MISSOURI
State Freight & Rail Plan

MISSOURI FREIGHT PROFILE: VOLUME 1

2022

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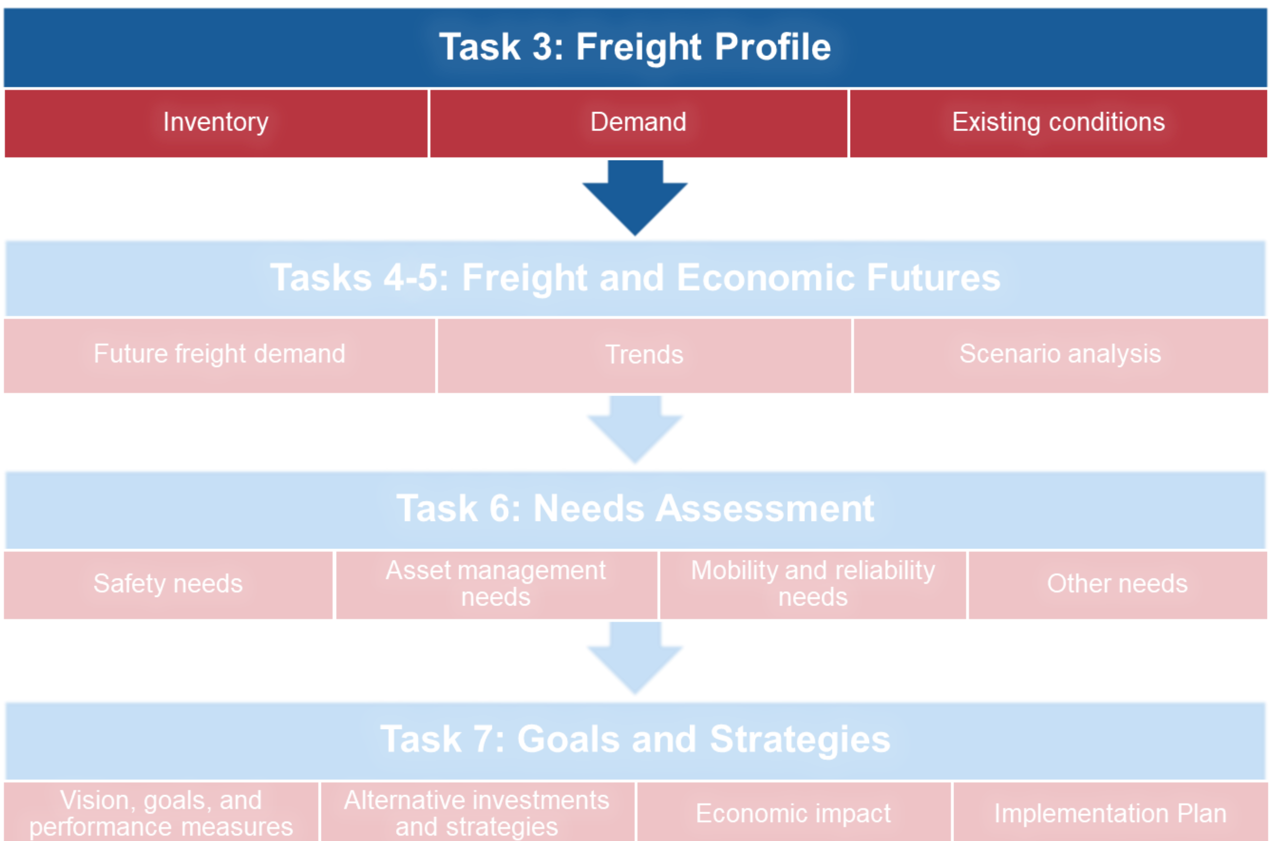
1.1 The Missouri State Freight and Rail Plan Overview

Missouri's economic vitality and quality of life are inextricably linked to the state's freight transportation network. The road, railways and other multimodal assets of this network move more than one billion tons of freight valued at more than one trillion dollars.

The *Missouri Freight and Rail Plan* will provide the Missouri Department of Transportation with a next-generation blueprint and plan for freight investment. This plan is data driven and supported by stakeholders. It is intended to help Missouri maintain its competitive advantage and economic vitality aligned with freight movement within the state. Figure 1.1 shows the overall sequence of events for the development of the *Missouri Freight and Rail Plan.*

FIGURE 1.1 MISSOURI STATE FREIGHT AND RAIL PLAN TASK BREAKDOWN



The Missouri Freight Profiles are a critical part of the overall plan. Not only do they provide the context and background for the Plan, but they will also help inform the identification of needs, issues and ultimately policies and projects that come out of the Plan. The profiles are split into multiple volumes and include detailed descriptions of Missouri's multimodal freight system inventory, demand and existing conditions. This volume includes the Highway profile. Volume 2 includes Rail, Air, Port, Pipeline, Intelligent Transportation Systems and Freight Generators profiles. There are also additional chapters and technical memorandums that cover Truck Parking, Economic Impact of Freight and Commodity Flow profiles.

Missouri's Multimodal Transportation Goals

MoDOT is built on a foundation of three primary pillars: safety, service and stability. MoDOT's mission is "to provide a world-class transportation system that is safe, innovative, reliable and dedicated to a prosperous Missouri." Building on those pillars and its mission, MoDOT developed the 2018 Missouri's Multimodal Transportation Goals, which include:

- Take care of the transportation system and services we enjoy today
- Keep all travelers safe, no matter the mode of transportation
- Invest in projects that spur economic growth and create jobs
- Give Missourians better transportation choices
- Improve reliability and reduce congestion on Missouri's transportation system

1.2 Highway Profile Overview

Highways are critical to Missouri's freight network and economy for one primary reason: trucks. Trucks are the dominant method of moving freight to, from, within and through Missouri. As of 2018, more than 400 million tons of freight were transported on Missouri's highways by 32.5 million trucks. Though other modes compete to transport freight over long distances, trucks provide the ultimate flexibility for businesses, and serve the critical first- and last-mile connections between rail, air and/or waterway terminals and the suppliers/customers.

This freight profile provides an overview of Missouri's freight highway system through four different lenses. The first lens examines the *supply* of system infrastructure through an inventory: What and where is the highway system? The second examines the *demand* on the highway system: How many and what types of goods use the highway system, and where are they going? The third section examines the *condition and performance* of the highway system: How is it meeting the needs of the freight shippers and carriers that rely on it to move goods statewide? The final section examines the *safety* of the highway system: How safe are the different parts of the highway system, and what factors potentially influence it? The final section includes a summary of key highway performance trends in Missouri.

The remainder of this document is organized as follows:

- Section 2 – An inventory of highway infrastructure
- Section 3 – An analysis of the freight transportation demand and use of the highway system
- Section 4 – A review of the condition and performance of the freight highway system

- Section 5 – An examination of the safety of the freight highway system
- Section 6 – A summary of key highway performance trends
- Appendix A includes additional details about truck volumes on non-interstate routes
- Appendix B includes highway performance maps that show highway performance during all time periods
- Appendix C includes details into the safety crash rate calculations

2.0 Highway Freight Network Inventory

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The highway is the work horse of Missouri's freight network and economy. MoDOT manages 33,832 miles of state highway, which ranks 7th nationally in state highway miles.[1] This includes 1,380 miles of interstate highway, which ranks 5th nationally. Missouri is home to the 20th and 30th largest metropolitan areas in the country, St. Louis and Kansas City. There, across all vehicle types, people drive just less than 70,000 miles per day and just more than 50,000 miles per day, respectively. That means that St. Louis and Kansas City rank 20th and 31st on the list of the most daily vehicle miles traveled in all the nation's urbanized areas.

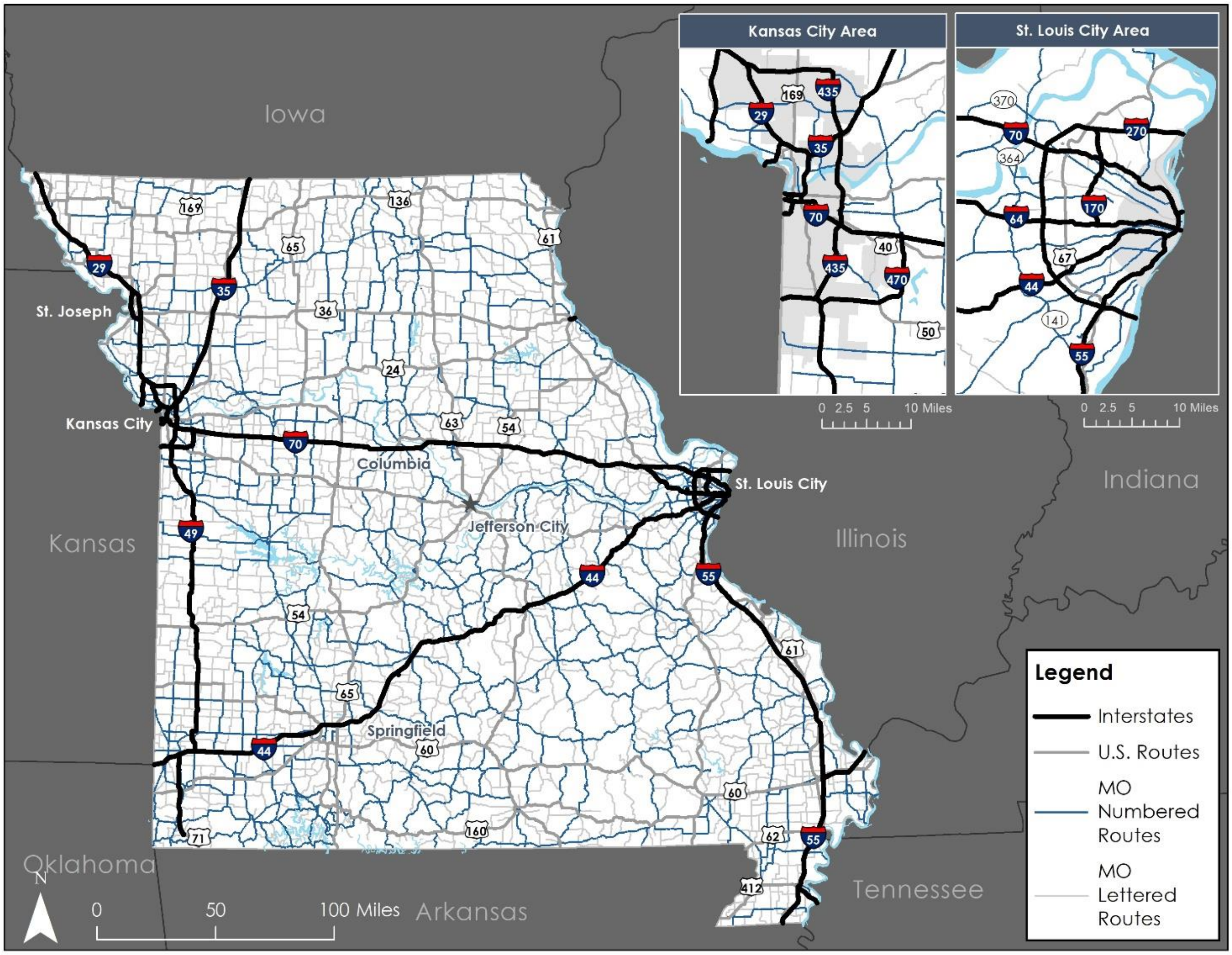
2.1 Overview of Highways in Missouri

There are various classification systems for highways. The most familiar is to examine the state highway system. This can be divided into four major categories based on ownership and signage: interstates, U.S. Highways, state numbered routes and state lettered routes. In Missouri, these four classifications make up 32,073 miles of highway. There are an additional 1,759 miles of other roads, such as outer roads and business routes, as part of the state highway system. When measured by highway miles,[2] state lettered routes make up by far the largest portion, which at 19,014 miles is 56% of the total miles. Interstates make up about 4% of the total, U.S. Highways make up 10%, state numbered routes make up 25%, and the remaining 6% consists of other roads. Figure 2.1 shows a map of the state highways (excluding other roads) and Table 2.1 shows the number of highways miles shared by each of these major classes.

