoma		412	402	435	1,440	233	144	552	1,740		
Total truck trip attraction		**4,133**	**3,475**	**6,678**	**25,927**	**2,064**	**1,208**	**5,520**	**22,059**		

Source: Oklahoma Truck Model Output, based on FAF[3], Version 3.1

The Oklahoma truck flows are shown graphically in **Figure 16.** Each line combines a two-way flow (A to B plus B to A). The largest inter-division flows can be found between Divisions 3 and 4, as the two cover Oklahoma City. The next biggest flow is between Divisions 4 and 8, connecting Oklahoma City with Tulsa.

The flows between each division and anywhere else are shown as a single line even though these flows travel to many different destinations. The 3,057 daily trucks from Division 4 to anywhere else travel to many different destinations, such as Kansas, Arkansas, Texas, and New Mexico. To keep the number of lines readable, import and export flows were aggregated to a single line. Therefore, the lines do not indicate directionality.

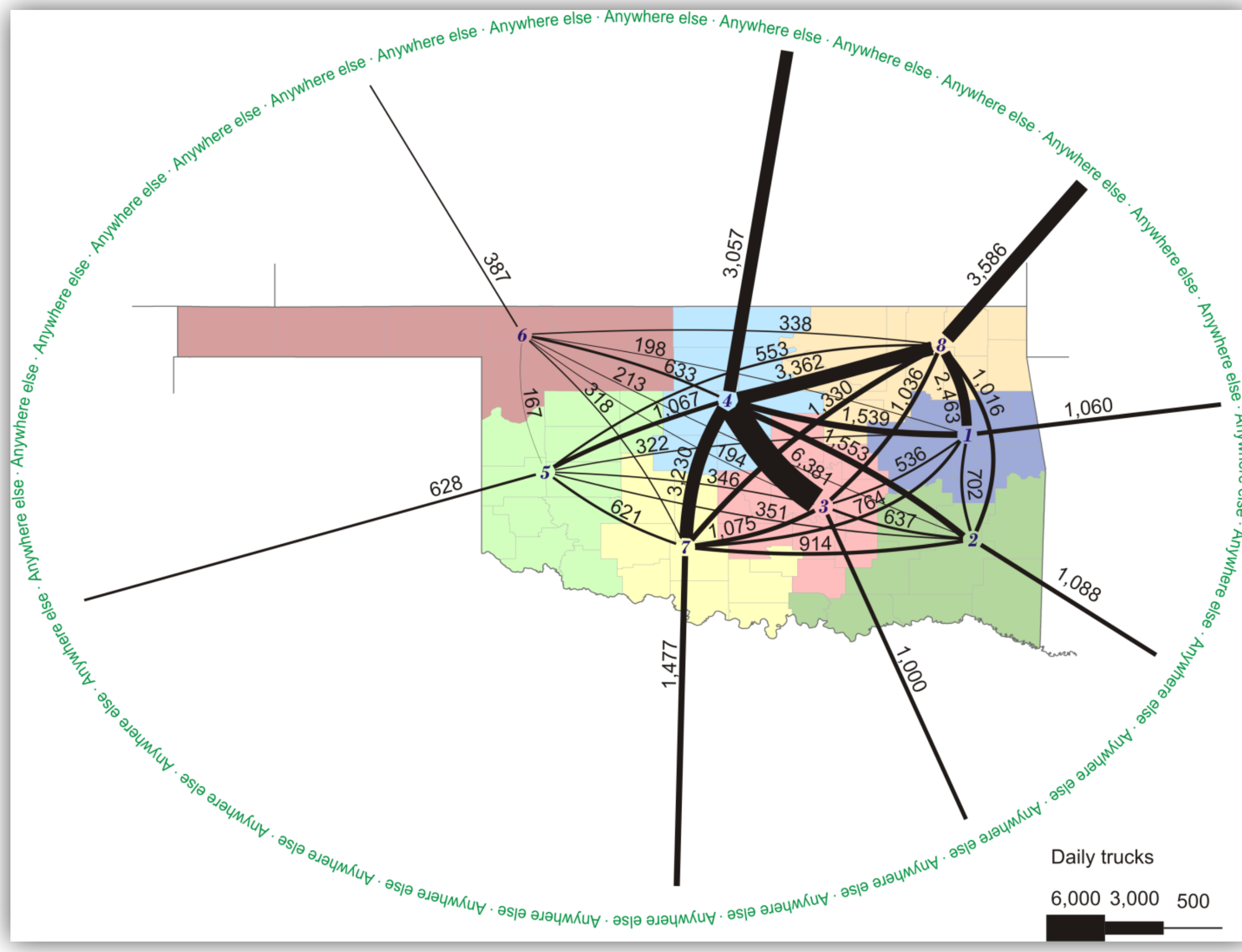


Figure 16. Daily truck flows between Oklahoma field divisions in 2009

Corridor truck volumes by origin—destination pattern

While parts of the Oklahoma road network are used primarily for internal-to-internal trips (i.e., trips that have both their origin and their destination within the State of Oklahoma), other parts of the network are mostly used by external-to-external trips, or trips that have neither their origin nor their destination within Oklahoma. The model has been used to differentiate these flows by defining different vehicle classes not only by truck type (single-unit and multi-unit trucks) but also by flow direction.

Three flow directions are distinguished:

- Internal-to-internal trips—both origin and destination are located within Oklahoma
- Internal-to-external (outbound) and external-to-internal (inbound) trips—one trip end is located within Oklahoma and one trip end is located outside of Oklahoma
- External-to-external trips (through)—both origin and destination are located outside of Oklahoma

In the following maps, single-unit trucks and multi-unit trucks have been combined to expose different patterns by flow direction.

Internal, outbound, and inbound truck trips

Figure 17 shows in gray the volume of total daily truck traffic. Red lines show the volume of truck traffic with both origin and destination within Oklahoma (internal-to-internal). The scale of all trucks in gray and internal-to-internal trucks in red is set to be equal, allowing for a comparison between internal-to-internal truck volumes and total volumes. A few very thin red lines appear outside of Oklahoma, as the shortest path from the panhandle to southern parts of the state leads through Texas.

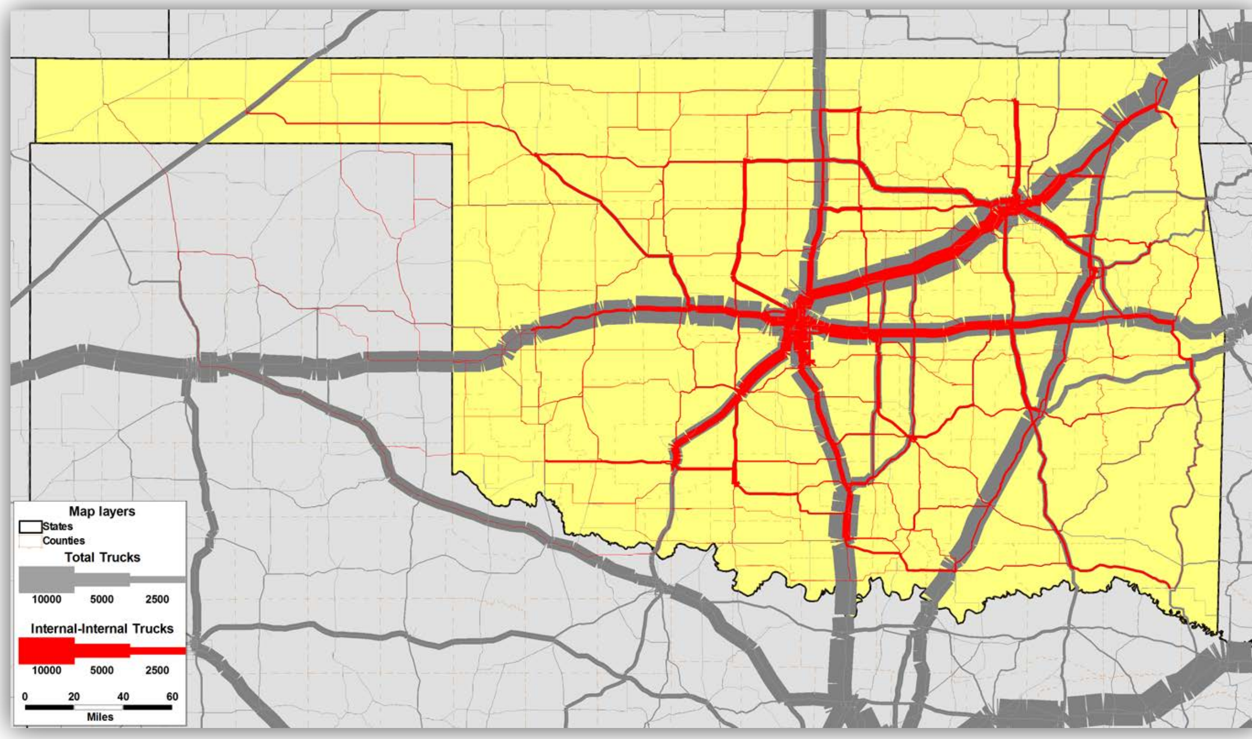


Figure 17. Internal-to-internal (in red) in relation to total truck trips in 2009, average daily

Figure 18 shows the share of internal-to-external plus external-to-internal trucks trips in comparison to all truck trips. These are truck trips that have one trip end outside of Oklahoma and one trip end within. Again, the scale is set equal for total traffic and internal-to-external plus external-to-internal traffic to make flow volumes comparable. In comparison to total traffic, internal-to-external and external-to-internal trips comprise a relatively small portion. internal-to-external and external-to-internal trips tend to connect to locations east and south of Oklahoma, and to a lesser extend north and west of Oklahoma. The Dallas/Fort Worth area is a generator and attractor for many trips connecting to Oklahoma. Approximately one-third (32 percent) of all truck traffic tonnage in Oklahoma is represented by truck shipments inbound, outbound, or within the State (Table 3).

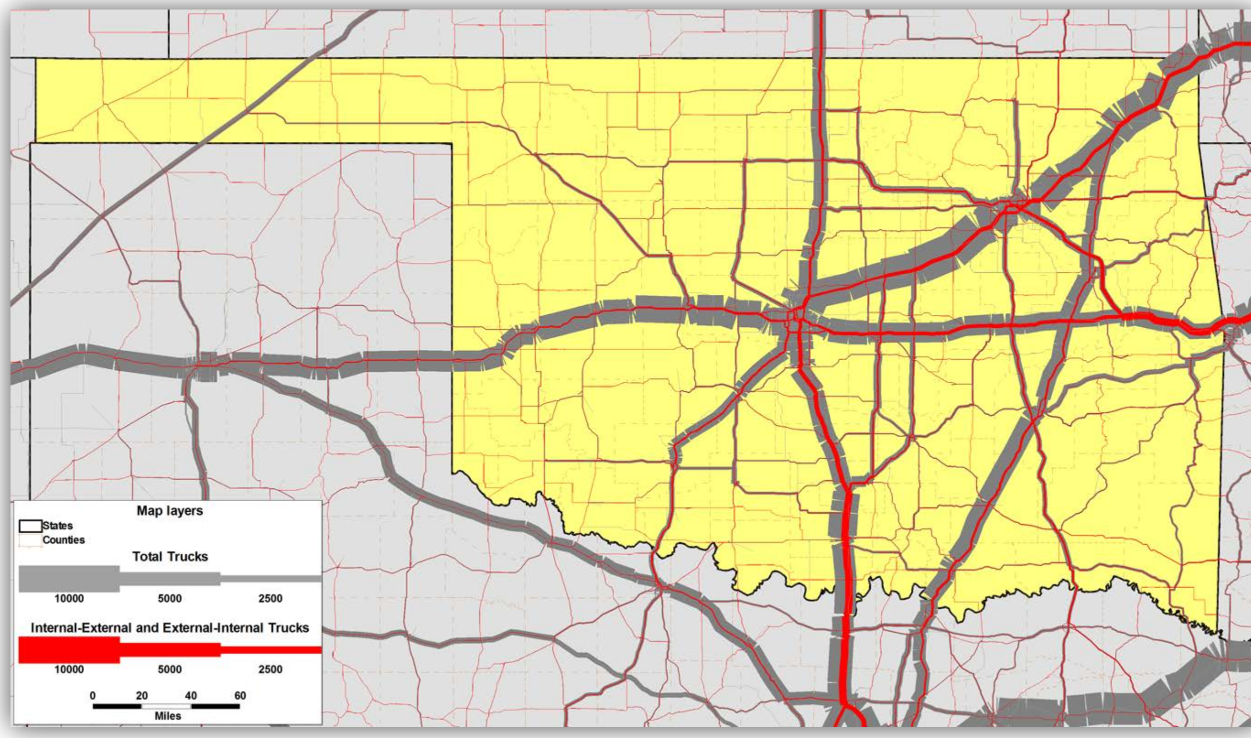


Figure 18. Internal-to-external plus external-to-internal (in red) in relation to total truck trips in 2009, average daily

Truck trips through Oklahoma

Figure 19 shows the same plot for external-to-external, or E-E, trips. Long-distance truck trips traveling through Oklahoma mostly use Interstate highways. Minor arterials, in contrast, are mostly used by truck trips that have at least one trip end within the state. The majority of truck traffic In Oklahoma (68 percent of all truck tonnage) is through transport.