[1] https://www.modot.org/fast-facts

[2] "Highway miles" refers to measuring the length of a roadway, without taking into account the number of lanes. This is contrasted with "lane miles", which incorporates both the length of a roadway and the number of lanes.

FIGURE 2.1 MISSOURI STATE HIGHWAY SYSTEM



Note: "Other" state highways are not shown on this map.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

TABLE 2.1 MISSOURI STATE HIGHWAY MILES, BY OWNERSHIP TYPE

Highway Type	Highway Miles	Percent of Total Highway Miles
Interstate	1,380	4%
U.S. Highways	3,412	10%
State Numbered Route	8,267	25%
State Lettered Routes	19,014	56%
Other	1,759	6%
Total	**33,832**	**100%**

Source: MoDOT

2.2 Missouri Roads by Functional Classification Criteria

A more technical way of classifying roads is to use the Functional Classification criteria under the Highway Performance Monitoring System.[3] This divides highways into the following categories:

- **Classification 1:** Interstates, which are part of the Interstate Highway System.
- **Classifications 2 and 3:** Primary arterials, which are main thoroughfares. These are sub-classified as either:
  - **Classification 2:** Freeways and expressways, if they have on- and off- ramp access and egress.
  - **Classification 3:** Other, if they do not have on- and off-ramp access and egress.
- **Classification 4:** Minor arterials, which interconnect and augment primary arterials.
- **Classification 5:** Major collectors.
- **Classification 6:** Minor collectors, both of which serve local roads and funnel into the arterial network.
- **Classification 7:** Local roads, which are the remaining roads.

The HPMS does not capture data on all the local roads in a given state, and in Missouri, the local roads make up a negligible amount of the data tracked. States are required to submit a significant amount of data to the HPMS on an annual basis. Among this data, lane miles is one metric that demonstrates how the different functional classifications are designed to handle differing volumes of traffic. Contrary to highway miles, which measure the length of road, lane miles incorporate the number of lanes a road has into its distance. Therefore, when a given classification has more lane miles in proportion to its highway miles, that indicates that classification has more lanes designed to handle a greater volume of traffic.

Figure 2.2 shows a map of Missouri roads by functional classification and Figure 2.3 shows a map of roads by functional classification for the urban areas of St. Louis, Kansas City and Springfield. Full highway miles and lane miles for the roads tracked by the HPMS are included in Table 2.2.[4] Of the roads that are tracked by the HPMS, by far the largest number of highway miles is for functional classification 5, major collectors, which make up just under 60% of total highway miles. The second largest amount of highway miles is for functional classification 4, minor arterials, which comprise 20% of highway miles. Interstates make up about 6% of highway miles, and primary arterials make up 15% of highway miles.

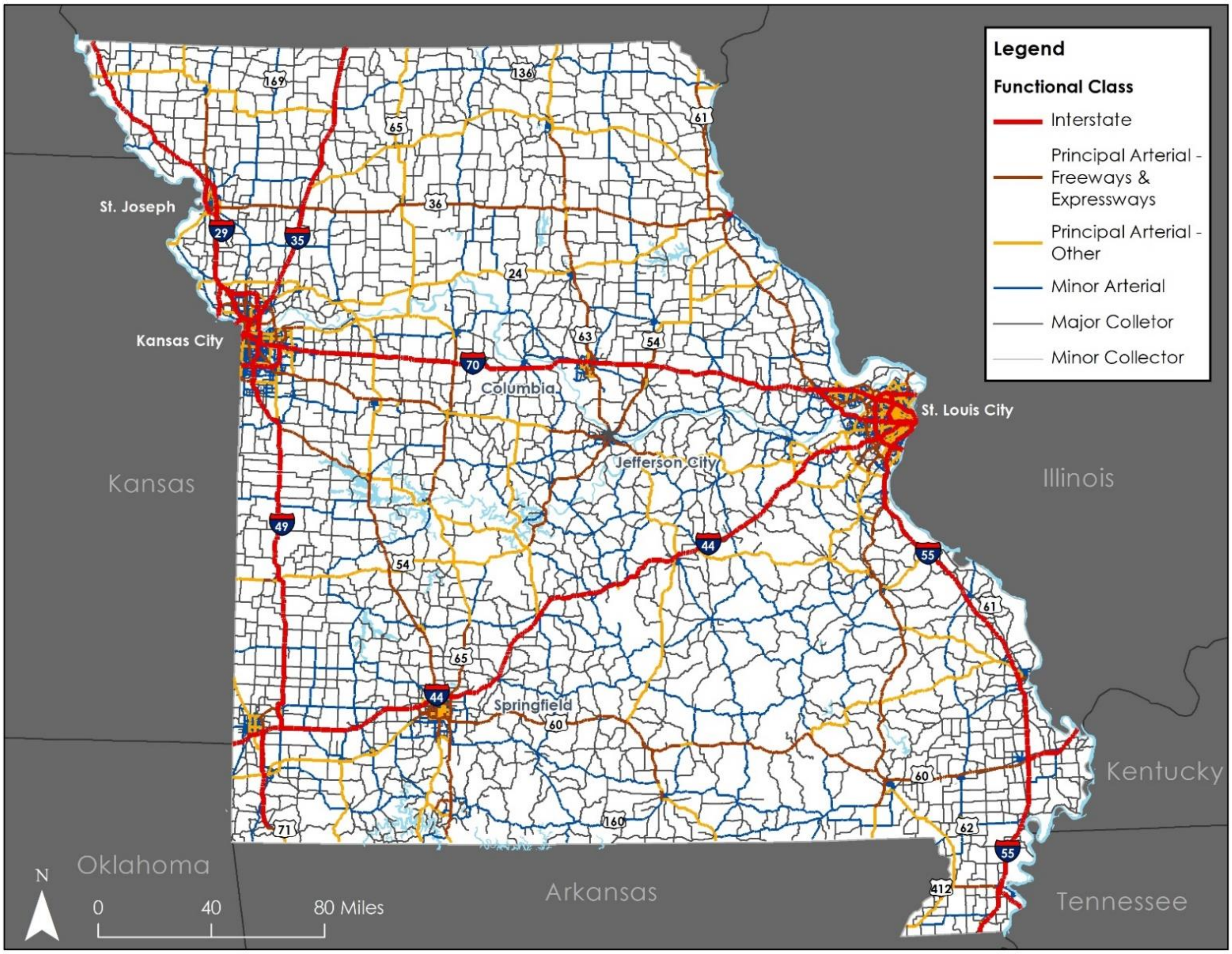
In Missouri, the interstate and principal arterial roads comprise a significantly higher percentage of lane miles than they do highway miles. This is because they feature multiple lanes designed to accommodate higher amounts of traffic. Of the total miles tracked by the HPMS, the length of the interstates total 5% of Missouri's highway miles but

[3] https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/

[4] The total number of highway miles differs from that of Table 2.1 because of differences between the HPMS and the state highway system in tracking smaller roads such as county roads, forest roads and off-interstate business roads.

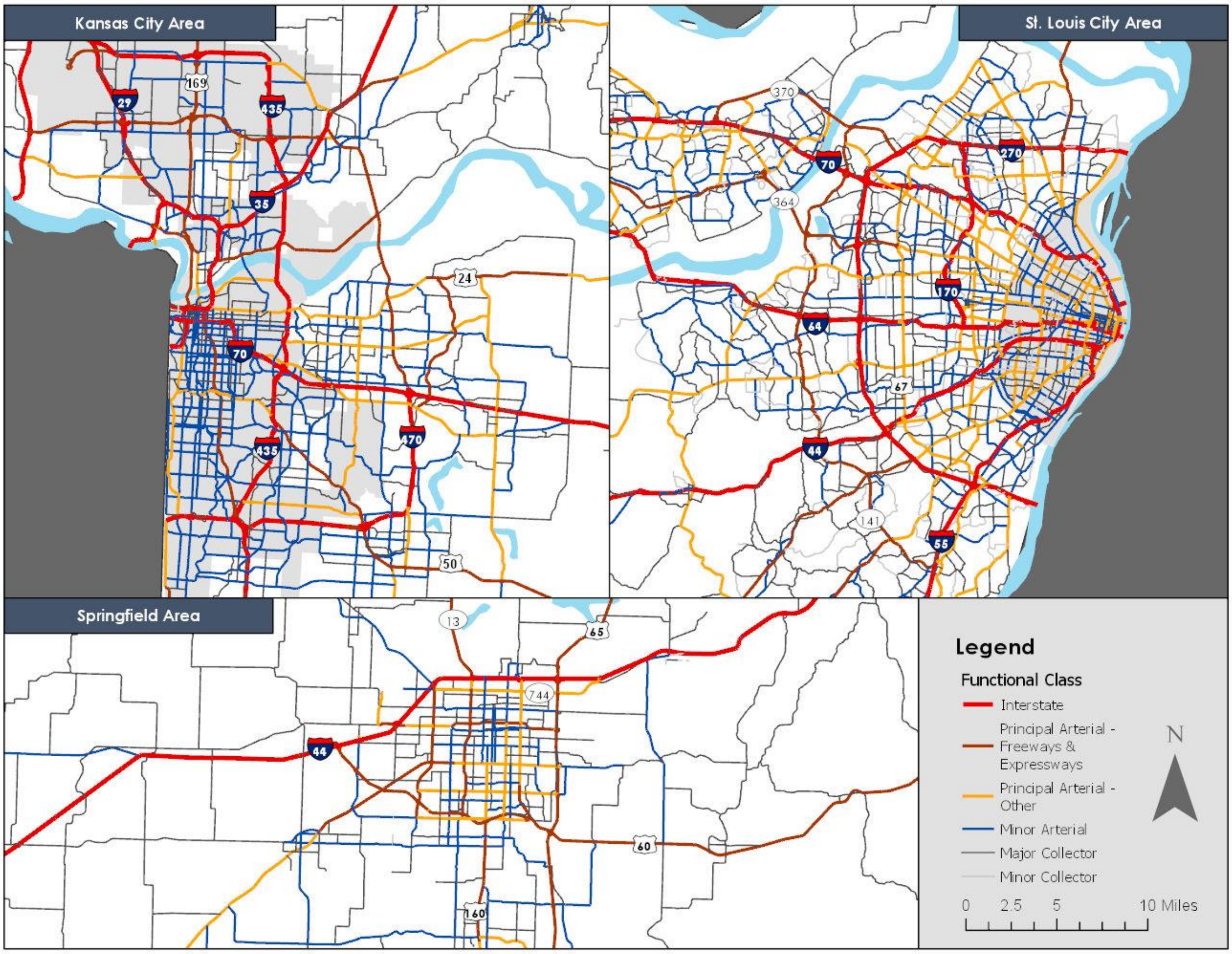
10% of Missouri's total lane miles. Major collectors, on the other hand, make up 60% of the total highway miles yet only 51% of the total lane miles. These different proportions give a sense of the vehicle capacity of each of the different road classifications.

FIGURE 2.2 MISSOURI ROADS BY FUNCTIONAL CLASSIFICATION



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

FIGURE 2.3 URBAN AREA ROADS BY FUNCTIONAL CLASSIFICATION



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

TABLE 2.2 HIGHWAY MILES AND LANE MILES OF MISSOURI ROADS TRACKED BY THE HPMS

FWHA Functional Classification	Highway Miles	Percent of Total Highway Miles	Lane Miles	Percent of Total Lane Miles
1 – Interstate	1,380	5%	6,553	9%
2 – Principal Arterial – Other Freeways and Expressways	1,621	5%	6,764	9%
3 – Principal Arterial – Other	2,752	9%	7,690	10%
4 – Minor Arterial	6,184	20%	14,019	19%
5 – Major Collector	18,585	60%	38,599	51%
6 – Minor Collector	385	1%	1,135	2%
7 - Local	0	0.0%	1	0%
Total	**30,907**	**100%**	**75,877**	**100%**

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

2.3 The National Highway System

Another classification system for roads is the National Highway System, which is a federally designated system of roads that is vital for the economic stability, national defense and overall health of the United States.[5] The NHS is composed of interstates, principal arterials, strategic highway network, major strategic highway network connectors and intermodal connectors that form the National Transportation Network.

Included in the NHS is the designation of *Intermodal Connectors,* which are roads leading to major intermodal[6] facilities where different modes of transportation intersect and, for certain facilities, where large volumes of freight are exchanged. Criteria used to determine inclusion as an NHS freight intermodal connector are listed in Table 2.3. Among the categories of freight intermodal facilities, Missouri has three airports, four ports and five truck/rail facilities which may have more than one intermodal connector road leading to that facility. The NHS and identified intermodal facilities are mapped out in Figure 2.4.[7]

[5] http://www.fhwa.dot.gov/planning/national_highway_system/.

[6] Note that the definition of an "intermodal facility" used here is that of the FHWA, which includes major rail, port, airport and intermodal freight facilities. This is a broader definition than the colloquial use of "intermodal" which often refers to containerized freight moving between truck, rail and marine vessels. Bulk, break-bulk or other types of freight facilities, as well as those handling containerized traffic, are candidates for designation as an intermodal facility for the purposes of the NHS.

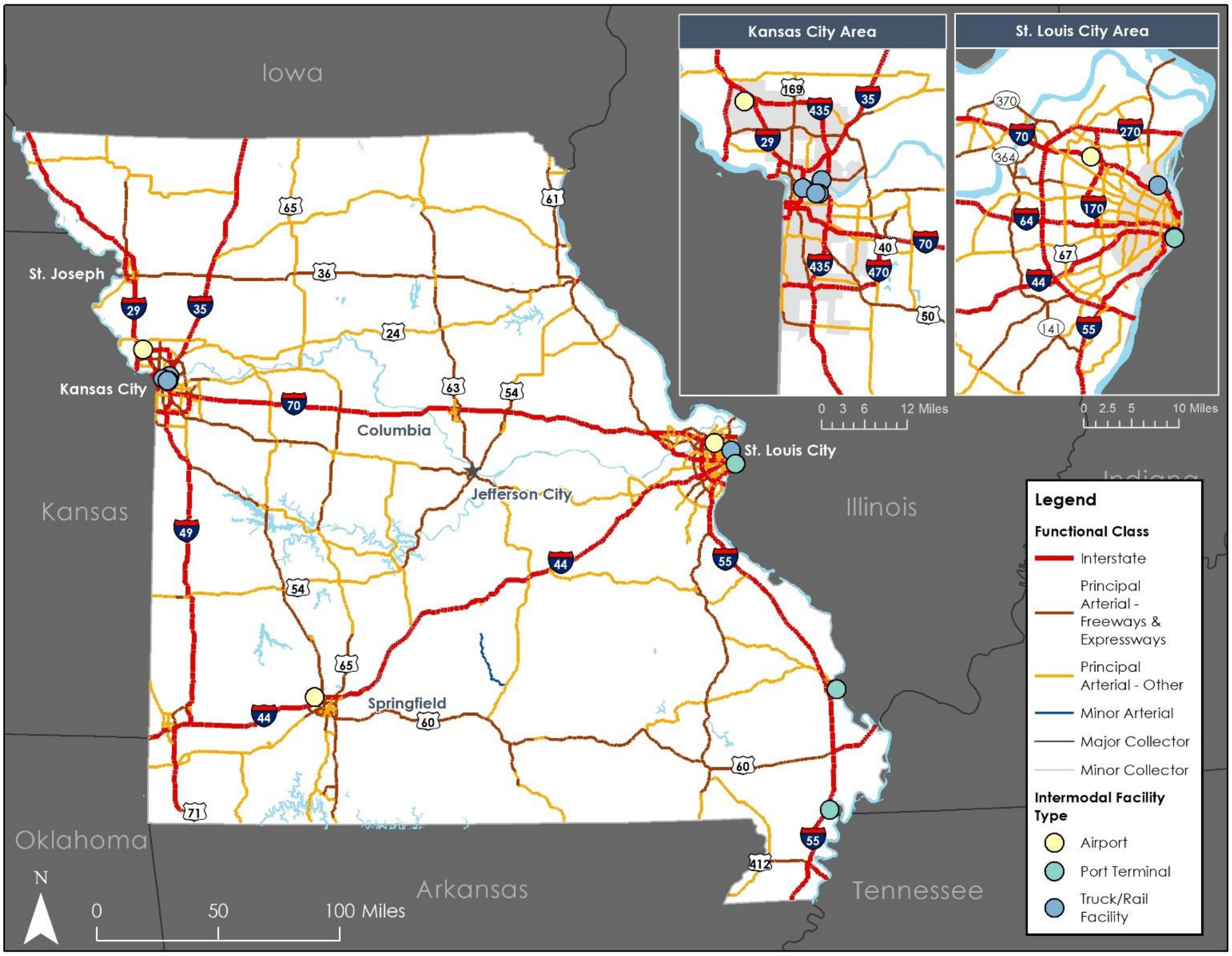
[7] Note that passenger intermodal facilities, such as Amtrak stations, intercity bus terminals or public transit, are not included in this analysis.

TABLE 2.3 NATIONAL HIGHWAY SYSTEM FREIGHT INTERMODAL FACILITY CRITERIA

Primary Criteria	
Airports	• Passengers – scheduled commercial service with more than 250,000 annual enplanements. • Cargo – 100 trucks per day in each direction on the principal connecting route, or 100,000 tons per year arriving or departing by highway transport vehicles.
Port Terminal	• Terminals that handle more than 50,000 Twenty-Foot Equivalent Units per year, or other units measured that would convert to more than 100 trucks per day in each direction. • Bulk commodity terminals that handle more than 500,000 tons per year by highway transport vehicles or 100 trucks per day in each direction on the principal connecting route. • Passengers – terminals that handle more than 250,000 passengers per year or 1,000 passengers per day for at least 90 days during the year.
Truck/Rail Facilities	• 50,000 TEUs per year or 100 trucks per day in each direction on the principal connecting route, or other units measured that would convert to more than 100 trucks per day in each direction.
Secondary Criteria	
• Intermodal terminals that handle more than 20% of passenger or freight volumes by mode within a state. • Intermodal terminals identified in either the Intermodal Management System or the state/metropolitan transportation plans as a major facility. • Significant investment in, or expansion of, an intermodal terminal. • Connecting routes targeted for investment by the state, MPO or others to address an existing or anticipated deficiency as a result of increased traffic.	

Source: Federal Highway Administration

FIGURE 2.4 MISSOURI'S NATIONAL HIGHWAY SYSTEM AND IDENTIFIED FREIGHT INTERMODAL FACILITIES



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

2.4 Freight System Designations

State and federal governments identify freight systems for multiple purposes, including regulating size and weight of trucks, identifying routes with heavy volumes of truck traffic for planning and enforcement purposes, and other uses. There are both federally and state designated highway freight networks in Missouri: the federal National Highway Freight Network and the state Designated Highway Network. Both are distinct systems from the NHS and serve specific functions related to truck traffic.

Federal: National Highway Freight Network

In the fall of 2015, Congress passed and the president signed the Fixing America's Surface Transportation Act, creating a new, long-term funding program for the nation's transportation system.

One key element of the FAST Act is the creation of a NHFN which has four components:

- **The Primary Highway Freight System** – A network of highways identified as the most critical highway portions of the U.S. freight system. Though most highway miles in the PHFS are interstates, a portion are non-interstate Intermodal Connectors. These are a subsection of the Intermodal Connectors designated under the NHS that connect intermodal facilities with interstates that are part of the PHFS. Missouri has 1,023 miles of interstates and intermodal connectors that are part of the PHFS.

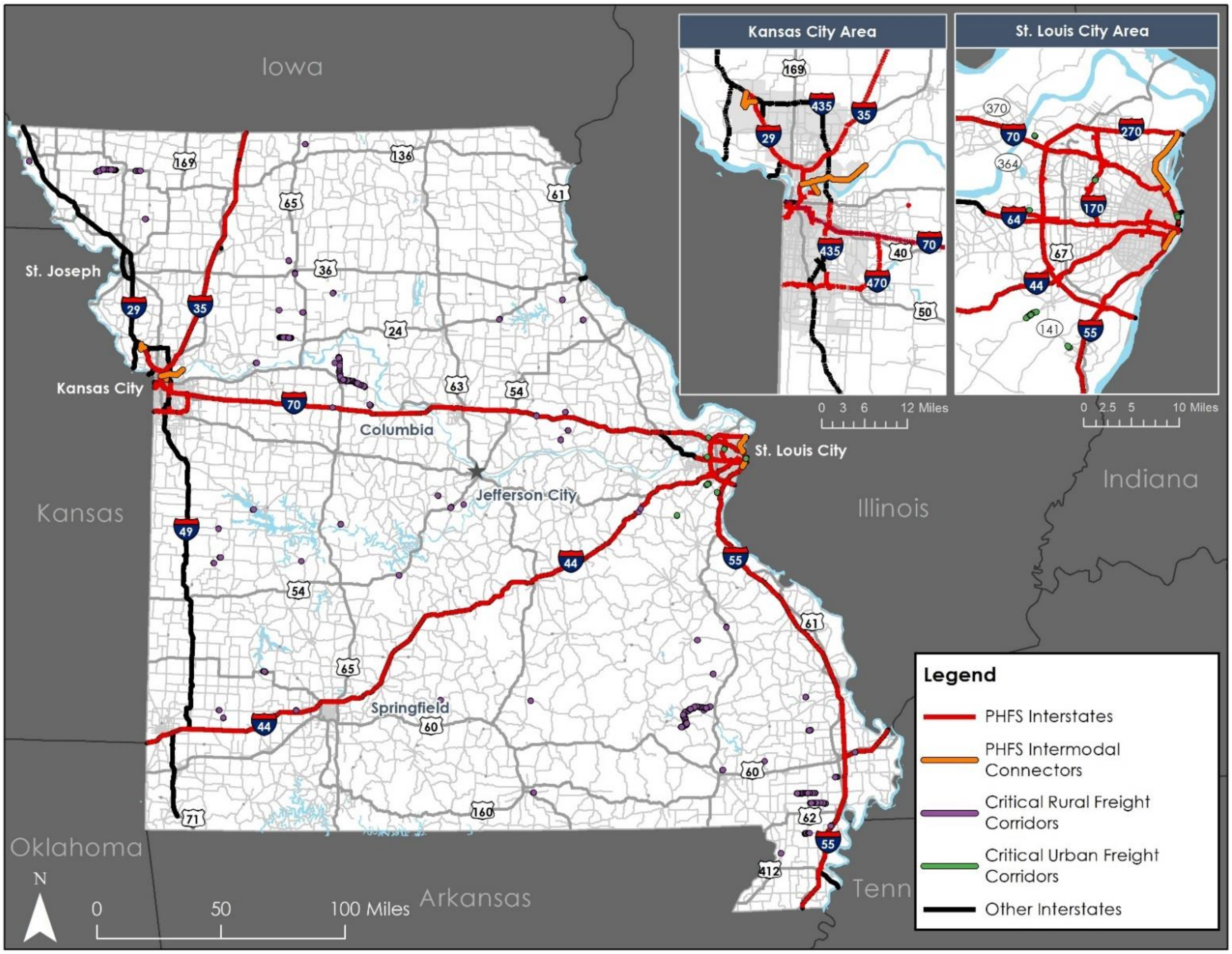
- **Interstate routes not part of the PHFS** – This consists of the remaining portion of interstate highways that are not part of the PHFS.

- **Critical Rural Freight Corridors** – These are public roads that are not in an urbanized area which provide access and connection to the PHFS or meet one of seven other criteria related to freight traffic and access to certain industries and/or facilities. These corridors are designated by each individual state and are limited to 150 miles of highway or 20% of the PHFS mileage in the state, whichever is greater. Missouri may designate 204 miles of CRFCs.

- **Critical Urban Freight Corridors** – These are public roads that are in an urbanized area which provide access and connection to the PHFS or meet one of four other criteria related to freight traffic and access to certain industries and/or facilities. These corridors are either designated by the metropolitan planning organization in consultation with the state, for urbanized areas with a population of 500,000 or greater; or are designated by the state, for urbanized areas with a population of less than 500,000. States are limited to a maximum of 75 miles of highway or 10% of the PHFS mileage in the state, whichever is greater. Missouri may designate 102 miles of CUFCs.