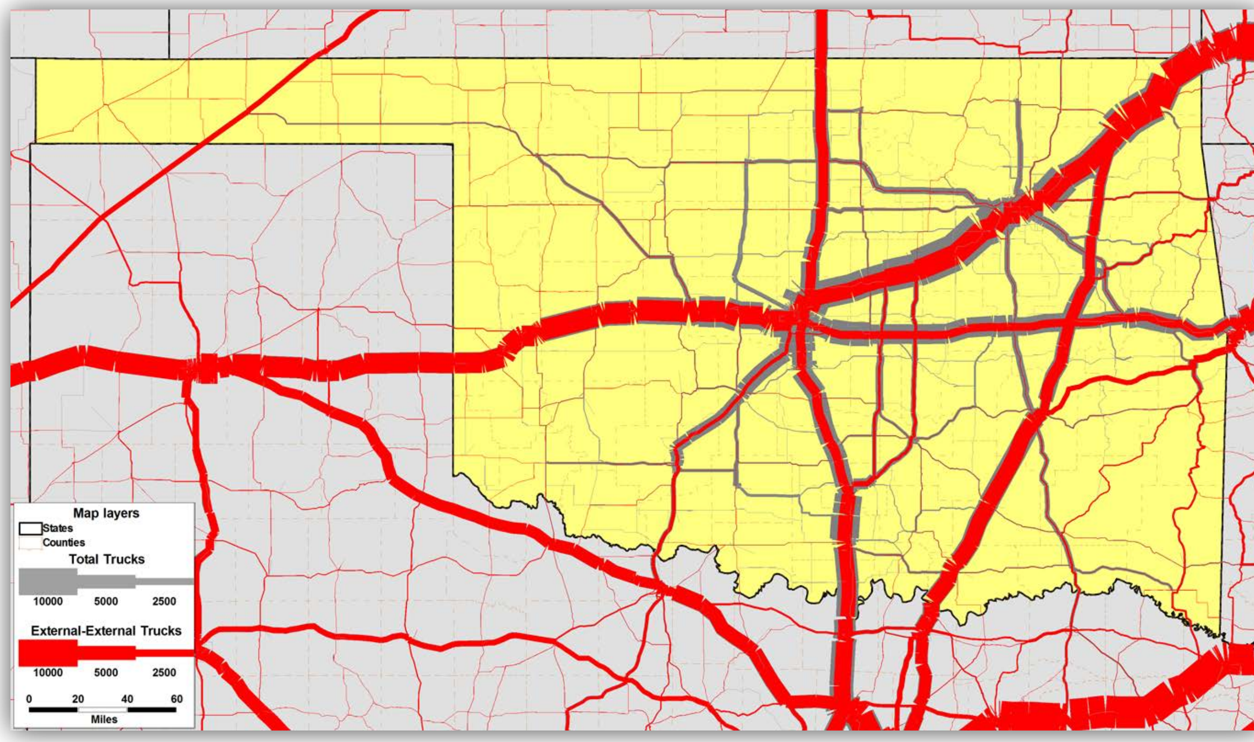


Figure 19. External-to-external (in red) in relation to total truck trips in 2009, average daily

Additional analysis of commodities traveling through Oklahoma

The truck model converts commodity flows into truck trips before assigning these to the national highway network. While this step is important to ensure that different commodities may be grouped on a single truck, it hides which commodities are traveling through the State of Oklahoma after the assignment of truck trips to the network. It is possible to unambiguously identify from the raw FAF^3 data, which commodities travel into the state (external-to-internal), out the state (internal-to-external) and within the state (internal-to-internal), as shown in Table 3. However, because the routing is not given by FAF^3 data, it is impossible to extract through trips (external-to-external) without assigning flows to a network. To represent the congestion effect and to ensure that different commodities may be grouped on a single truck, it is necessary to convert commodity flows into truck trips.

To provide information about which commodities are traveling through the State of Oklahoma, 43 SCTG commodities where aggregated into 20 commodity groups, as shown in **Table 7**. This definition was mostly done based on the truck type that is likely to carry a certain commodity. Some commodities, such as life animals and petroleum, would never be carried on the same truck and they were kept separate. Other commodities, such as food and alcoholic beverages, are often combined in single truck loads, making it logical to merge these commodities in one commodity group. The average payload factor (i.e., how many pounds of a commodity are carried on a single truck on the average) was also taken into account when forming commodity groups, ensuring that only commodities with comparable payload factors were combined in one group. The last column of Table 7 shows the total freight volume in million tons traveling in the US in the FAF^3 base year 2007. These numbers were not used in the subsequent analysis (hence they were not interpolated to this report's base year 2009), but rather helped to identify the importance of a given commodity when defining these 20 commodity groups. This grouping required some heuristic judgment on whether commodities where similar enough to be grouped and whether their quantity nationwide justified a separate class.

For this analysis, the model that processes the FAF^3 data was restructured to write out truck flows by these 20 commodity classes. For all other truck flow analyses shown in this report, the model wrote out only two trip tables (with 3,241 counties times 3,241 counties) for the two truck types single-unit and multi-unit trucks. For this specific analysis, the model writes out 20 truck trip tables for 20 commodities groups.

The 20 truck trip tables were fed into a subarea analysis in TransCAD. The subarea analysis allows storing all trips that cross the Oklahoma border, and thereby makes it possible to extract through trips. By distinguishing 20 truck types that carry certain commodities, it is possible to trace back which commodities crossed the Oklahoma border, without sacrificing the equilibrium traffic assignment that is sensitive to congestion in metropolitan areas.

Table 8 summarizes truck trips traveling through the State of Oklahoma (external-to-external) in 2009 by commodity group, sorted by volume of tons carried. The column "Total Trucks" shows trucks that travelled through Oklahoma in the assignment. As an empty-truck rate of 19.4 percent was added globally, the column "Loaded Trucks" shows only trucks that were carrying commodities. Using the average payload factors of every commodity group, the number of tons travelling through Oklahoma by commodity group was calculated. The total number of through trucks (23,509 trucks) closely resembles the blue number (23,961 trucks) in Table 5, confirming consistency across the two assignments. The two numbers do not match exactly as different truck classifications result in slightly different levels of congestion, which in turn affects traffic volumes to some extent.

Table 7. Grouping of commodities

SCTG	Commodity	Group	Truck type	Payload	US Truck Tons 2007 (millions)
1	Live animals/fish	a	Livestock	24,492	106,275
2	Cereal grains	b1	Bulk for food, medium	27,945	1,207,263
3	Other agricultural products	b2	Bulk for food, heavy	22,140	364,487
4	Animal feed			22,967	229,774
5	Meat/seafood	c	Reefer	30,691	108,171
6	Milled grain products	d1	Van, light	11,831	122,235
7	Other foodstuffs	d2	Van, heavy	25,926	487,249
8	Alcoholic beverages			20,573	121,747
9	Tobacco products			25,168	4,496
10	Building stone	e	Flatbed with lift	25,429	55,466
11	Natural sands	f	Bulk	29,501	527,822
12	Gravel			30,840	1,939,431
13	Non-metallic minerals			29,101	289,045
14	Metallic ores			39,464	39,123
15	Coal			43,866	267,722
31	Non-metallic mineral products			31,044	1,311,295
16	Crude petroleum	g1	Tank, heavy	28,007	4,613
18	Fuel oils			23,442	369,735
19	Coal products not elsewhere classified			18,608	457,693
17	Gasoline	g2	Tank, medium	48,686	589,187
20	Basic chemicals	h	Van for chemicals	29,391	246,626
22	Fertilizers			19,833	158,979
23	Chemical products			24,432	130,671
21	Pharmaceuticals	i1	Van for consumer goods, non-food, heavy	10,260	16,572
29	Printed products			11,024	49,646
35	Electronics			13,821	64,199
39	Furniture			14,103	45,251
40	Miscellaneous manufactured products			16,462	98,649
43	Mixed freight			11,826	334,651
27	Newsprint/paper	i2	Van for consumer goods, non-food, medium	33,046	115,872
28	Paper articles			26,282	93,613
30	Textiles/leather			20,608	57,305
25	Logs	j	Logging	35,073	506,984
32	Base metals	k1	Flatbed, medium	24,458	335,388
33	Articles-base metal			14,395	181,619
34	Machinery	k2	Flatbed, heavy	6,064	171,184
36	Motorized vehicles	l1	Automobile, heavy	15,690	154,291
37	Transport equipment	l2	Automobile, medium	34,282	5,888
41	Waste/scrap	m	Trash truck	29,113	1,249,162
24	Plastics/rubber	n	Van for non-consumption products	19,324	159,913
26	Wood products			18,494	355,706
38	Precision instruments			9,024	4,958

Source: Classification developed for Oklahoma Freight Flows Study, Payload factors and tons based on FAF^3, version 3.1

Table 8: Summary of daily truck trips through Oklahoma in 2009

Commodity Group	Total Trucks	Loaded Trucks	Payload Factor	Approximate tons	SCTG Commodities
f	1,987	1,601	33,969	54,401,000	Natural sands, Metallic ores, Gravel, Coal, Non-metallic minerals, Non-metallic mineral products
i1	4,253	3,428	12,916	44,274,000	Pharmaceuticals, Electronics, Printed products, Furniture, Mixed freight, Miscellaneous manufactured products
k1	2,394	1,930	19,427	37,485,000	Base metals, Articles-base metal
d2	1,849	1,490	23,889	35,595,000	Other foodstuffs, Alcoholic beverages, Tobacco products
n	2,629	2,119	15,614	33,082,000	Plastics/rubber, Wood products, Precision instruments
h	1,645	1,326	24,552	32,552,000	Basic chemicals, Fertilizers, Chemical products
i2	1,132	912	26,645	24,303,000	Newsprint/paper, Paper articles, Textiles/leather
b2	1,255	1,012	22,554	22,814,000	Animal feed, Other agricultural products
m	771	622	29,113	18,096,000	Waste/scrap
l1	1,374	1,108	15,690	17,380,000	Motorized vehicles
c	614	495	30,691	15,198,000	Meat/seafood
g1	717	578	23,352	13,504,000	Crude petroleum, Fuel oils, Coal products not elsewhere classified
d1	1,313	1,058	11,831	12,521,000	Milled grain products
b1	464	374	27,945	10,442,000	Cereal grains
k2	753	607	6,064	3,678,000	Machinery
l2	119	96	34,282	3,288,000	Transport equipment
g2	81	66	48,686	3,189,000	Gasoline
a	108	87	24,492	2,124,000	Live animals/fish
e	35	28	25,429	722,000	Building stone
j	16	13	35,073	457,000	Logs
Total	23,509	18,948		385,105,000	

Source: Oklahoma Truck Model Output, based on FAF[3], version 3.1

Rail Flows

Introduction

Oklahoma's rail network carries a wide variety of products critical to the state and the national economy. This section describes the Oklahoma rail traffic base and the rail network from the perspective of key freight rail commodities. Data presented in this section are drawn from the 2009 Surface Transportation Board (STB) Rail Waybill Sample for the State of Oklahoma. This section is extracted from the *Oklahoma State Rail Plan, 2012*.

Overview of freight rail traffic flows

In 2009, over 278 million tons and over 46 million carloads of rail freight moved through the Oklahoma rail network. **Figure 20** depicts the concentrations of rail traffic on the various lines.

Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 20. Rail traffic flows on Oklahoma's rail network

A mapping of rail flows in Oklahoma shows most rail traffic in the state moves in a north-south direction over five Class I mainlines:

- BNSF line in the far western part of the state through Boise City, part of the BNSF route between the Powder River Basin and Texas
- BNSF west-central Oklahoma line through Woodward/Alva, part of the east-west Transcon
- BNSF line through Oklahoma City, the former Santa Fe line between Kansas City and Fort Worth, which is part of the MidCon traffic line

- UP mainline in eastern Oklahoma through Muskogee/Durant, the former Katy line Kansas City to Dallas
- Kansas City Southern Railway mainline in far eastern Oklahoma through Sallisaw connecting Kansas City and the Gulf ports

Some of the east-west intermodal[8] traffic on the BNSF Transcon also uses the route through Tulsa to reach destinations in Memphis and Birmingham.