Figure 2.5 shows the NHFN routes in Missouri, which are divided based on the different subsystems noted above. Note that I-49 was not originally designated under the 2015 FAST Act as part of the PHFS, but it is included in the NHFN within the category of interstate route that is not part of the PHFS. CRFCs and CUFCs were identified under the 2017 Missouri State Freight Plan and are included in Figure 2.5 for context. This Plan will identify a current set of both CRFCs and CUFCs as part of the Freight Network designation.

FIGURE 2.5 MISSOURI NATIONAL HIGHWAY FREIGHT NETWORK

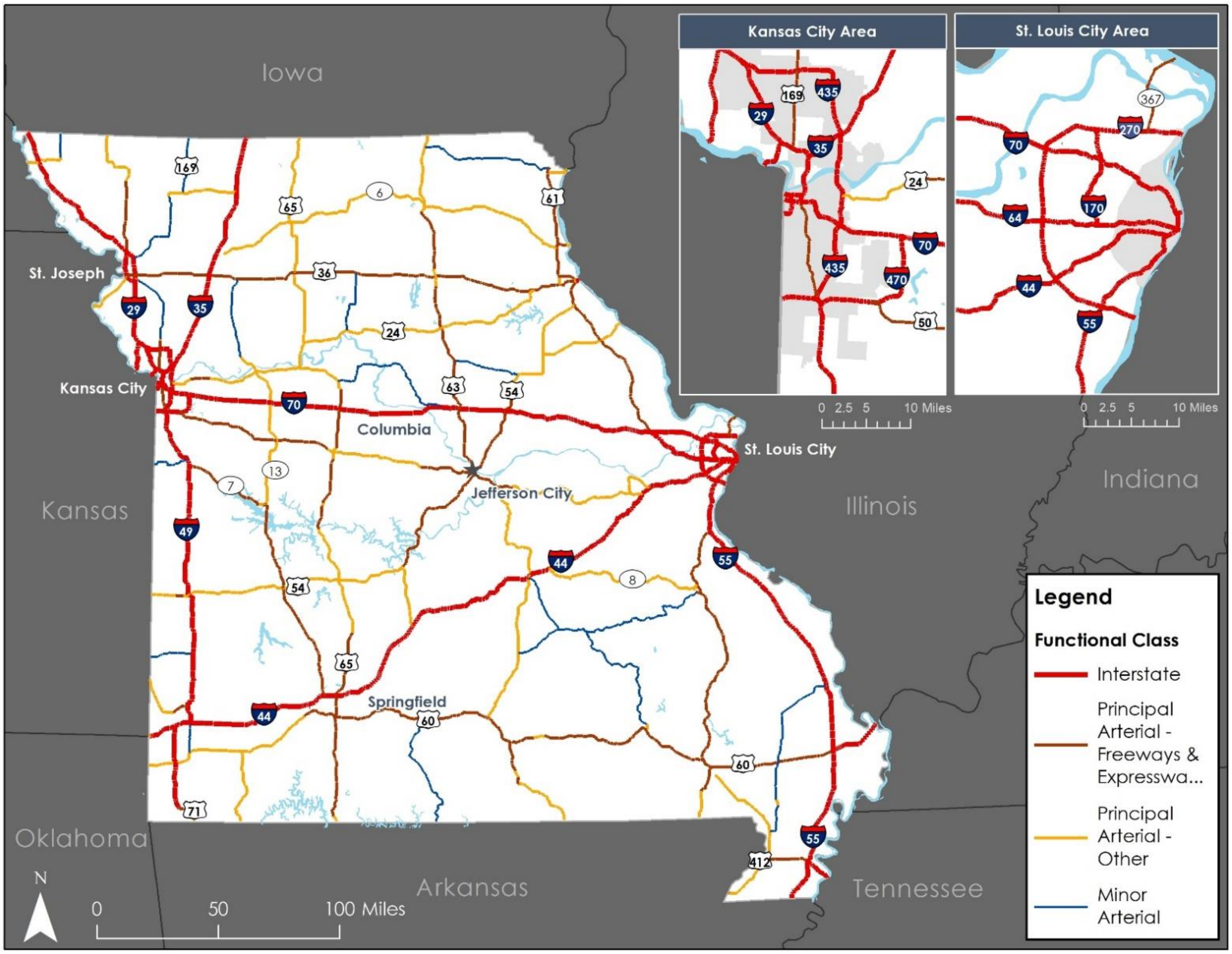


Source: *Federal Highway Administration; analysis by Cambridge Systematics, 2020. CUFC and CRFC are those that were identified in the 2017 Missouri State Freight Plan.*

State: Designated Highway Network

Missouri's state designated highway network pre-dates the 2015 FAST Act, to the Surface Transportation Assistance Act passed in 1982, which required Missouri to create the Designated Highway Network. Though this network has been superseded by the NHFN, the DHN is still used in Missouri for the imposition of regulations related to truck size and weight, as summarized in Table 2.4. A map of the DHN in Missouri is included in Figure 2.6.

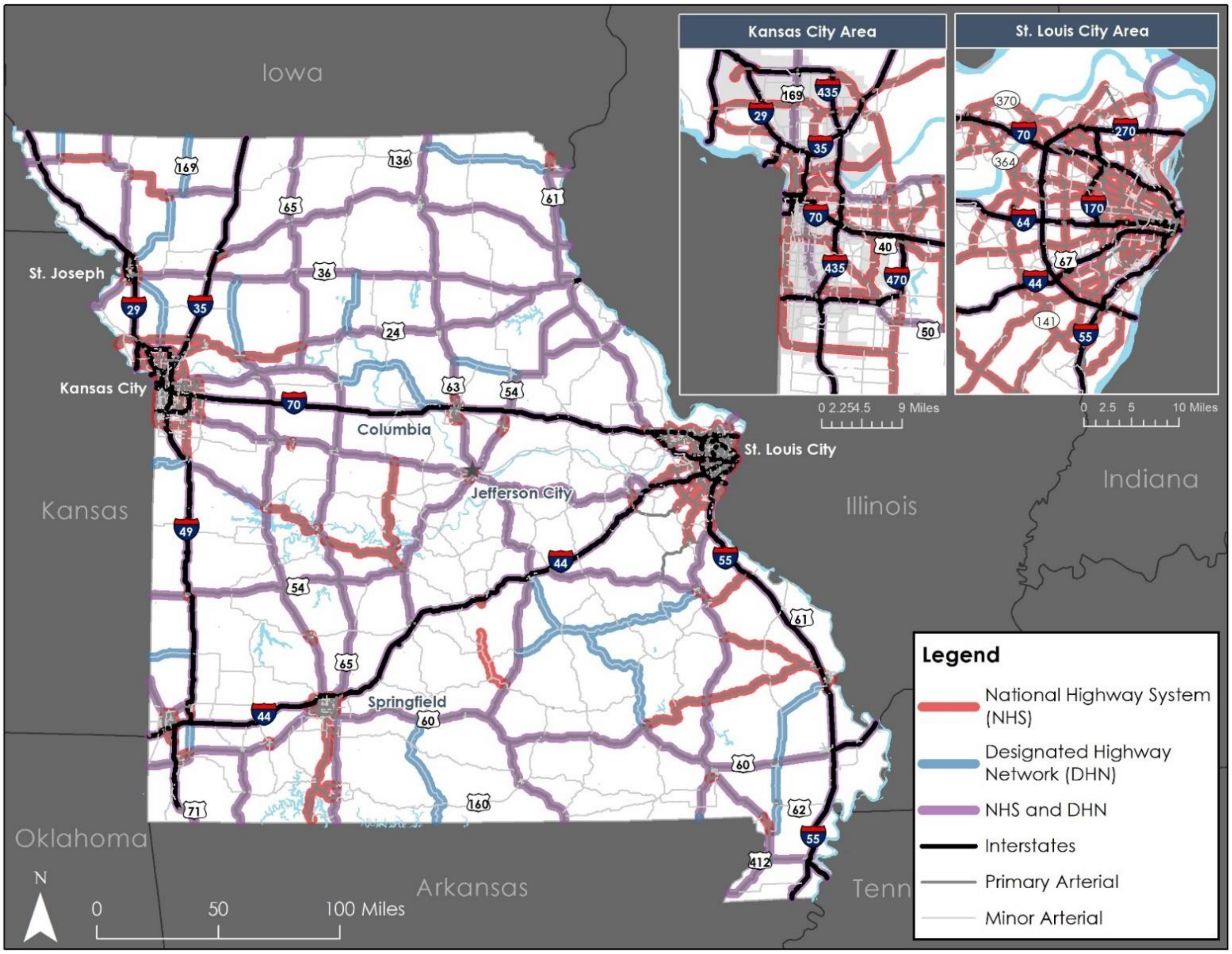
FIGURE 2.6 DESIGNATED HIGHWAY NETWORK IN MISSOURI



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Figure 2.7 compares the DHN with the NHS. The figure shows a map of all roads with a functional classification 4 or greater (i.e. all minor arterials, primary arterials and interstates) and highlights which roads are part of the NHS, DHN or both. Overall, there is broad overlap between the NHS and DHN, with the NHS extending into urban areas and the DHN covering more rural roads.

FIGURE 2.7 COMPARISON OF DESIGNATED HIGHWAY NETWORK AND THE NATIONAL HIGHWAY SYSTEM



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

2.5 Oversize Overweight Network and Weigh Stations

Size and Weight Restrictions

In Missouri, size and weight restrictions for trucks, legally designated as Commercial Motor Vehicles, are broadly delineated based on three main categories: (1) Commercial Zones, which surround major metropolitan areas; (2) the Designated Highway Network, which include all interstates, primary arterials, select minor arterials, and all areas within 10 air miles of those roads; and (3) the primary highway system, which includes all other minor arterials and areas beyond 10 air miles of the Designated Highway Network. Weight restrictions are based on the number of truck axles and the length of the truck and go up to a maximum of 80,000 pounds for all trucks.[8] However, there are exceptions that allow trucks hauling livestock and milk to carry loads up to a gross weight of 85,500 pounds, and trucks hauling grain and grain co-products to carry loads up to 88,000 pounds.[9] Table 2.4 includes a summary of those requirements.

TABLE 2.4 COMMERCIAL MOTOR VEHICLE LEGAL RESTRICTIONS IN MISSOURI

Restriction Area	Description	Legal Restrictions
Commercial Zones	Applies to areas within major metropolitan areas in Missouri including St. Louis, St. Charles, Columbia, Springfield, Kansas City and St. Joseph	• Overall Height: 15’0” • Overall Width: 8’6” • Length of semitrailer in a truck-tractor/semitrailer combination: 53’0” • Overall Length for other combinations (truck/ trailer, towing, etc.): 65’0” • Overall Length of each semitrailer or trailer in a truck-tractor semitrailer and trailer combination: 28’0” • Maximum weight per axle: 22,400 pounds
Designated Highway Network	Applies to all interstates and primary arterials and select minor arterials plus all areas within 10 air miles of those roads	• Overall Height: 14’0” • Overall Width: 8’6” • Length of semitrailer in a truck-tractor/semitrailer combination: 53’0” • Overall Length for other combinations (truck/ trailer, towing, etc.): 65’0” • Overall Length for single unit: 45’0” • Overall Length of each semitrailer or trailer in a truck-tractor semitrailer and trailer combination: 28’0” • Maximum gross weight: 80,000 pounds*
Primary Highway Network	Applies to all remaining minor arterials as well as areas that are more than 10 miles away from the Designated Highway Network	• Overall Height: 13’6” • Overall Width: 8’6” • Overall Length for truck-tractor/semitrailer combination (applies only to areas more than 10 miles beyond the Designated Highway Network): 60’0” • Overall Length for Other combinations (truck/trailer, towing, etc.) (applies only to areas more than 10 miles beyond interstates and the primary highway system): 55’0” • Maximum gross weight: 80,000 pounds*

** Under Section 304.180, the total gross weight of any vehicle or combination of vehicles hauling milk from a farm to a processing facility shall not exceed 85,500 pounds while operating on highways other than interstate and defense highways.*

Source: https://www.modot.org/sites/default/files/documents/MoVehRouteMap-Statewide%5B1%5D.pdf

[8] https://www.modot.org/sites/default/files/documents/MoVehRouteMap-Statewide%5B1%5D.pdf

[9] https://www.modot.org/sites/default/files/documents/LegalSizeandWeight%5b1%5d_0.pdf

Oversize Overweight Vehicles

In Missouri, if a truck is hauling a load that cannot be reduced below the set restrictions, the carrier can obtain a single trip Oversize Overweight permit beyond these limits. For size, OSOW permits allow vehicles to transport loads with routine maximum permittable limits of 16 feet high, 16 feet wide and 150 feet long.[10] For weight, they also allow vehicles to transport loads with a routine maximum permittable weight limit of 160,000 pounds on the interstate and DHN and no routine maximum permittable weight limit for travel within commercial zones. Additional permit fees apply to superloads, which are loads that exceed the routine permittable maximum. Furthermore, house-moving carriers must follow additional restrictions, including obtaining a Missouri House Move License. Finally, there are additional permissions given to farmers and others carrying grain or livestock to carry overweight loads on the state highways (other than interstates).

Shippers that apply for single trip OSOW permits must come with detailed information about the vehicle used, the load, and the origin, destination, and proposed route of transit. A map on the MoDOT website lists specific OSOW restrictions for individual roads, highways and metropolitan areas as well as points where vertical clearance may be restricted.[11] Once a shipper submits the information required to obtain an OSOW permit, MoDOT assigns a route using a complex, computerized system that tests for height, weight, width, length, axle load and other regulated factors to safely move OSOW loads. This method ensures safety when determining when and how shippers transport OSOW loads.

Blanket permits are available for carriers who move certain commodities multiple times over the year on state-maintained highways. These permits allow for loads up to 12 feet 6 inches in width and 150 feet in overall length and can include mobile homes, pipes/poles/beams, farm implements, construction equipment, government movement, multiple commodity combinations, implements of husbandry and hay. Overweight blanket permits are available for emergency response vehicles, concrete trucks, well digging rigs, 3- and 4-axle cranes and raw milk.[12] [13]

Figure 2.8 shows the number of OSOW permits issued in Missouri from 2016 to 2020, which includes blanket permits and single-trip permits. Recent years have seen a steady increase in the number of OSOW permits issued, rising by 6% from 144,513 in 2016 to 152,595 in 2019. However, the number of permits issued in 2020 correspond to a slight decrease in year over year numbers as compared to 2019.

Figure 2.9 shows the number of superload permits issued over the same time period. There was a significant increase in the number of superload permits beginning in 2020. This is largely due to growth in the wind farm sector. In 2020 there was an increase in wind farm construction statewide, which required superloads to transport large components.

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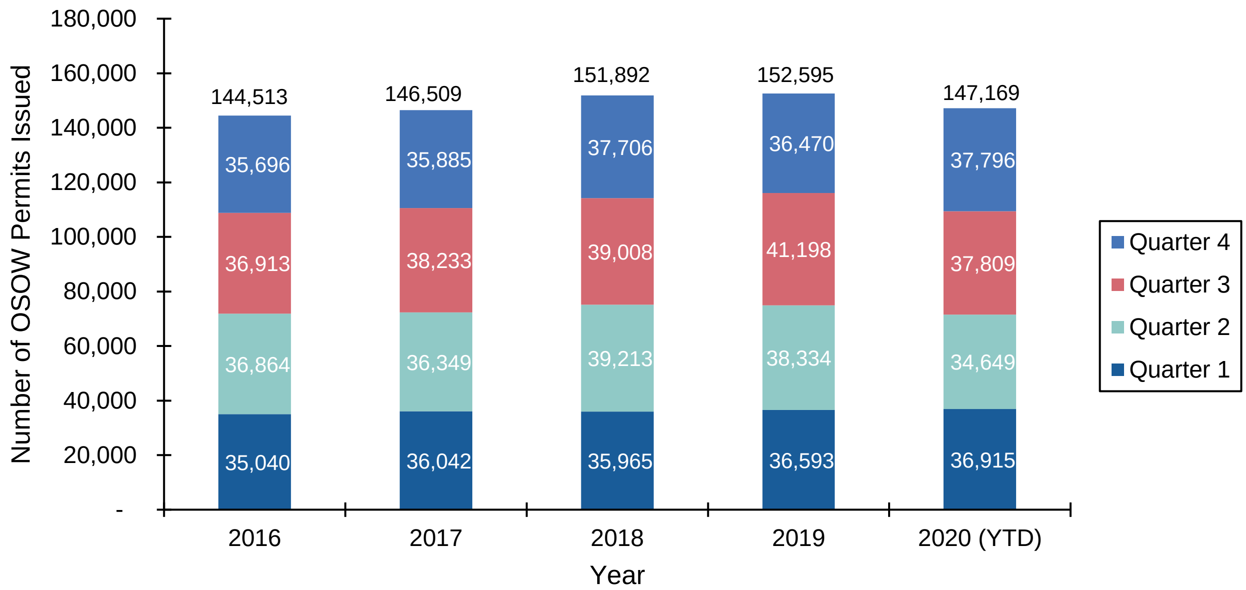
[10] https://www.modot.org/sites/default/files/documents/Missouri%20Trucking%20Guide.pdf

[11] https://traveler.modot.org/mcm/MotorCarriersMap.html

[12] MoDOT is currently reviewing rules that may allow haulers moving cranes that have up to five axles to obtain a blanket permit.

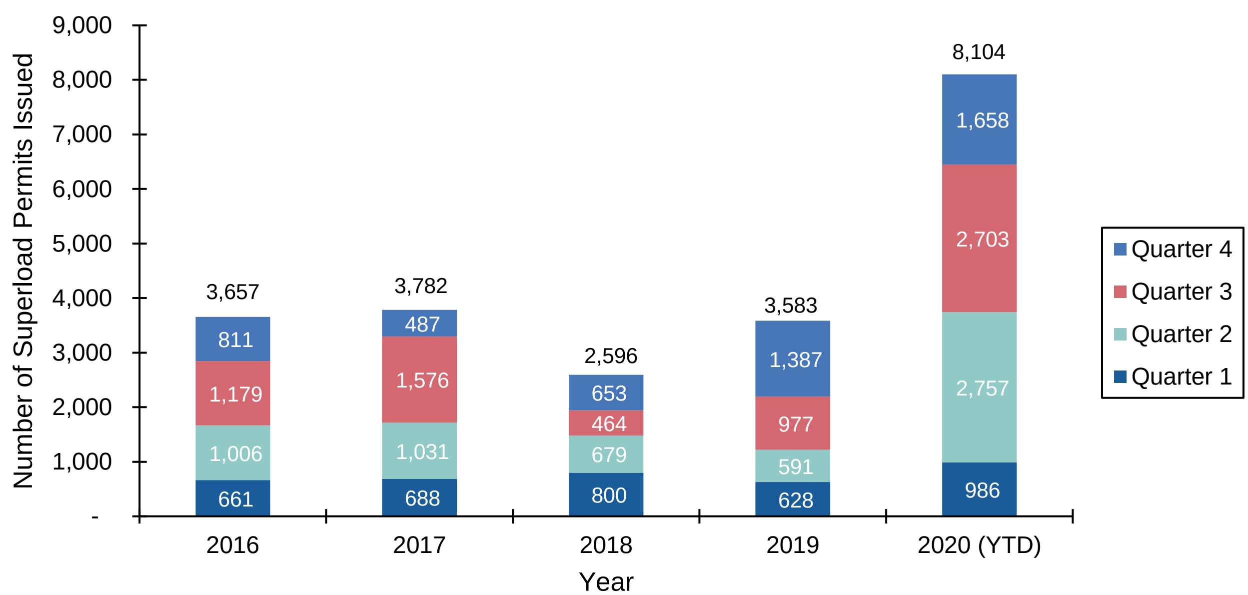
[13] As of May 30, 2021, blanket permits allow for loads up to 12 feet 6 inches in width. Prior to this date, loads could be up to 12 feet 4 inches in width. Additionally, 3- and 4- axle cranes are eligible for blanket permits as of May 30, 2021.

FIGURE 2.8 NUMBER OF OVERSIZE OVERWEIGHT PERMITS ISSUED FROM 2016 - 2020



Source: MoDOT.

FIGURE 2.9 NUMBER OF SUPERLOAD PERMITS ISSUED FROM 2016 - 2020



Source: MoDOT.

Weigh Stations

There are 21 weigh stations with fixed scales statewide, all but three of which are along the interstates. Under Section 304.235 of the Revised Statutes of Missouri, all trucks, except for those licensed to carry 18,000 pounds or less, are required to stop at an official weigh station. Trucks must stop at any open weigh station they pass. However, there are programs that allow carriers electronic permission to bypass sites if they meet certain conditions based on their safety history, credentials status and vehicle size/weight.

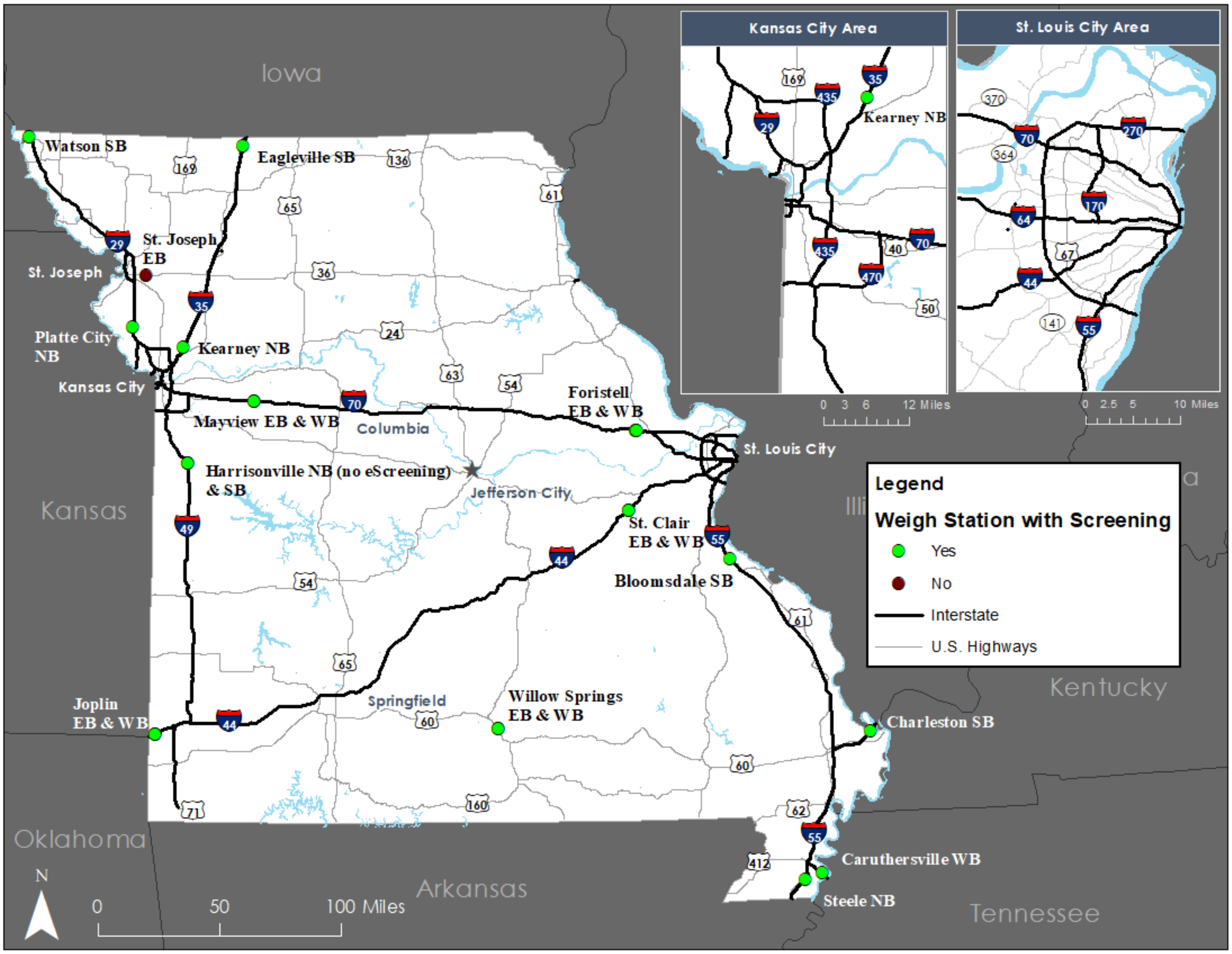
A map of Missouri weigh stations is displayed in Figure 2.10. Note that some sites are pairs—located on opposite sides of the highway in the same area—that appear as a single point on this map. These weigh stations are run by the Commercial Vehicle Enforcement Division of the Missouri State Highway Patrol. In 2019, static scales at these 21 sites weighed more than 1.1 million trucks. In addition, nearly 12 million trucks were weighed using weigh in motion, a technology that weighs vehicles as they travel on the highway at high speeds.[14] WIM provides information for planning purposes, allows enforcement to notice trends that occur when an officer is not available to formally weigh a vehicle, and if located near a static scale can be used to screen vehicles and allow enforcement to focus on those most likely to be overweight. Finally, approximately 1,100 weighings occurred in 2018 using portable scales that officers carry in their vehicle.[15]

WIM and other vehicle screening technology used in Missouri will be discussed further in the Truck Parking profile and Intelligent Transportation System profile.