Overhead/through freight rail traffic

As shown in **Table 9**, a vast majority of this freight is through traffic that neither originated nor terminated in Oklahoma. This traffic is predominately coal, grain, and intermodal containers or trailers. Together, these commodities make up over 65 percent of the state's through rail traffic (**Table 10**).

Table 9. Rail traffic in Oklahoma by traffic type

Direction	Tons (thousands)	Percent	Units (thousands)	Percent
Through	229,043	82	4,905	91%
Inbound	31,704	11	297	6%
Outbound	16,006	6	165	3%
Local	1,636	1	17	0%
Total	278,389	100	5,384	100%

Source: 2009 Surface Transportation Board Rail Waybill Sample

Table 10. Oklahoma rail traffic through traffic commodity mix

STCC	Commodity	Tons (thousands)	Percent Total
11 21	Bituminous coal	92,337	40.3%
46 11	Freight of all kind (consolidated freight)	29,859	13.0%
01 13	Grain	28,128	12.3%
28 18	Miscellaneous industrial organic chemicals	6,002	2.6%
01 14	Oil kernels, nuts, or seeds	5,324	2.3%
28 21	Plastic matter or synthetic fibers	5,258	2.3%
28 12	Potassium or sodium compound	5,023	2.2%
20 92	Soybean oil or by-products	5,002	2.2%
20 46	Wet corn milling or milo	3,808	1.7%
20 42	Prepared or canned feed	3,628	1.6%
	All other	44,675	19.5%
	Total Tons	229,043	100.0%

Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code

[8] Intermodal traffic consists of shipping containers or highway trailers. The goods shipped can vary greatly but tend toward high-value goods, such as manufactured products.

Inbound, outbound, and local freight rail flows

Eighteen percent of Oklahoma's rail traffic, approximately 50 million tons, either originates, terminates, or remains (local) within the state. Unlike through (also termed overhead) rail freight, which simply passes through the state, this traffic is both driven by and has a direct impact on Oklahoma's economy. Originating rail traffic reflects the production sectors of the economy. Terminating traffic meets the demands of the state's consumers as well as feeds the state's industries. Almost two thirds of the non-through traffic terminates in Oklahoma, making it a consumer of rail shipped products (**Table 11**). The remaining one-third of the non-through traffic originates with Oklahoma products.

Table 11. Oklahoma rail traffic categories—excludes overhead traffic

Direction	Tons (thousands)	Percent Total
Inbound	31,704	64%
Outbound	16,006	32%
Local	1,636	3%
Total	49,345	100%

Source: 2009 Surface Transportation Board Rail Waybill Sample

Table 12 shows the top ten inbound rail commodities, which account for more than 90 percent of the state's inbound rail traffic. Coal and grain constitute almost 80 percent of the state's rail terminations.

Given that the traffic statistics are for 2009, most traffic numbers are lower than today's (2012) volumes because of improved economic conditions following the recent recession.

Table 12. Oklahoma inbound rail traffic—commodity mix

STCC	Commodity	Tons (thousands)	Percent Total
11 21	Bituminous coal	22,194	70.0%
01 13	Grain	2,545	8.0%
24 11	Primary forest materials	736	2.3%
20 92	Soybean oil or by-products	641	2.0%
33 12	Primary iron or steel products	621	2.0%
14 41	Gravel or sand	607	1.9%
28 21	Plastic matter or synthetic fibers	460	1.5%
13 11	Crude petroleum	426	1.3%
24 21	Lumber or dimension stock	284	0.9%
28 12	Potassium or sodium compound	281	0.9%
	All other	2,910	9.2%
	Total Tons	31,704	100.0%

Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code

The petroleum volume also understates current traffic as it does not include crude petroleum being shipped into Oklahoma from the Dakotas, a growing business for the railroads. Only recently has a significant volume of oil been shipped by rail into Oklahoma for transfer to pipeline.

Rail shipments originating in Oklahoma are more diversified than terminations. **Table 13** shows the top ten originating rail commodities in Oklahoma by a 4-digit Standard Transportation Commodity Code (STCC). Although the leading ten commodities account for 90 percent of outbound rail tonnage, as with inbound traffic, greater diversification among the principal ten rail-transported products exists with stone, grain, and fertilizers being the leading commodities. Stone shipments alone constitute 45 percent of all originations. Combined with grain and fertilizer, these three commodities make up almost 70 percent of all rail tons originating in Oklahoma.

Table 13. Oklahoma outbound rail traffic—commodity mix

STCC	Commodity	Tons (thousands)	Percent Total
14 21	Broken stone or riprap	7,148	44.7%
01 13	Grain	2,334	14.6%
28 71	Fertilizers	1,401	8.8%
26 31	Fiber, paper, or pulpboard	791	4.9%
14 41	Gravel or sand	758	4.7%
29 11	Petroleum refining products	658	4.1%
28 19	Miscellaneous industrial inorganic chemicals	510	3.2%
14 91	Miscellaneous nonmetallic minerals, not elsewhere classified	277	1.7%
29 91	Miscellaneous coal or petroleum products	260	1.6%
40 21	Metal scrap or tailings	225	1.4%
	All other	1,643	10.3%
	Total Tons	16,006	100.0%

Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code

Table 14 shows major local rail commodities in Oklahoma (i.e., rail shipments both originating and terminating within the state). Local Oklahoma rail traffic is primarily bulk stone, gravel, and cement.

Table 14. Oklahoma local rail traffic—commodity mix

STCC	Commodity	Tons (thousands)	Percent Total
14 21	Broken stone or riprap	979	59.9%
14 41	Gravel or sand	288	17.6%
32 41	Portland cement	130	8.0%
29 91	Miscellaneous coal or petroleum products	56	3.4%
28 71	Fertilizers	44	2.7%
29 11	Petroleum refining products	38	2.3%
01 13	Grain	25	1.5%
24 11	Primary forest materials	23	1.4%
32 95	Nonmetal minerals, processed	15	0.9%
33 12	Primary iron or steel products	8	0.5%
28 19	Miscellaneous industrial inorganic chemicals	7	0.4%
26 31	Fiber, paper, or pulpboard	5	0.3%
37 42	Railroad cars	4	0.3%
20 85	Distilled or blended liquors	4	0.2%
40 29	Miscellaneous waste or scrap	3	0.2%
28 18	Miscellaneous industrial organic chemical	3	0.2%
26 11	Pulp or pulp mill products	3	0.2%
	Total Tons	1,636	100.0%

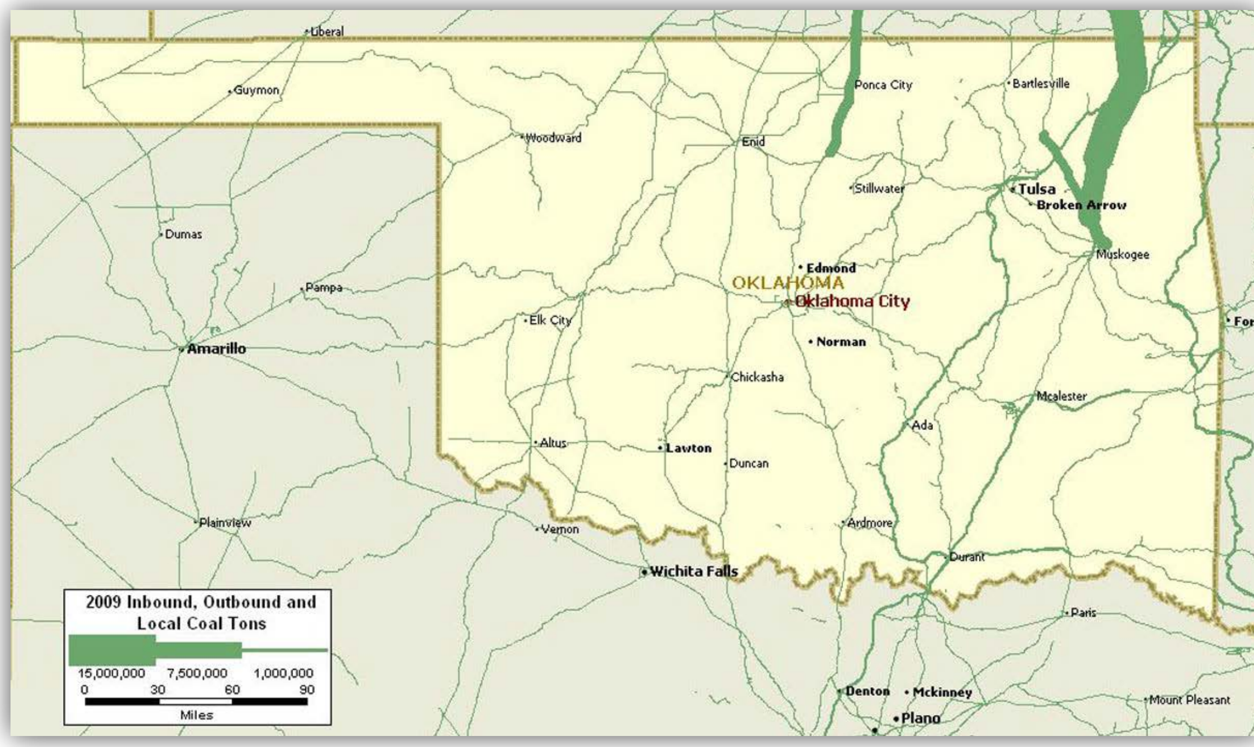
Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code

Rail commodity networks

Oklahoma's rail traffic is primarily composed of five major commodities—coal, grain, stone, petroleum, and fertilizers. Eighty percent of the state's originating or terminating rail traffic is in one of these five commodity categories.

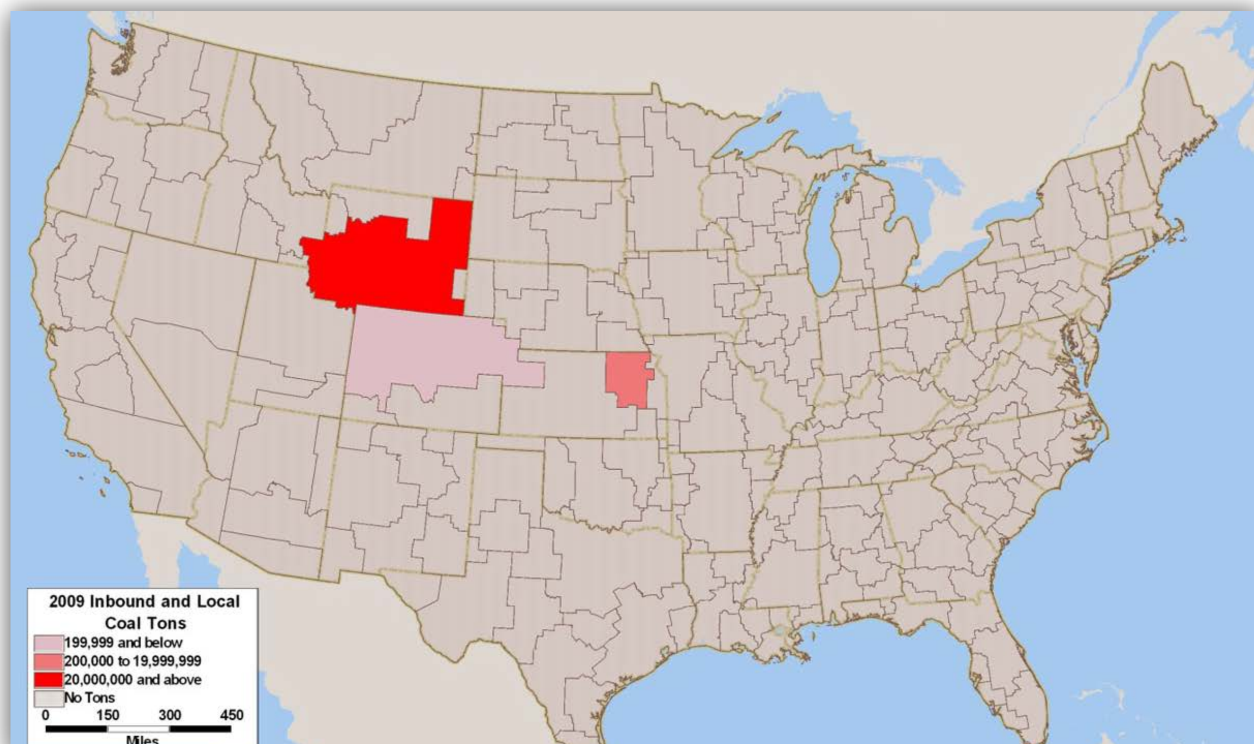
Coal

Coal is produced in Oklahoma but not in large quantities. In 2010, 1.4 million tons of bituminous coal was mined in seven counties of eastern Oklahoma. Consequently, most coal traffic moving in the state is from out-of-state mines. Much is overhead traffic passing through the state to other destinations; some terminates in the state. **Figure 21** shows the flow of this traffic over the Oklahoma rail network. Flows are concentrated along the eastern Oklahoma UP mainline to coal-burning utility plants near Muskogee. Not surprisingly, the majority of coal traffic originates in the producing regions of Colorado and the Wyoming Powder River Basin (**Figure 22**).



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 21. Coal rail traffic flows on Oklahoma's rail network

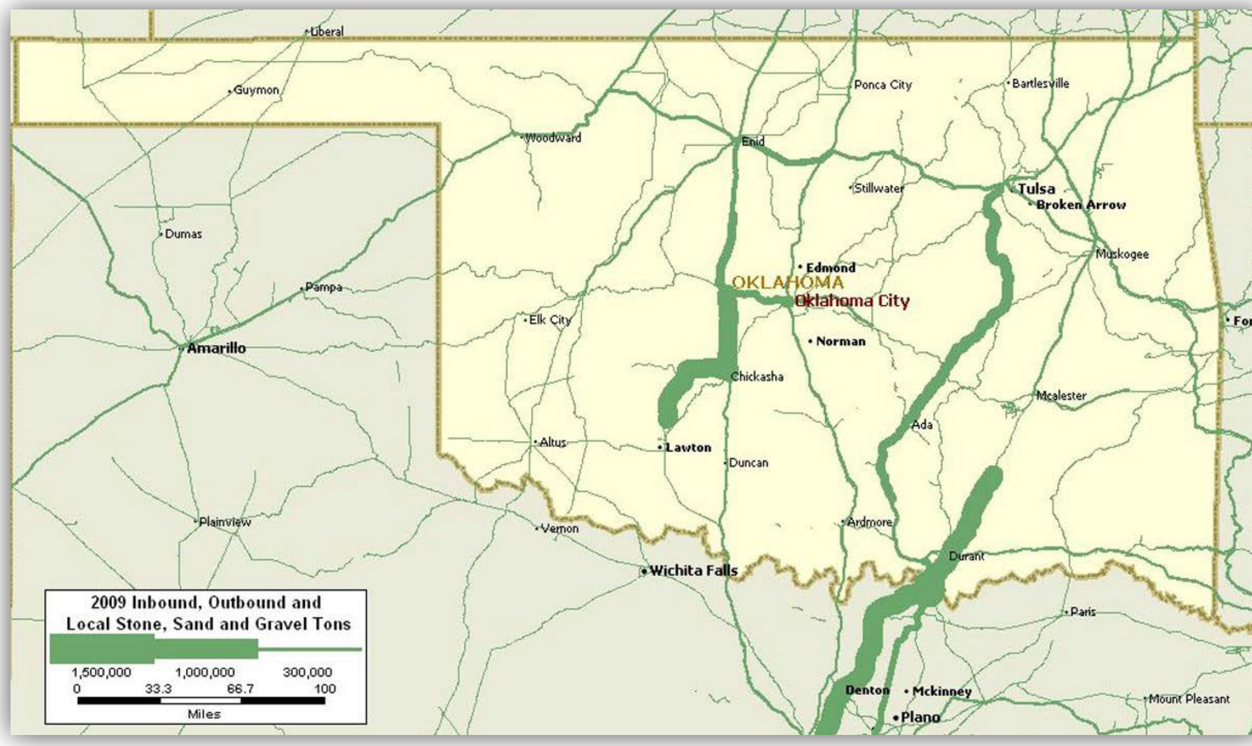


Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 22. BEA origins of Oklahoma's inbound rail coal traffic

Stone

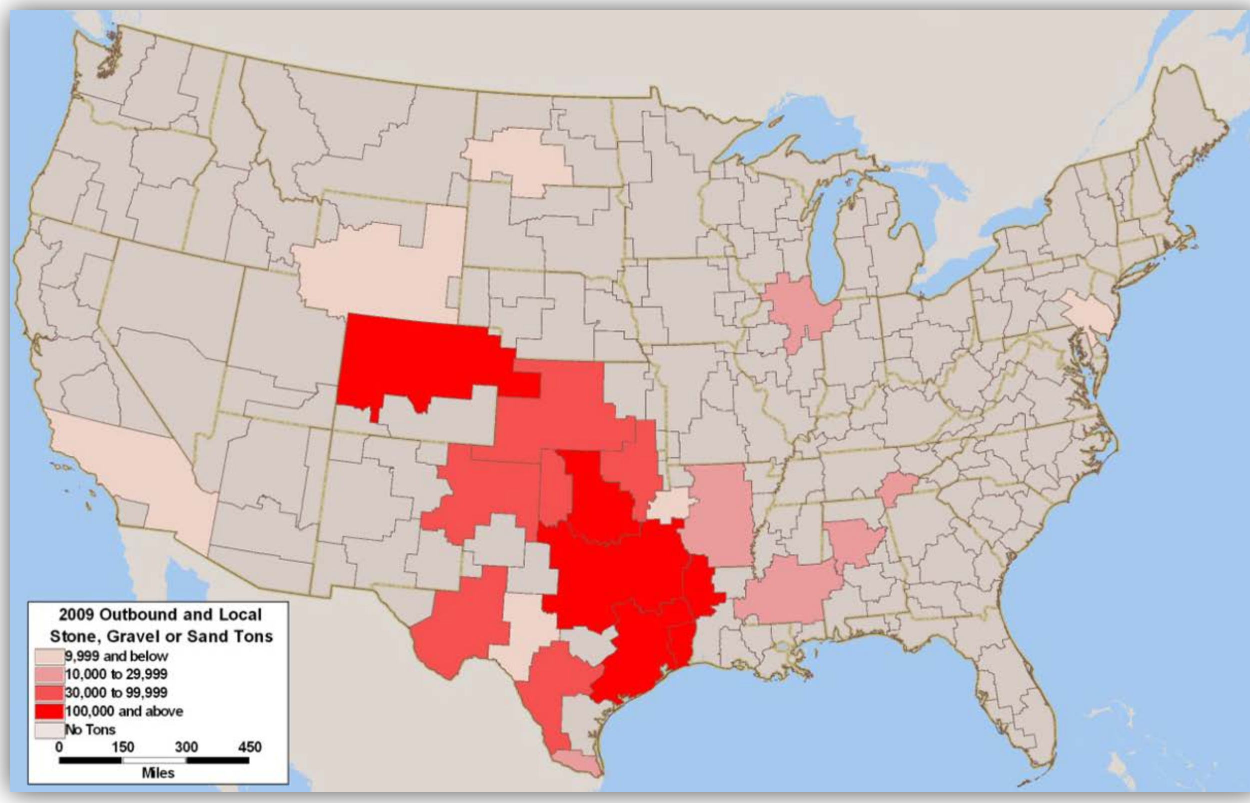
Stone, gravel, and sand (STCC codes 14 21 and 14 41) are the major outbound and local rail commodities in Oklahoma, constituting half of all state rail originations. **Figure 23** shows the Oklahoma rail network for these products. The major stone flow in Oklahoma is south from Atoka on the UP mainline to Texas. The principal movement of stone is in southeast Oklahoma. Other flows include movements between Tulsa and Johnston County (in south central Oklahoma) on BNSF as well as UP movements between Tulsa/El Reno and Comanche County north of Lawton.



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 23. Stone rail traffic flows on Oklahoma's rail network

As **Figure 24** shows, most Oklahoma stone shipments are local or regional short-haul shipments. They terminate either within the state or in neighboring states, primarily Texas, Colorado, and Kansas. As a low-value product with many sources throughout the U.S., shipping distances are short to keep delivery costs low.



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 24. BEA terminations of Oklahoma's outbound stone, gravel, and sand rail traffic

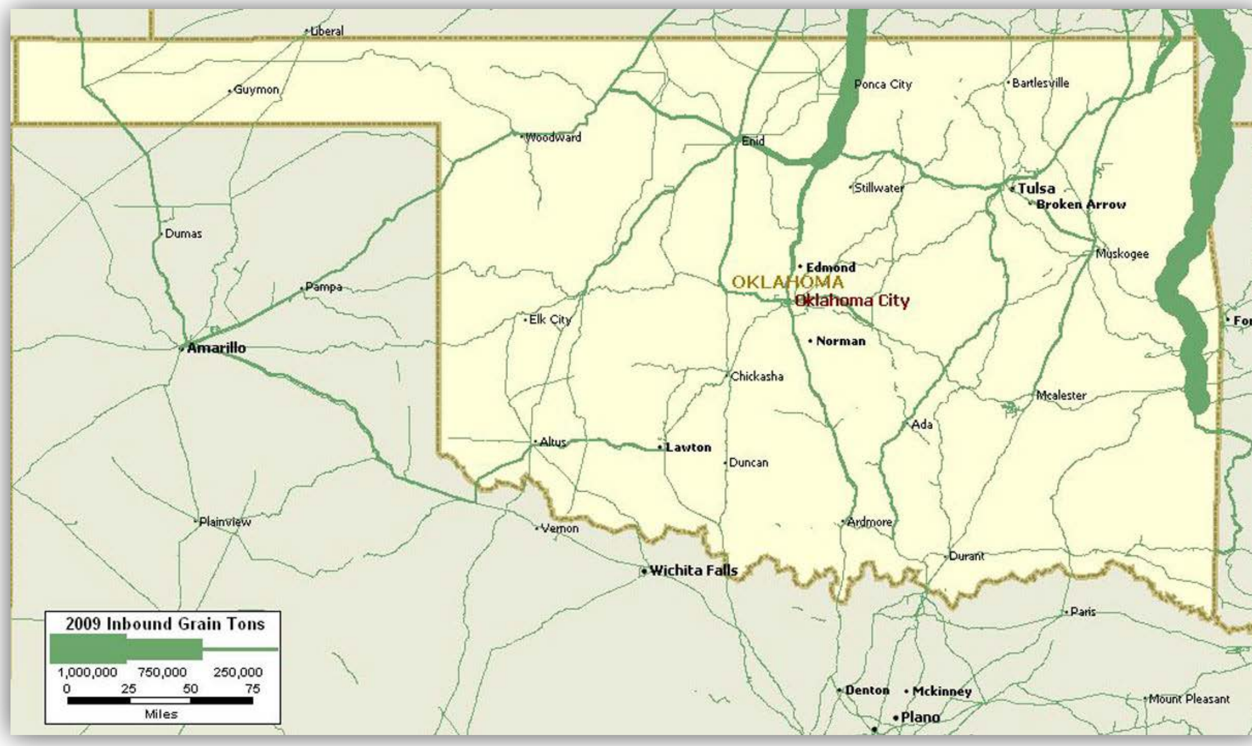
Grain

Grain rail shipments in Oklahoma move in and out of the state in equal volumes—2.5 million tons terminated in the state in 2009 while 2.3 million tons originated in Oklahoma. The characteristics of these flows differ markedly between inbound and outbound. Over 70 percent of Oklahoma's inbound grain is corn (**Table 15**), which travels primarily on the Kansas City Southern Railway mainline in eastern Oklahoma to Le Flore County or on the BNSF mainline in central Oklahoma to the Perry area (**Figure 25**). Originations of grain movements to Oklahoma are fairly concentrated in only seven BEAs (**Figure 26**), particularly from eastern Kansas and longer-haul shipments from Louisiana and Mississippi.