[14] A weighing obtained from WIM is not accurate enough to cite a vehicle for being overweight. Vehicles must be weighed on a fixed, static scale or using calibrated portable scales in order to issue a citation.

[15] Missouri Department of Transportation, State Enforcement Plan for 2019

FIGURE 2.10 MISSOURI WEIGH STATIONS



Source: Highway Performance Monitoring System, 2018; MoDOT, 2018.

3.0 Highway Freight Transportation Demand

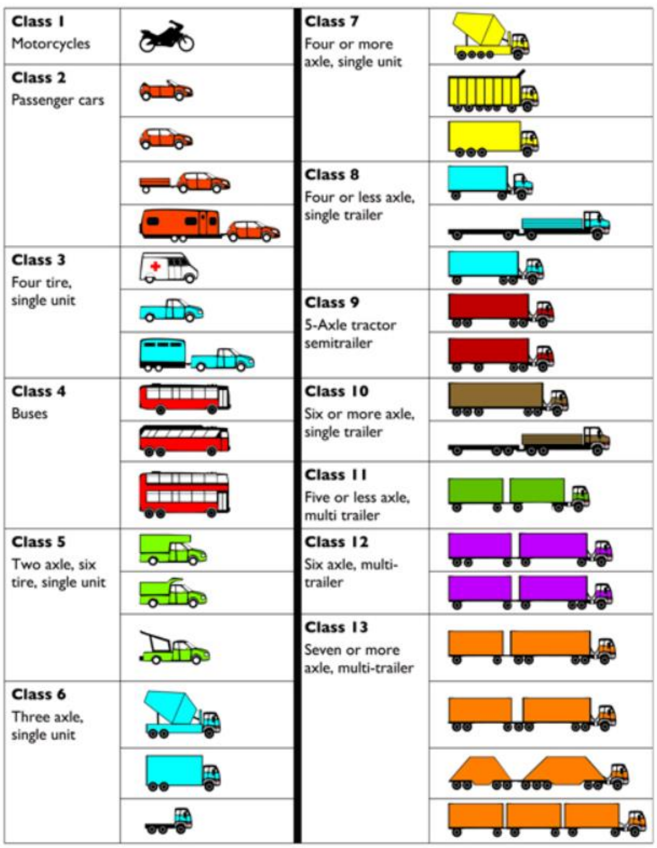
3

Highway freight transportation demand refers to how many trucks are using Missouri's highway infrastructure, what they are carrying and what markets they are serving.

3.1 Truck Volumes and Users

Overall traffic volume is tracked through average annual daily traffic. The FHWA defines this measure as estimating "the total traffic volume passing a point (or segment) of a road in both directions for a year divided by the number of days in the year."[16]. The corresponding measure for truck traffic is the average annual daily truck traffic.[17] The HPMS counts truck traffic within two broad categories: single unit truck AADTT, which include classes 4-7; and combination truck AADTT, which include vehicle classes 8-13 (see Figure 3.1 for an illustration). For purposes of this analysis, these two measurements have been summed into an overall AADTT value because freight can be transported both by single-unit and combination trucks.

FIGURE 3.1 FHWA VEHICLE CLASSES



Source: *https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm*

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[16] http://fhwa.dot.gov/policyinformation/pubs/pl18027_traffic_data_pocket_guide.pdf

[17] AADTT is measured using techniques that consider variations in traffic on different days of the week to compute the mean truck traffic volume on a given day. To avoid exacerbating distortions caused by very high or low values, this analysis uses the length-weighted AADTT across the entire route to compare truck volumes between different routes, corridors or designations.

The latest HPMS data available for Missouri is 2018. In that year, trucks drove approximately 19.6 million miles daily, which corresponds to 7.1 billion miles per year. Trucks drove more than 12 million miles per day on interstates alone, corresponding 4.6 billion miles per year. On all non-interstate roads, trucks drove 6.9 million miles per day, adding up to 2.5 billion miles per year. These numbers give context into the magnitude of the amount of freight that is transported by trucks in Missouri.

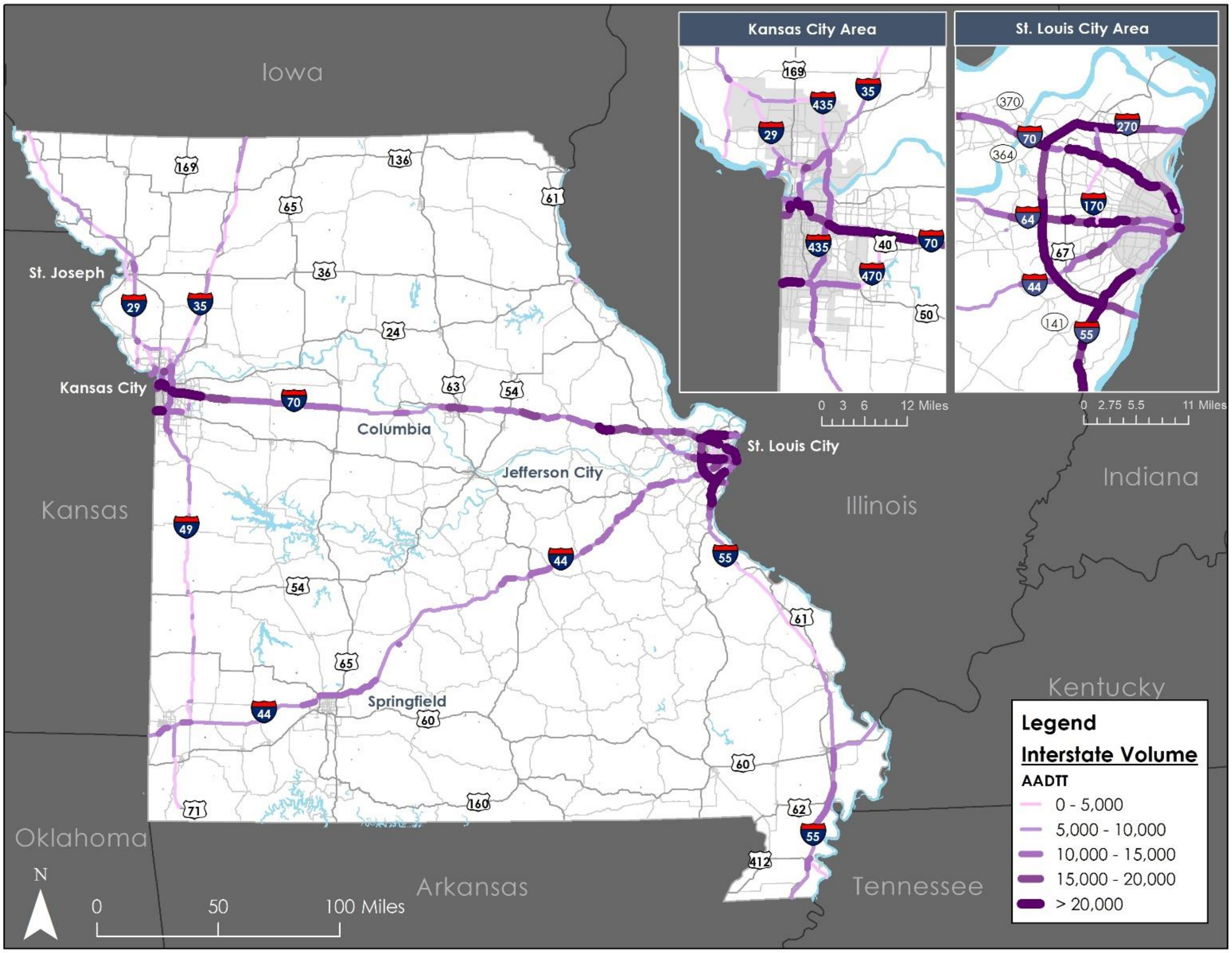
Interstate Truck Volumes

Interstates are by far the highest volume highways for truck traffic. The median AADTT for the entire Missouri interstate system was approximately 8,404 trucks, with a maximum of 35,996 on I-70 in St. Louis (between exit 243A and 243C). Across Missouri's interstate system, trucks comprise between 29% and 72% of AADT. The segment where the maximum percentage of truck traffic is found is on I-70 west of Warrenton between exits 188 (Truxton) and 193 (Warrenton).

Figure 3.2 depicts truck volumes on Missouri's interstate system, and Figure 3.3 shows truck volumes as a percent of all traffic. The highest volumes of truck traffic are found in and around St. Louis and Kansas City, as well as on I-70 which connects those two cities. There is also high truck traffic on the other major interstates, including I-44, which connects St. Louis with Springfield; I-49, which runs south of Kansas City; and I-55, which proceeds south of St. Louis to Memphis, Tennessee. These interstates also connect with destinations outside Missouri. For instance, many trucks traveling to and from St. Louis (on I-44) or Kansas City (on I-49) are traveling to destinations in the Gulf Coast and Great Lakes states. I-70 is also one of the main east-west highways in the nation, and it proceeds to destinations like Denver and Indianapolis, while I-55 is one of the main north-south highways, connecting Chicago with the Gulf Coast.