Table 15. Inbound rail grain volume in Oklahoma by type of grain

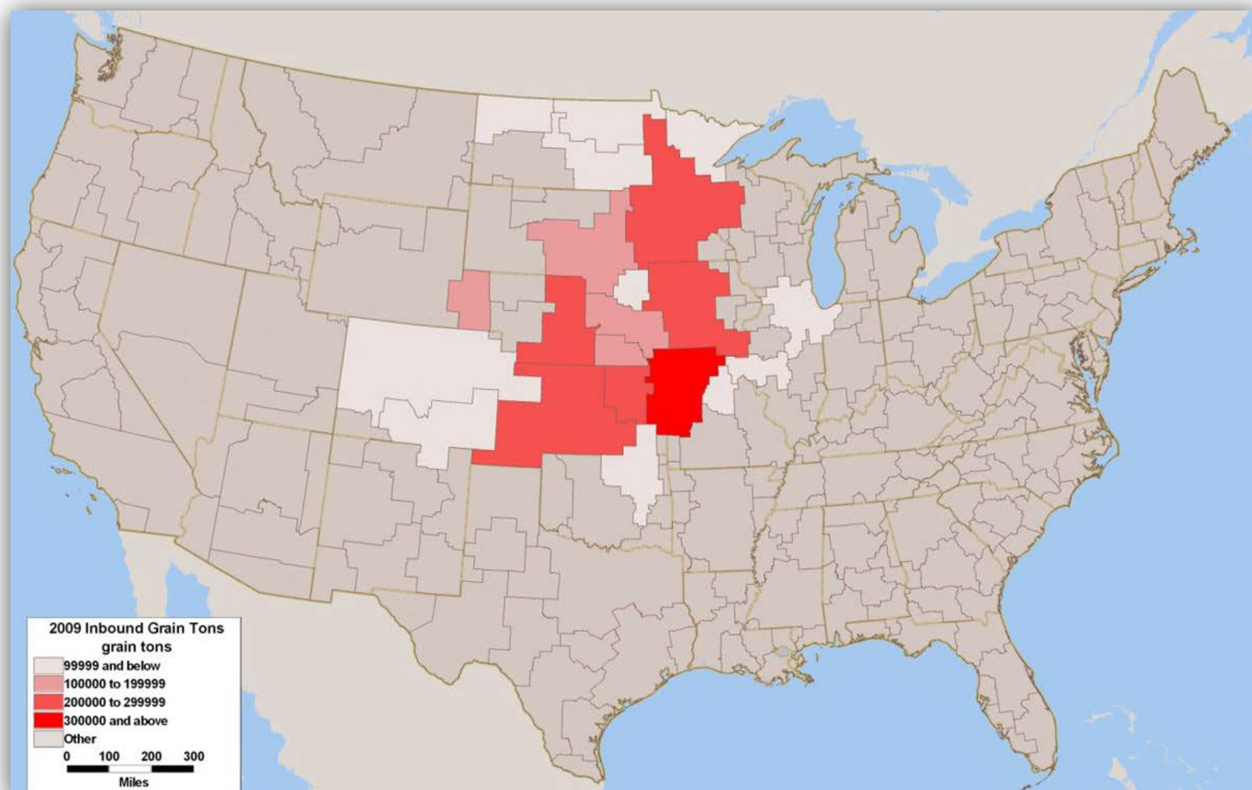
STCC	Commodity	Tons (thousands)	Percent Total
01 132	Corn	1,821	72%
01 133	Oats	27	1%
01 137	Wheat	693	27%
01 139	Grain, not elsewhere covered	4	0%
	Total Inbound Grain	2,545	100%

Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 25. Inbound grain rail traffic flows on Oklahoma's rail network



Source: 2009 Surface Transportation Board Rail Waybill Sample

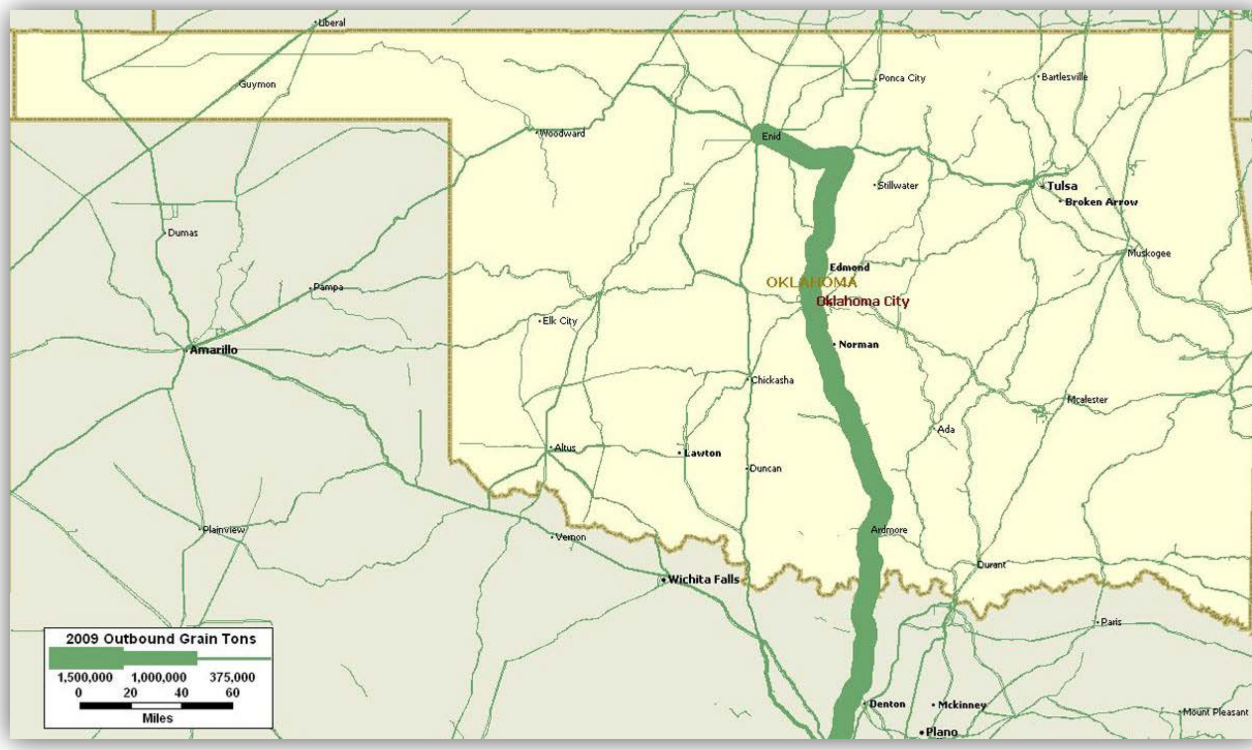
Figure 26. BEA origins of Oklahoma inbound rail grain traffic

Outbound grain from Oklahoma is almost exclusively wheat (**Table 16**). Destinations for this traffic are reasonably evenly distributed throughout west of the Mississippi River. Major outbound lanes in Oklahoma are shipments from Garfield County (Enid) on BNSF mainline in central Oklahoma south to Texas. A secondary outbound flow is movements from Jackson County (Altus) on BNSF to Texas (**Figure 27**). Destination BEAs (**Figure 28**) reflect primarily short-haul moves to neighboring states north of Oklahoma, including Kansas and Nebraska and south to northern Texas. Longer-haul destinations are in Washington, presumably for export.

Table 16. Outbound rail grain volume in Oklahoma by type of grain

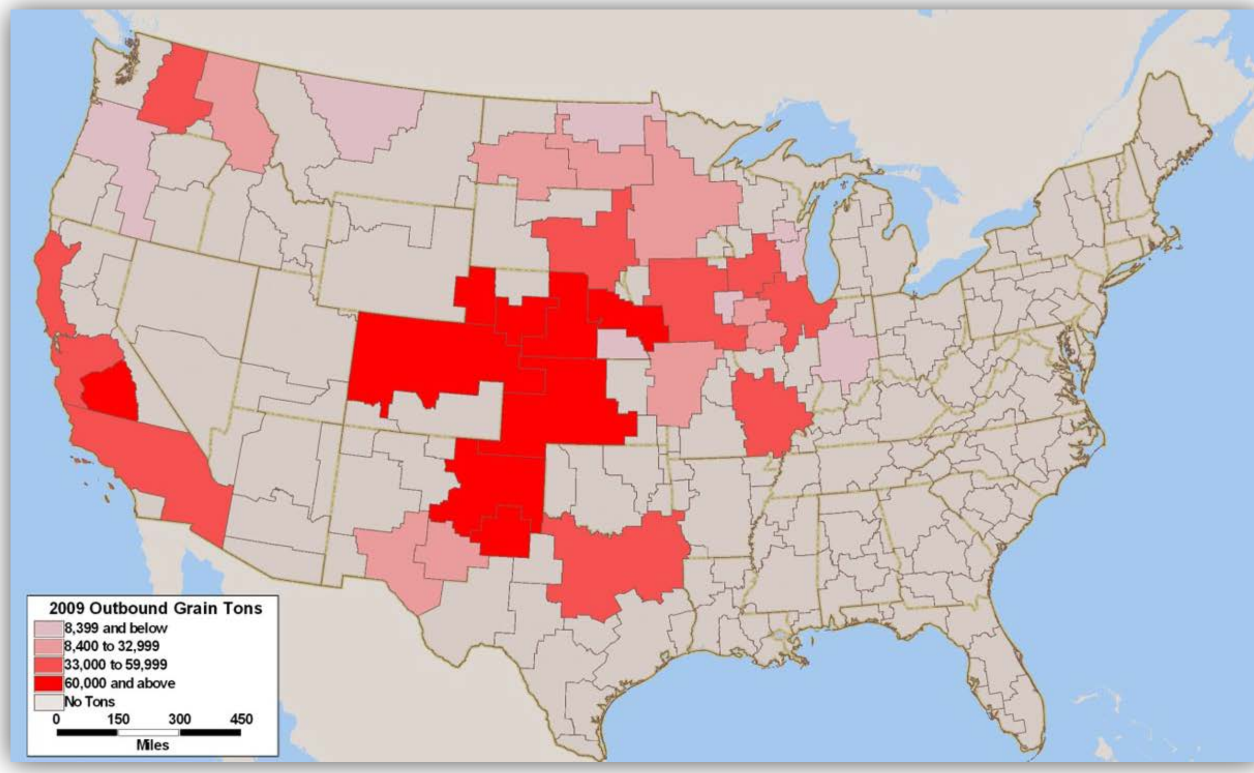
STCC	Commodity	Tons (thousands)	Percent Total
01 132	Corn	10	0%
01 136	Sorghum grains	142	6%
01 137	Wheat	2,182	93%
	Total Outbound Grain	2,334	100%

Source: 2009 Surface Transportation Board Rail Waybill Sample
STCC = Standard Transportation Commodity Code



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 27. Outbound grain rail traffic flows on Oklahoma's rail network

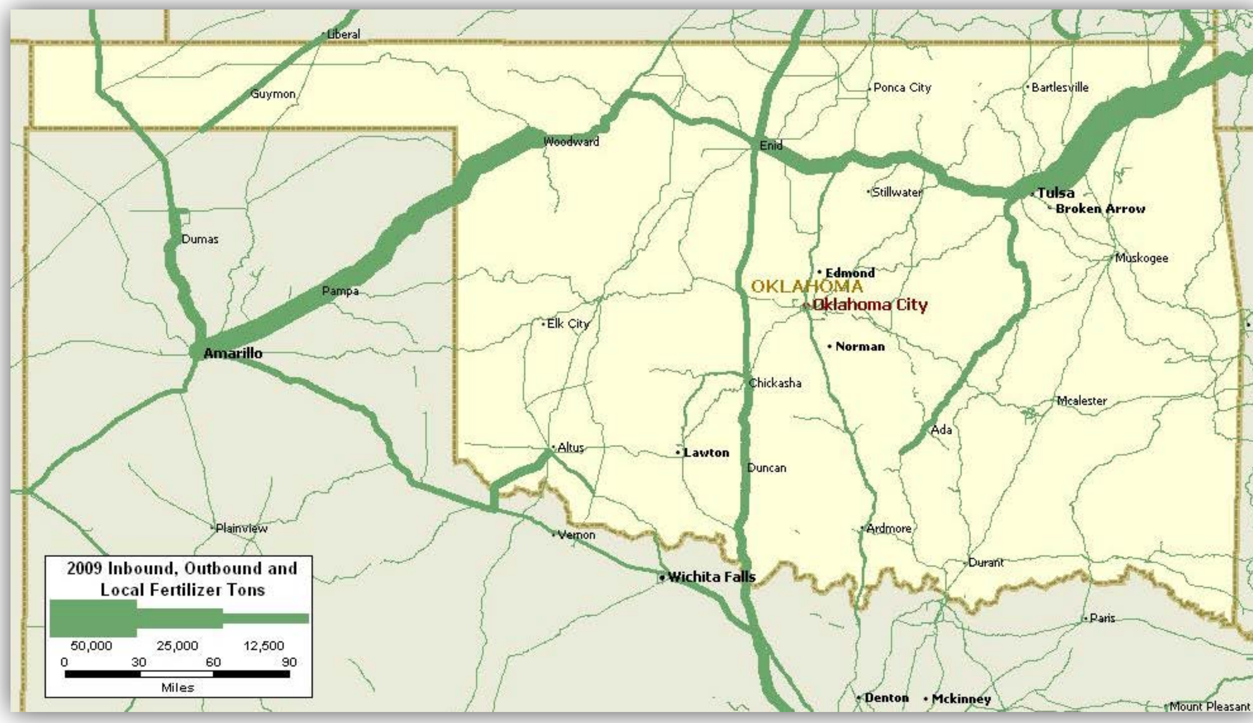


Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 28. BEA terminations of Oklahoma's outbound rail grain traffic

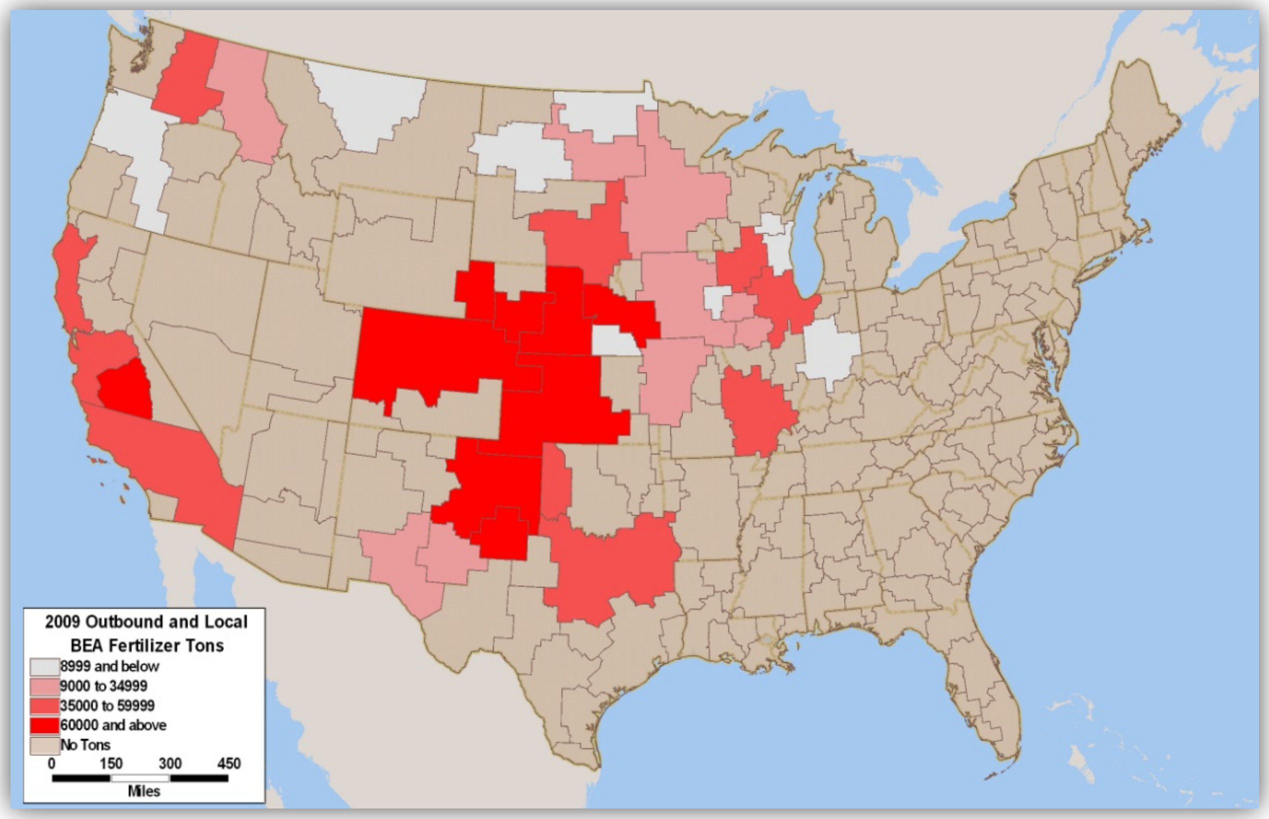
Fertilizer

Fertilizer is Oklahoma's third largest outbound rail commodity with over 1.4 million tons shipped in 2009. Unlike the state's other commodities, fertilizer shipments flow primarily east and west through the northern part of the state between Woodward, Enid, and Tulsa and the border to Missouri (**Figure 29**). Rail destinations of fertilizer from Oklahoma (**Figure 30**) exhibit a similar pattern as outbound gain, scattered throughout the mid-western and western U.S. They are primarily short-haul locations in Amarillo and nearby states north of Oklahoma—Kansas, Colorado, and Nebraska. Longer haul shipments also terminate in California and Washington.



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 29. Fertilizer rail traffic flows on Oklahoma's rail network

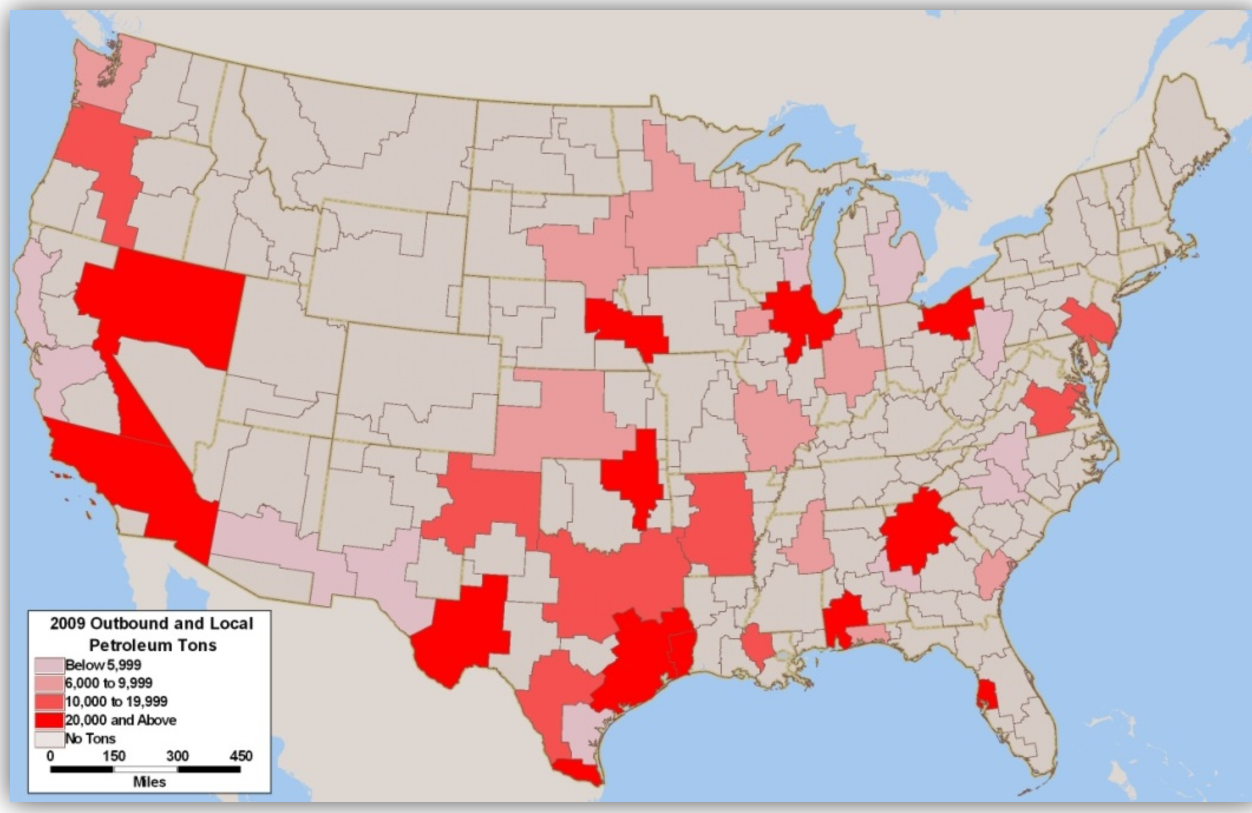


Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 30. BEA terminations of Oklahoma rail fertilizer traffic

Petroleum

Petroleum is one of Oklahoma's major outbound rail commodities with over 700,000 tons shipped from the state in 2009. These movements are highly scattered throughout the country with major BEA terminations being Houston, Atlanta, Cleveland, Mobile, Tampa, Omaha, and northern Nevada (**Figure 31**).



Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 31. BEA terminations of Oklahoma's rail petroleum traffic

No picture of inbound oil shipments is presented in this report since the surge in oil shipments terminating in the state is a very recent phenomenon. The significant volume of oil to be extracted from the Bakken formation and the development of additional unloading capacity in Oklahoma will create a significant inflow of oil to the state. Although starting slow, greater volumes of Oklahoma-produced Anadarko Basin oil will increase once the rail facilities serving the area are refurbished.

Intermodal

Since Oklahoma does not currently have an intermodal container/trailer transfer facility, all reported intermodal traffic is pass-through. Intermodal traffic is the second largest type of freight traveling through Oklahoma by rail. Much of this traffic moves on the BNSF Transcon line through Woodward and over the Avard subdivision to Tulsa and beyond to Memphis and Birmingham. (**Figure 32**). Additional intermodal traffic traverses the Oklahoma panhandle on the UP Golden State route.

Source: 2009 Surface Transportation Board Rail Waybill Sample

Figure 32. Intermodal traffic flows on Oklahoma's rail network

Rail freight flow summary

Most rail traffic in Oklahoma (over 80 percent) is through or overhead traffic that neither originates nor terminates in the state. This traffic is predominately coal, intermodal, and grain. Rail shipments that begin or end in Oklahoma are primarily coal, grain, and stone aggregates. These are traditional, heavy-loading, bulk rail commodities that primarily move locally or regionally between neighboring states. Grain in particular is balanced between outbound (wheat) and inbound (corn).

Waterway Flows

The McClellan-Kerr Arkansas River Navigation System (MKARNS) is Oklahoma's primary navigable waterway originating at the Tulsa Port of Catoosa and flowing southeast connecting to the Mississippi River. MKARNS is 445 miles long and has 18 locks and 10 dams that enable year-round navigation. Ports in Oklahoma along the MKARNS in addition to the Port of Catoosa include the Port of Muskogee and more than 30 private river terminals.

The Tulsa Port of Catoosa has five public terminal facilities; each is fully equipped and staffed to efficiently transfer inbound and outbound cargos between barges, trucks, and rail cars. The assets of these terminals, with the exception of the liquid bulk facilities, are owned by the Tulsa Port of Catoosa but are maintained and operated by independent contractors that have lease agreements with the Port Authority. The liquid bulk companies are private and own their own facilities.

The Port of Muskogee is an inland river port located on the Verdigris River, part of MKARNS. The port is situated on approximately 450 acres with 28 acres uncommitted. The port also owns the John T. Griffin Industrial Park, which consists of 527 acres. The Industrial Park is primarily comprised of manufacturing companies that facilitate the transportation of bulk and break bulk commodities, such as steel, tiles, clay materials, and granite.

According to representatives of the two ports, nearly all traffic moving on the waterway either terminates or originates in the Port of New Orleans. In 2009, 2.8 million tons moved through the two ports—2.1 million tons through Catoosa and 700,000 tons through Muskogee.[9] This represents approximately 0.3 percent of total freight tonnage in Oklahoma that is moved by waterway.

[9] Sources: Tulsa Port of Catoosa Tonnage Comparison Report- 2012; Port of Muskogee—Two Year Barge Tonnage Report–2011.

Appendix A—Truck Model Specification

Freight flows are given by FAF zones. For some other states, such as New Mexico, Mississippi, or Idaho, a single FAF region covers the entire state. Flows from and to these large states would appear as if everything was produced and consumed in one location in the state's center (or the polygon's centroid). To achieve a finer spatial resolution, truck trips are disaggregated from flows between FAF zones to flows between counties based on employment distributions.

The disaggregation from FAF zones to counties is based on county employment by 11 industry categories. The categories are as follows:

- Agriculture
- Construction Natural Resources and Mining
- Manufacturing
- Trade Transportation and Utilities
- Information
- Financial Activities
- Professional and Business Services
- Education and Health Services
- Leisure and Hospitality
- Other Services
- Government

County-level employment for agriculture was retrieved from the U.S. Department of Agriculture[10]. For all other employment categories, data were retrieved from the Bureau of Labor Statistics[11].

These employment types ensure that certain commodities are only produced or consumed by areas that have the appropriate industry structure, as represented by the county employment data. For instance, SCTG25 (logs and other wood in the rough) is produced in those zones that have agriculture employment (as a proxy for forestry). This commodity is shipped to those zones that have employment in industries consuming this commodity, particularly manufacturing. Make/use Coefficients, also called input/output Coefficients, are used to connect commodities to industries.