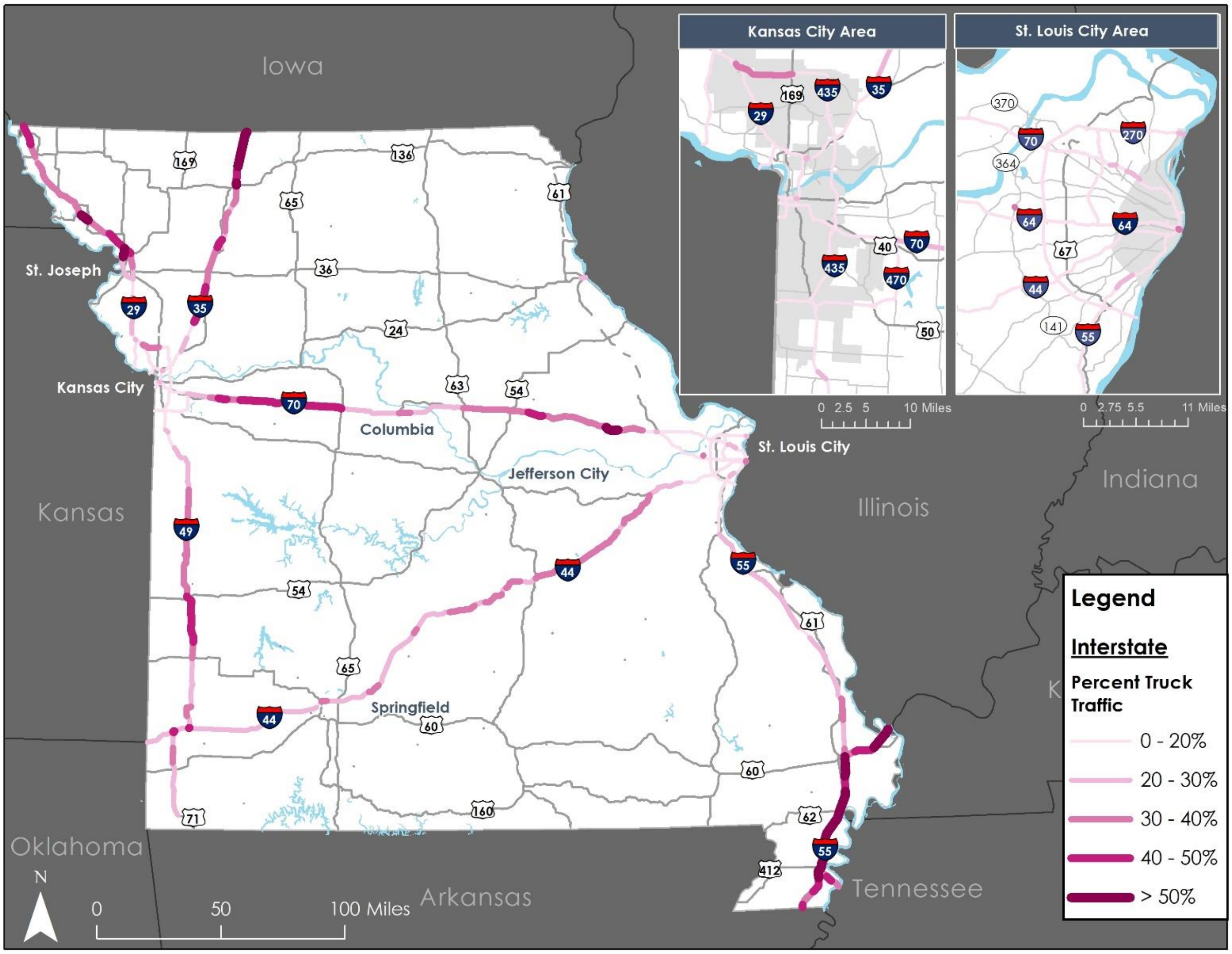
The high volumes of trucks seen in the state's urban areas do not necessarily translate into trucks being a high percentage of overall traffic. Many of the areas that see the highest percent of trucks are those that are between major urban centers, such as on I-70 between Kansas City and Columbia. Additionally, trucks make up a high percentage of traffic on interstates that connect with the surrounding states, such as I-55 near the borders of Kentucky, Tennessee and Arkansas, and on I-35, near the border with Iowa.

FIGURE 3.2 MISSOURI INTERSTATE AVERAGE ANNUAL DAILY TRUCK TRAFFIC



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

FIGURE 3.3 MISSOURI INTERSTATE AVERAGE ANNUAL DAILY TRUCK TRAFFIC AS A PERCENT OF AVERAGE ANNUAL DAILY TRAFFIC



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Table 3.1 lists the 10 highest volume interstates for truck traffic in the state. Truck traffic volumes are highest on the interstates that are in and surround St. Louis, such as I-270, I-255 and I-64, and on the interstates that are in and surround Kansas City, such as I-635 and I-670. I-70 and I-44, the two interstates that span the state, also accommodate many trucks every day.

TABLE 3.1 TOP MISSOURI INTERSTATES FOR AVERAGE ANNUAL DAILY TRUCK TRAFFIC

Rank	Interstate Name	Length-Weighted Bi-directional AADTT	Brief Description of Location
1	I-270	23,726	Beltway interstate that surrounds the city of St. Louis and most of St. Louis County
2	I-255	14,853	Beltway interstate spur south of St. Louis off of I-270 and I-55 that crosses the Mississippi River
3	I-70	13,763	Interstate that spans the state of Missouri and connects St. Louis with Kansas City
4	I-64	12,664	Interstate that originates at I-70, bisects St. Louis and connects with multiple interstates in Illinois
5	I-635	10,392	Interstate originating in Northwest Kansas City and connecting with I-35 in Kansas
6	I-670	9,964	2-mile interstate that connects I-70 and I-35 in downtown Kansas City
7	I-44	9,518	Interstate that begins in St. Louis and spans Missouri through Springfield and Joplin on the way to Oklahoma
8	I-55	8,230	Interstate running from St. Louis down the eastern edge of the state and into Arkansas
9	I-435	8,145	Beltway interstate that surrounds Kansas City
10	I-470	7,349	Beltway interstate in the south Kansas City metro area that connects I-435 with I-70

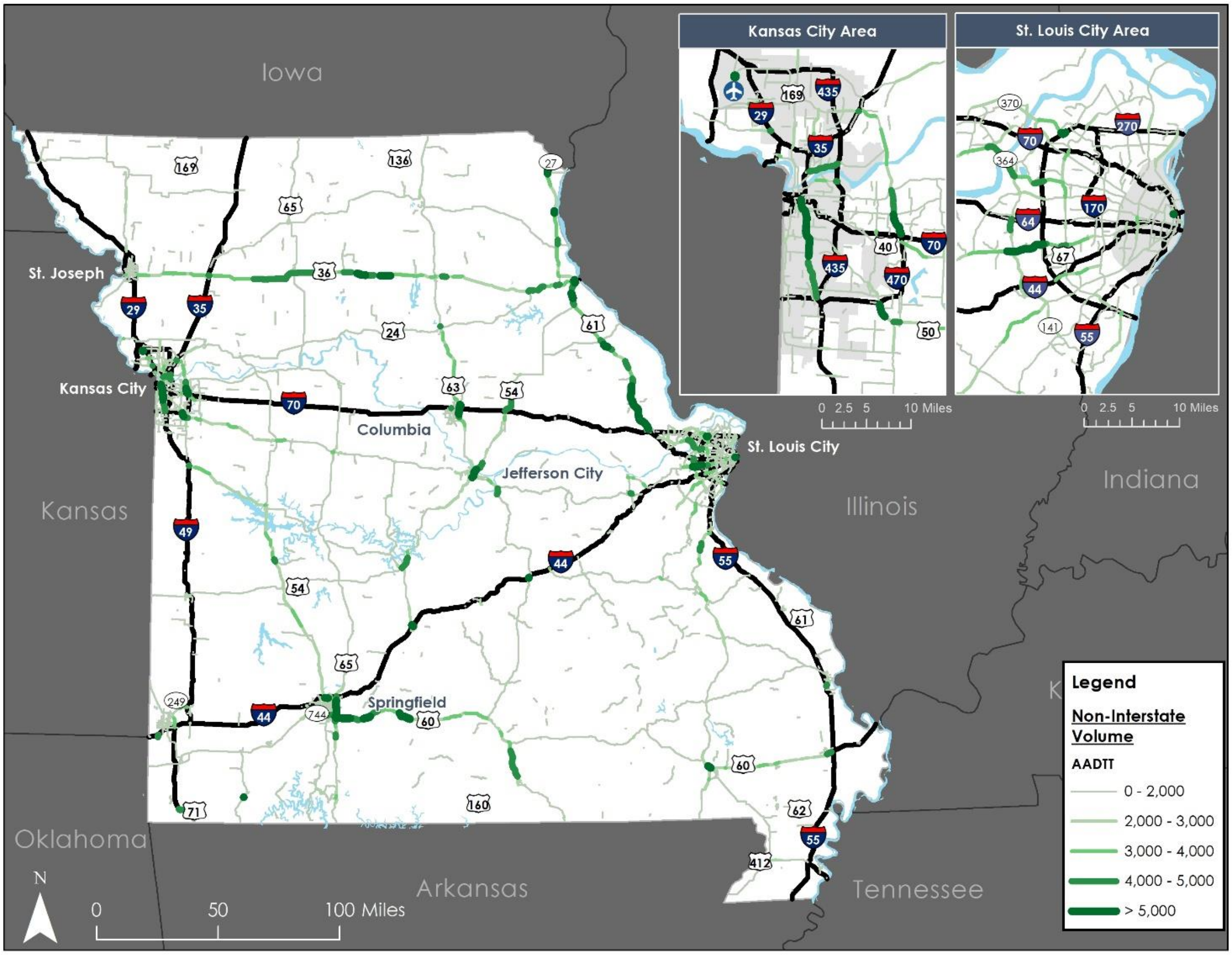
Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020.

Non-Interstate Truck Volumes

In general, non-interstate routes accommodate far fewer trucks per day than interstates. Though AADTT values on interstates can regularly measure greater than 10,000, the highest AADTT measurement on non-interstates is 9,656 on U.S. 54 in Jefferson City, crossing the Jefferson City Bridge. Nonetheless, vehicle traffic on non-interstates is crucial to the Missouri economy, as it serves first-mile/last-mile connections statewide. Non-interstate routes are also particularly important for the agriculture industry, which is dispersed throughout the rural areas of the state. However, traffic on non-interstates can vary greatly across the length of a route, with some portions seeing high volumes and others seeing lower volumes. This section presents an overview of volumes on non-interstate routes, and more details are presented in Appendix A.

Figure 3.4 shows truck volumes on the non-interstate routes in Missouri (note the difference in scale in the legend of the corresponding interstate truck volume map, Figure 3.2). Figure 3.5 shows truck volumes as a percent of AADT. Table 3.2 lists the top ten highest non-interstates based on the length-weighted AADTT across the length of each route. This table highlights routes that play a role in first-mile or last-mile connections, such as the International Circle near the Kansas City International Airport and MO-744 in Springfield, which serves several trucking companies including Prime, Inc. and Old Dominion Freight Lines, two of the largest in the nation. Additionally, routes such as U.S. 36 and U.S. 61 provide alternative routes to the interstates that span large portions of the state, either east-to-west (in the case of U.S. 36) or north-to-south (in the case of U.S. 61). Finally, routes such as MO-364, MO-370 and MO-249 connect parts of the urban areas of the state with the interstates.