[10] www.nass.usda.gov/Statistics_by_Subject/index.php
[11] ftp://ftp.bls.gov/pub/special.requests/cew/2010/county_high_level/

The following equation shows the calculation to disaggregate from FAF zones to counties. A flow of commodity *c* from FAF zone *a* to FAF zone *b* is split into flows from county *i* (which is located in FAF zone *a*) to county *j* (which is located in FAF zone *b*) by:

$$flow_{i,j,com} = flow_{FAF_a,FAF_b} \cdot \frac{weight_{i,com} \cdot weight_{j,com}}{\sum_{M \in FAF_a} \sum_{N \in FAF_b} weight_{m,com} \cdot weight_{n,com}} \qquad \textbf{(1)}$$

where $flow_{i,j,com}$ = flow of commodity *com* from county *i* to county *j*

$county_i$ = located in FAF_a

$county_j$ = located in FAF_b

$county_m$ = all counties located in FAF_a

$county_n$ = all counties located in FAF_b

To disaggregate flows from FAF zones to counties, employment in 11 categories and make/use coefficients (borrowed from coefficients that were developed for Oregon previously) are used. These weights are commodity-specific. They are calculated by:

Production

$$weight_{i,com} = \sum_{ind} \left(empl_{i,ind} \cdot mc_{ind,com} \right) \qquad \textbf{(2a)}$$

Consumption

$$weight_{j,com} = \sum_{ind} \left(empl_{j,ind} \cdot uc_{ind,com} \right) \qquad \textbf{(2b)}$$

where $emp_{i,ind}$ = the employment in zone *i* in industry *ind*

$mc_{ind,com}$ = make coefficient describing how many goods of commodity *com* are produced by industry *ind*

$uc_{ind,com}$ = use coefficient describing how many goods of commodity *com* are consumed by industry *ind*

Table A-1 shows the make/use coefficients applied. Many cells in this table are set to 0, as most commodities are produced by a very few industries. No value was available for commodities SCTG09 (tobacco products) and SCTG15 (coal). They were assumed to be produced by agricultural employment and mining, respectively. As only the relative importance of each industry for a single commodity is required, it is irrelevant to which value the entry for these two commodities is set, as long as the industry that produces this commodity is set to a value greater than 0 and all other industries are set to 0.

Table A-2 shows this reference in the opposite direction, indicating which industry consumes which commodities.

Table A-1. Make coefficients by industry and commodity

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG01	811.6238	0	0	0	0	0	0	0	0
SCTG02	198.234	0	0	0	0	0	0	0	0
SCTG03	3669.689	0	0	0	0	324.679	0	0	0
SCTG04	159.456	0	0	0	114.4688	0	0	0	0
SCTG05	0	0	0	0	786.7564	220.2534	0	0	0
SCTG06	0	0	0	0	1289.469	0	0	0	0
SCTG07	205.8607	0	0	0	6551.506	0	0	0	0
SCTG08	0	0	0	0	1150.509	0	0	0	0
SCTG09	1	0	0	0	0	0	0	0	0
SCTG10	0	0	0	0	4.254867	211.2682	0	0	0
SCTG11	0	0	0	0	0.643628	25.07928	0	0	0
SCTG12	0	0	0	0	3.647224	142.1159	0	0	0
SCTG13	0	0	0	0	3.740241	95.63332	0	0	0
SCTG14	0	0	0	0	0	42.32755	0	0	0
SCTG15	0	0	0	0	0	1	0	0	0
SCTG16	0	0	0	0	0	138.1041	0	0	0
SCTG17	0	0	0	0	46.14806	12.86544	0	0	0
SCTG18	0	0	0	0	46.14806	12.86544	0	0	0
SCTG19	0	0	0	0	222.981	156.6388	0	0	0
SCTG20	0	0	0	0	1133.067	7.601936	0	0	0
SCTG21	0	0	0	0	393.104	0	0	0	0
SCTG22	0	0	0	0	267.6962	0	0	0	0
SCTG23	0	0	0	0	1082.518	0	0	0	0
SCTG24	0	0	0	0	1839.762	0	0	0	0
SCTG25	93.52182	5031.908	0	0	0	0	0	0	0
SCTG26	0	0	0	0	7578.98	0	0	0	0
SCTG27	0	0	0	0	392.5042	0	0	0	0
SCTG28	0	0	0	0	3254.577	0	0	0	0
SCTG29	0	0	0	0	621.0631	0	0	0	561.9978
SCTG30	0	0	0	0	747.4527	0	0	0	0
SCTG31	0	0	0	0	1439.455	9.26281	0	0	0
SCTG32	0	0	0	0	3039.151	0	0	0	0
SCTG33	0	0	0	0	4198.737	0	0	0	0
SCTG34	0	0.067042	0	0	3546.295	0	0	0	0
SCTG35	0	0	0	0	12377.87	0	0	0	0
SCTG36	0	0	0	0	6003.092	0	0	0	0
SCTG37	0	0	0	0	1785.718	0	0	0	0

Table A-1. Make coefficients by industry and commodity (continued)

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG38	0	0	0	0	3133.745	0	0	0	0
SCTG39	0	0	0	0	711.9008	0	0	0	0
SCTG40	0	0	0	0	1088.497	0	0	0	0
SCTG41	0	0	0	1.052104	29.10704	0	0	0	8.608894
SCTG43	0.06671	0.041744	0	1.37E-05	0.84238	0.041744	0	0	0.007408
SCTG99	0.06671	0.041744	0	1.37E-05	0.84238	0.041744	0	0	0.007408

Table A-2. Use coefficients by industry and commodity

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG01	166.435	8.623	1.006	0.576	11.188	8.623	26.532	26.532	87.325
SCTG02	2.810	7.737	0.583	0.110	8.045	7.737	6.805	6.805	28.851
SCTG03	107.551	182.070	8.192	3.078	105.791	182.070	127.262	127.262	291.450
SCTG04	6.897	4.603	0.353	0.796	17.855	4.603	12.377	12.377	38.949
SCTG05	190.286	8.577	9.624	3.631	60.307	8.577	43.047	43.047	74.914
SCTG06	27.336	3.295	0.003	6.097	57.220	3.295	103.089	103.089	181.644
SCTG07	854.169	16.416	0.240	17.500	727.346	16.416	406.972	406.972	574.950
SCTG08	44.799	1.365	0.018	1.568	104.258	1.365	80.459	80.459	113.579
SCTG09	0	0	0	0	1	0	0	0	0
SCTG10	0.324	0.432	0	0.216	1.807	0.432	9.840	9.840	20.447
SCTG11	0.052	0.034	0	0.025	0.367	0.034	1.138	1.138	2.850
SCTG12	0.292	0.193	0	0.142	2.082	0.193	6.446	6.446	16.150
SCTG13	0.210	0.119	0	0.100	1.519	0.119	5.224	5.224	11.377
SCTG14	0.089	0.271	0	0.006	0.770	0.271	1.391	1.391	1.881
SCTG15	0	0	0	0	1	0	0	0	0
SCTG16	0	14.709	0.001	0.021	5.266	14.709	4.810	4.810	40.067
SCTG17	0	4.504	0.001	0.062	0.214	4.504	0.587	0.587	0.684
SCTG18	0	4.504	0.001	0.062	0.214	4.504	0.587	0.587	0.684
SCTG19	0	19.706	0.002	0.292	10.691	19.706	9.784	9.784	47.663
SCTG20	5.555	6.648	0.003	2.795	124.747	6.648	69.714	69.714	98.951
SCTG21	0.007	0.927	0.003	0.446	54.918	0.927	21.135	21.135	85.901
SCTG22	0	1.962	0	0.427	23.736	1.962	34.287	34.287	21.988
SCTG23	0	2.086	0.004	2.092	130.089	2.086	43.369	43.369	139.217

Table A-2. Use coefficients by industry and commodity (continued)

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG24	0	5.313	0.012	10.806	170.388	5.313	71.067	71.067	166.788
SCTG25	1.192	439.025	0.773	0.534	14.600	439.025	84.419	84.419	116.618
SCTG26	4.259	682.990	0.021	44.158	1013.975	682.990	364.036	364.036	492.067
SCTG27	0	13.153	0	0.753	24.780	13.153	14.936	14.936	18.074
SCTG28	0	130.718	0.022	12.418	262.769	130.718	273.317	273.317	271.229
SCTG29	0	3.585	0.421	18.980	63.615	3.585	74.467	74.467	354.167
SCTG30	1.170	1.011	0.001	4.451	44.320	1.011	41.063	41.063	103.563
SCTG31	0	9.376	0.005	8.515	79.061	9.376	117.192	117.192	138.139
SCTG32	0	25.823	0.009	7.868	107.547	25.823	231.599	231.599	225.025
SCTG33	0	13.984	0.020	20.462	189.055	13.984	170.017	170.017	414.986
SCTG34	0	6.001	0.019	16.051	206.897	6.001	139.227	139.227	329.660
SCTG35	0	26.945	0.128	24.231	1573.704	26.945	602.492	602.492	1576.753
SCTG36	0	9.136	0.003	4.341	487.881	9.136	316.719	316.719	294.676
SCTG37	0	1.969	0.012	5.082	149.155	1.969	61.745	61.745	159.730
SCTG38	0	4.902	0.036	19.310	353.619	4.902	111.608	111.608	418.334
SCTG39	0	1.783	0.006	5.501	103.988	1.783	36.846	36.846	84.256
SCTG40	0.547	1.445	0.007	6.542	64.723	1.445	42.580	42.580	122.633
SCTG41	0	0	0	0	0	0	0	0	1
SCTG43	0.054	0.064	0.001	0.010	0.244	0.064	0.144	0.144	0.275
SCTG99	0.054	0.064	0.001	0.010	0.244	0.064	0.144	0.144	0.275

The disaggregated commodity flows in short tons need to be transformed into truck trips. Depending on the commodity, a different amount of goods fit on a single truck. FAF^2 provided average payload factors for four different truck types (Battelle 2002: 29) that were used to calculate number of trucks based on tons of goods by commodity (**Table A-3**).

Table A-3. Average payload factors by commodity

SCTG	Commodity	Provided by FAF^2 Payload (lbs)
SCTG01	Live animals and fish	24,492
SCTG02	Cereal grains	27,945
SCTG03	All other agricultural products	22,140
SCTG04	Animal feed or products of animal origin	22,967
SCTG05	Meat, seafood, and their preparation	30,691
SCTG06	Bakery and milled grains	11,831
SCTG07	All other prepared foodstuff	25,926
SCTG08	Alcoholic beverages	20,573
SCTG09	Tobacco products	25,168
SCTG10	Monumental or building stones	25,429
SCTG11	Natural sand	29,501
SCTG12	Gravel and crushed stones	30,840
SCTG13	All other nonmetallic minerals	29,101
SCTG14	Metallic ores and concentrates	39,464
SCTG15	Coal	43,866
SCTG16	Crude petroleum	28,007
SCTG17	Gasoline and aviation turbine	48,686
SCTG18	Fuel oils	23,442
SCTG19	All other coal and refined petroleum	18,608
SCTG20	Basic chemicals	29,391
SCTG21	Pharmaceutical products	10,260
SCTG22	Fertilizers and fertilizer materials	19,833
SCTG23	All other chemical products	24,432
SCTG24	Plastic and rubber	19,324
SCTG25	Logs and other wood in rough	35,073
SCTG26	Wood products	18,494
SCTG27	Pulp, newsprint, paper, or paperboard	33,046
SCTG28	Paper and paperboard articles	26,282
SCTG29	Printed products	11,024
SCTG30	Textile, leather, and related article	20,608
SCTG31	Non-metallic mineral products	31,044
SCTG32	Base metal in finished or semi-finished form	24,458
SCTG33	Articles of base metal	14,395
SCTG34	Non-powered tools	6,064
SCTG34	Powered tools	10,698
SCTG34	Machinery	26,072
SCTG35	Electronic and other electrical equipment	13,821
SCTG36	Vehicle, including parts	15,690
SCTG37	All other transportation equipment	34,282
SCTG38	Precision instruments and apparatus	9,024
SCTG39	Furniture, mattresses, lamps, etc.	14,103
SCTG40	Miscellaneous manufactured products	16,462
SCTG41	Hazardous waste	29,113
SCTG41	All other waste and scrap	16,902
SCTG41	Recyclable products	18,859
SCTG42	Products not classified, blank, not reported or applicable	21,739
SCTG43	Mail and courier parcels	11,826
SCTG43	Empty shipping containers	19,129
SCTG43	Passengers	2,613
SCTG43	Mixed freight	33,268
SCTG43	Multiple categories	14,621

Unfortunately, these payload factors are only provided for an average truck. As two truck types are distinguished in this model, the average payload factors have to be converted into single-unit und multi-unit truck payload factors. Based on analysis of payload factors by truck type[12], it was determined that a single-unit truck would carry 90 percent of the average payload factor, and multi-unit trucks are assumed to carry 180 percent more than the average payload factor.

To split goods flows between single-unit and multi-unit trucks, the traveled distance is used as the explaining variable. This split is based on the assumption that single-unit trucks are more frequently used for short-distance trips, whereas multi-unit trucks dominate the long-distance market. VIUS data were analyzed to extract the relationship between truck type and distance traveled. The VIUS attribute AXLE_CONFIG distinguishes 44 truck types, where ID 1 through ID 5 (straight trucks and truck tractors not pulling a trailer) were defined as single-unit trucks and ID 5 through ID 64 (straight trucks and truck tractors pulling a trailer) were defined as multi-unit trucks. The VIUS attribute TRIP_PRIMARY describes the trip distance this truck type is primarily used for. Records with TRIP_PRIMARY set to “Off Road,” “Not reported,” and “Not applicable” were excluded from this analysis. The summery is shown in **Table A-4**.

Table A-4. Share of truck types by distance class

Distance in Miles	SUT	MUT
0 to 50	82.4%	17.6%
51 to 100	63.3%	36.7%
101 to 200	44.0%	56.0%
201 to 500	26.8%	73.2%
>500	16.9%	83.1%

Finally, the average payload factors by truck type and the share of truck type by distance class are used to convert tons into truck trips.

$$SUT_{i,j} = \sum_{com} \frac{tons_{com,i,j}}{pl_{SUT,com} + \frac{shareMUT_{d_{i,j}}}{shareSUT_{d_{i,j}}} \cdot pl_{MUT,com}} \qquad \textbf{(3)}$$

$$MUT_{i,j} = \sum_{com} \frac{tons_{com,i,j}}{\frac{shareSUT_{d_{i,j}}}{shareMUT_{d_{i,j}}} \cdot pl_{SUT,com} + pl_{MUT,com}}$$

where $SUT_{i,j}$ = the number of single-unit trucks from i to j

$MUT_{i,j}$ = the number of multi-unit trucks from i to j

$tons_{i,j,com}$ = the number of tons of this commodity going from i to j

$pl_{SUT,com}$ = the payload factor for single-unit trucks for commodity *com*

$pl_{MUT,com}$ = the payload factor for multi-unit trucks for commodity *com*

$shareSUT_{d_{i,j}}$ = the share of single-unit trucks given for distance $d_{i,j}$ given by Table A-4

$shareMUT_{d_{i,j}}$ = the share of multi-unit trucks given for distance $d_{i,j}$ given by Table A-4

[12] Table 3.2 at http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c3_payload.htm

As FAF[3] provides tons moved, an empty-truck rate needs to be added to the estimated truck trips. An average empty-truck rate of 19.36 percent of all truck miles traveled (estimated based on U.S. Census Bureau 2008: 14) was assumed.

$$totalTruck_{i,j} = \frac{loadedTruck_{i,j}}{1 - etr} \quad (4)$$

where *totalTruck*$_{i,j}$ = the number of total trucks (including empties) from *i* to *j*

loadedTruck$_{i,j}$ = the number of trucks carrying freight from *i* to *j*

etr = the empty truck rate, currently set to 19.36 percent

Finally, FAF[3] provides yearly commodity flows. Thus yearly truck trips need to be converted into daily trucks to represent an average weekday. As there are slightly more trucks traveling on weekdays than on weekends, a weekday conversion was added.

$$trucks_{daily} = \frac{trucks_{yearly}}{365.25} \cdot \frac{AAWDT}{AADT} \quad (5)$$

where *trucks*$_{daily}$ = the number of daily truck trips for an average weekday

trucks$_{yearly}$ = the number of yearly truck trips

AAWDT = the average annual weekday truck count

AADT = the average annual daily truck count

Based on Automatic Traffic Recorder truck count data, the ratio *AAWDT/AADT* was estimated to be 1.02159, meaning that the average weekday has just 2 percent more traffic than the average weekend day. This reflects the nature of long-distance truck travel that is not affected by the course of the week.

Appendix B—Truck Model Results Validation

To show that the model is replicating real-world traffic flows reasonably well, the model is validated against traffic flows. Traffic counts were collected from a study on Oklahoma freight and goods movement[13]. A total of 35 truck counts for the year 2009 were available, 24 on interstate highways and 11 on arterials. The FAF^3 data have flows for 2007, and flows were scaled up to match 2009 truck flows.

One of the challenging aspects of truck modeling is collecting good count data. It is common to collect truck count data with loop detectors on the street. While these counts are reasonably close to actual traffic flows, some uncertainty is introduced by converting number of axles (which are counted by the loop detector) into actual vehicles, distinguishing autos and trucks. In some cases, manual traffic counts are preformed, and the vehicles are classified into autos and trucks by the person counting. Depending on which vehicles the counter classified as trucks, volumes may vary substantially between different counters. Finally, the variation from day to day is substantial. While the model simulates average annual daily truck traffic (or AADTT), counts commonly are collected over a 48-hour period only. Comparisons with Weigh-In-Motion truck counts, which count truck volumes continuously over the course of the year, show that 48-hour counts may under- or overestimate true truck traffic by up to 20 percent. Thus, counts at specific count locations should be considered subject to error. The overall pattern, however, should resemble the model. **Figure B-1** shows a scatter plot comparing count volumes with model results. The green line would be a perfect match between count data and model results.

Two sets of count data have been distinguished: external stations in red are counts that are at or near the border of the State of Oklahoma, and blue dots show counts elsewhere in the state. The model has been calibrated to match the red dots at the external stations. This is because FAF data are known to under-represent short-distance truck flows. Furthermore, the spatial resolution within the State of Oklahoma is too coarse to expect high precisions within urban areas of the state. The external stations show a close match between count data and model results. With an R^2 of 0.9596 (where 1.0 would be a perfect correlation), the model is able to replicate traffic volumes correctly at external stations. Within Oklahoma, the counts shown with blue dots scatter further, with an R^2 of 0.4981. Particularly within urban areas of Oklahoma City and Tulsa, the model misses some of the short-distance truck flows. This is common for long-distance truck models, as the focus is on obtaining the correct overall travel patterns. The network and the zone system do not have the spatial detail required to obtain correctly all counts within the State of Oklahoma. In general, however, the validation shows that the model is capable of reasonably reproducing truck traffic for the State of Oklahoma. The long-distance patterns are well-represented and valid to extract flow patterns within and through the State of Oklahoma.

[13] ODOT (2010): Freight and Goods Movement. December 2010, pp. 7-8.

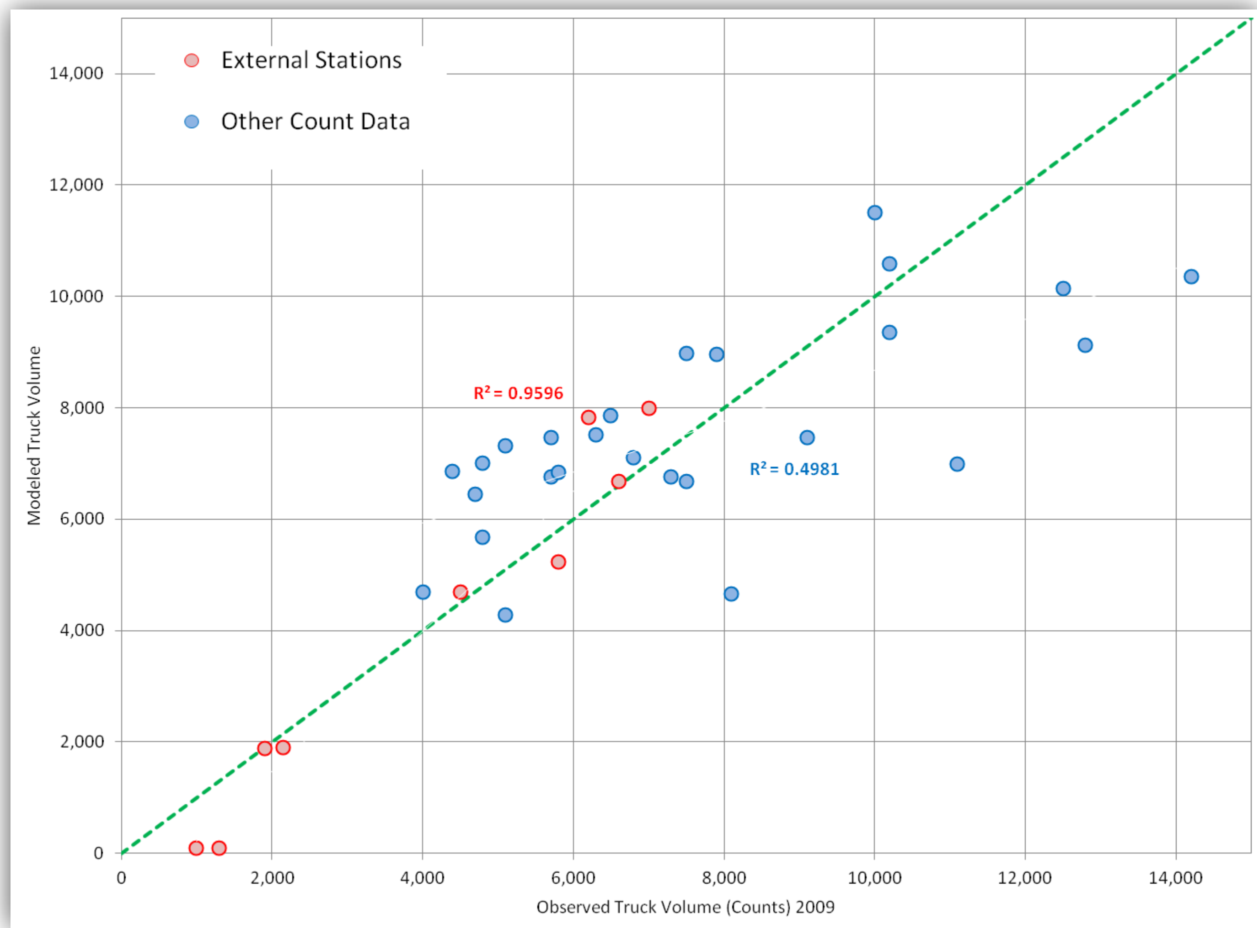


Figure B-1. Comparison of truck volumes with count data

Appendix C—Recommendations for Future Enhancements

The truck model was built to analyze truck flows in the State of Oklahoma. While the overall pattern of truck flows validates reasonably well against traffic flows, local truck trips are underrepresented in this model. This is a known shortcoming of the FAF data, which are derived from a commodity flow survey, which in turn is known to focus on long-distance traffic. While the patterns of truck travel may be used for statewide freight flow analysis, this model is not suitable to analyze local truck flows.

Two enhancements would be necessary before using the truck model for local analyses. First, a statewide local truck model covering short-distance truck trips would need to be implemented. The FHWA has published a *Quick Response Freight Manual* (QRFM) that can be used to simulate short-distance trips. The QRFM is widely considered to be a feasible short-distance truck model concept. Experience shows that some QRFM parameters need to be adjusted to local conditions. Another refinement may include routing truck flows through distribution centers to replicate high traffic volumes in the neighborhood of such facilities.

Secondly, a finer geographic scale is recommended as a future enhancement. The current model uses 3,241 counties across the U.S. as zones. While this spatial resolution is sufficient for long-distance truck flows, local flows are skewed toward the county centroid, which was set to be in the center of the largest city in every county. While counties offer the advantage that input data may be collected from publicly available sources at low costs, a finer zone system would allow for spreading out flows more realistically across the county. Increasing the resolution of the zone system requires increasing the detail of the highway network as well. For validation purposes, more traffic counts would be desirable, particularly counts that distinguish single-unit and multi-unit trucks.

Given that a truck model has been set up and validated for the State of Oklahoma, it is a simple additional step to simulate future truck flows. FAF^3 data contain forecasts for the years 2015 to 2040 in five-year increments. According to FAF^3, commodity flows in the United States are expected to grow by 46 percent from 2007 to 2040, with truck flows growing by 50 percent. Given the geographic location of Oklahoma, this growth will affect the Oklahoma highway system even if Oklahoma did not add a single truck. As a result of the large number of through trips, congestion in the Oklahoma City and Tulsa regions is expected to become more severe. Adding the internal growth forecasted for the State of Oklahoma, traffic volumes caused by truck trips will increase continuously over the next three decades. Using the truck model to identify the growth in truck volumes on the Oklahoma highway network could help the state prepare for this future growth in truck traffic.