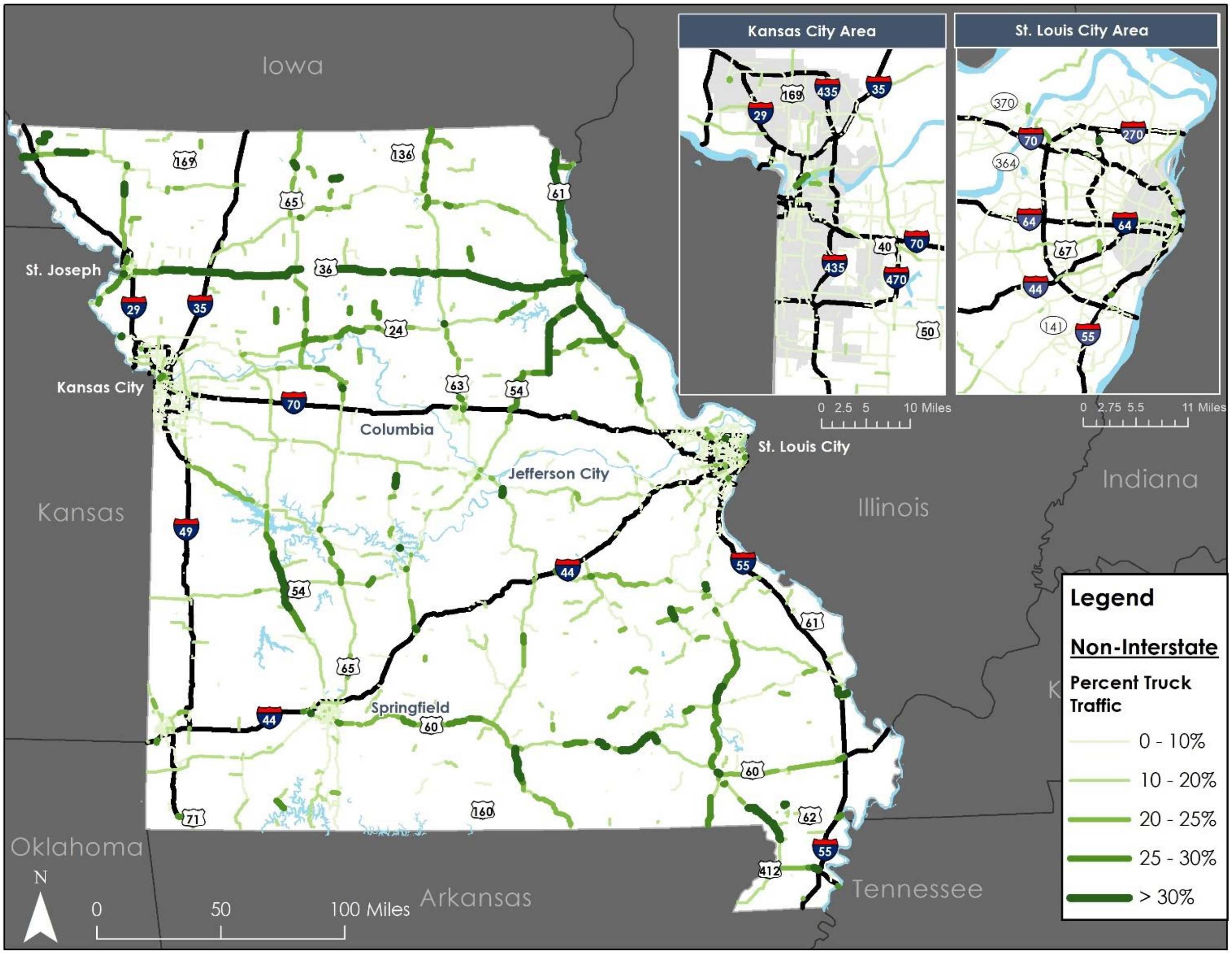
FIGURE 3.4 MISSOURI NON-INTERSTATE AVERAGE ANNUAL DAILY TRUCK VOLUMES



Note: Roads with no truck traffic data have been excluded from this map.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

FIGURE 3.5 MISSOURI NON-INTERSTATE AVERAGE ANNUAL DAILY TRUCK TRAFFIC AS A PERCENT OF AVERAGE ANNUAL DAILY TRAFFIC



Note: *Routes with no truck traffic data have been excluded from this map.*

Source: *Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020*

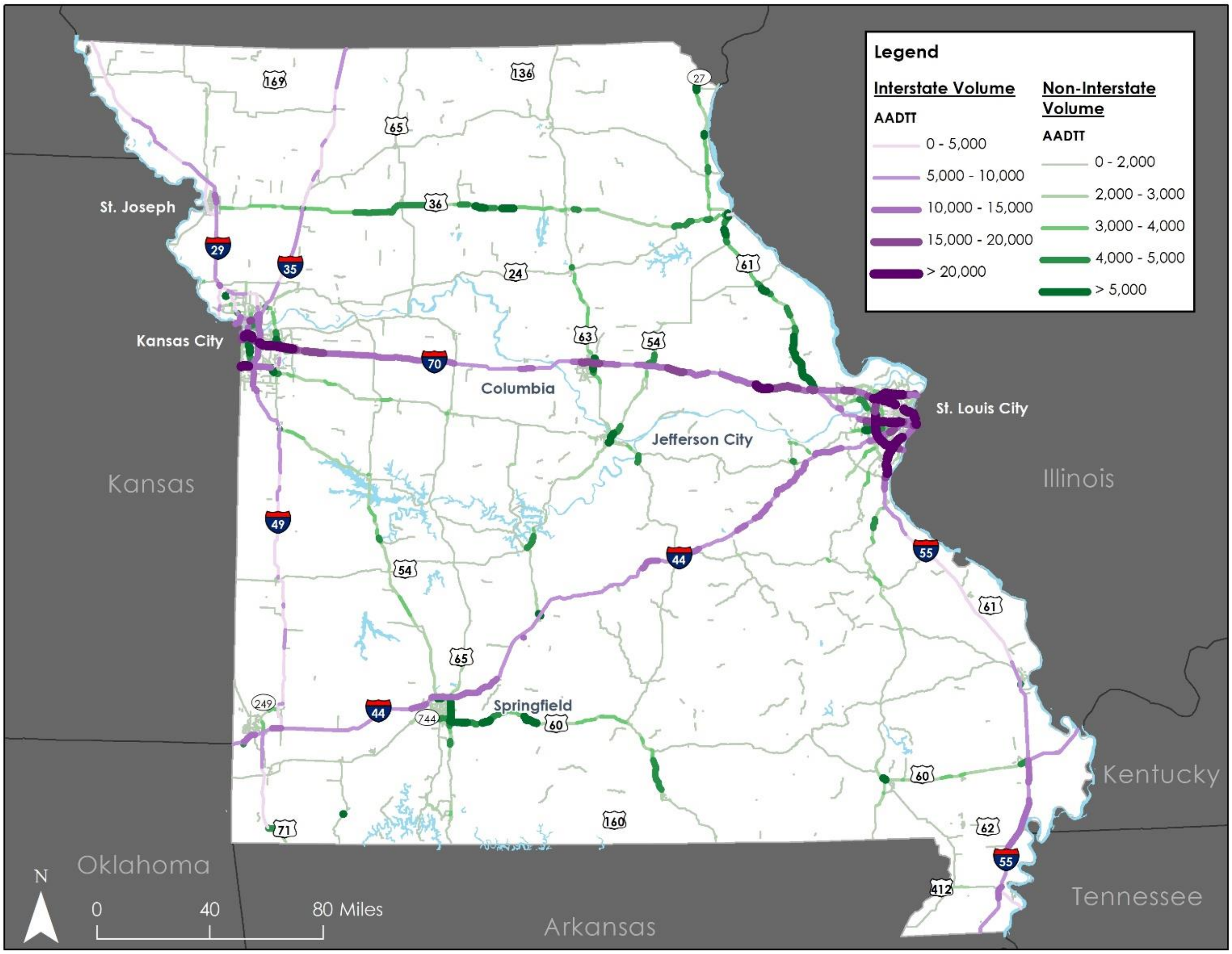
TABLE 3.2 TOP MISSOURI NON-INTERSTATES FOR AVERAGE ANNUAL DAILY TRUCK TRAFFIC

Rank	Route Name	Length-Weighted AADTT	Brief Description of Location
1	International Circle	6,584	Circulator route located at Kansas City International Airport adjacent to I-29 and I-495 that connects with air cargo freight facilities
2	I-70 Connector / US-63 Connector	4,976	Connector route in Columbia, Mo., that connects US-63 with I-70
3	US-36	3,454	US Route between St. Joseph in the west with Hannibal in the east that connects Chicago and Kansas City traffic.
4	MO-27	3,393	Missouri state route in the northeast corner of the state that merges with US Route 61
5	US-61	3,344	US Route that runs parallel to the path of I-55 south of St. Louis and extends north to Iowa
6	MO-364	3,068	State numbered route west of St. Louis that originates at I-270, crosses the Missouri river into St. Charles and terminates at MO-94
7	MO-249	3,031	Route in Joplin, Mo., branching off of I-49 and I-44
8	MO-744	2,975	Missouri state route in northern Springfield that serves many industrial businesses as well as Springfield-Branson National Airport.
9	MO-370	2,873	State numbered route northwest of St. Louis that originates at I-270, crosses the Missouri river into St. Charles and terminates at I-70
10	MO-180	2,760	Route in the northwestern St. Louis area, in Bridgeton, that connects multiple freight carriers such as FedEx and UPS with I-270 and MO-180

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Truck volumes for interstates and non-interstates are shown together in Figure 3.6 (statewide) and Figure 3.7 (urban areas of St. Louis, Kansas City and Springfield). Truck traffic percentages for interstates and non-interstates are shown together in Figure 3.8 (statewide) and Figure 3.9 (urban areas of St. Louis, Kansas City and Springfield). Note the significant difference in scale in the legends of each figure, which reflect different magnitudes of interstate vs. non-interstate measurements of AADTT and percentage of AADT.

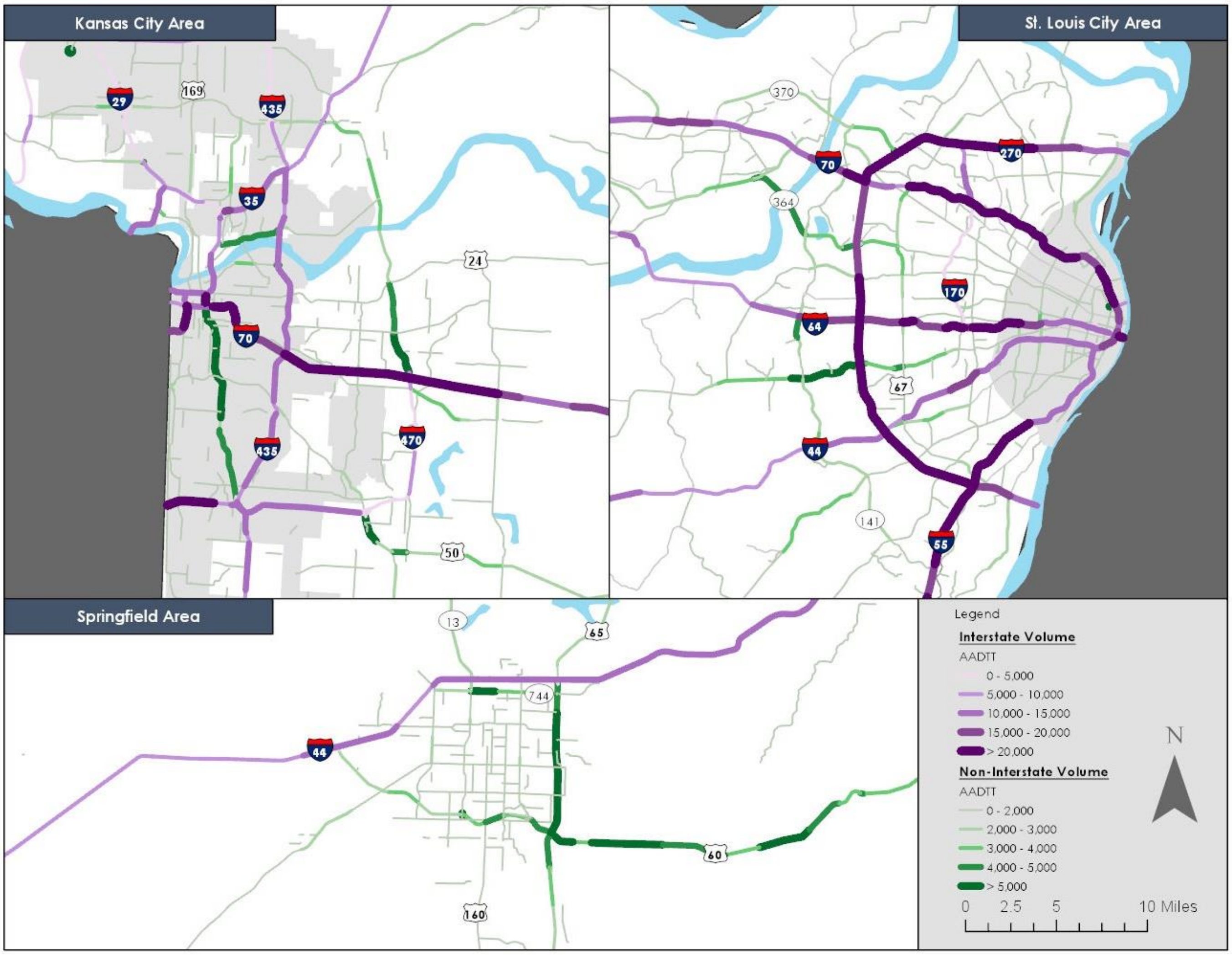
FIGURE 3.6 AVERAGE ANNUAL DAILY TRUCK TRAFFIC ON INTERSTATES AND NON-INTERSTATES



Note: *Routes with no truck traffic data have been excluded from this map.*

Source: *Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020*

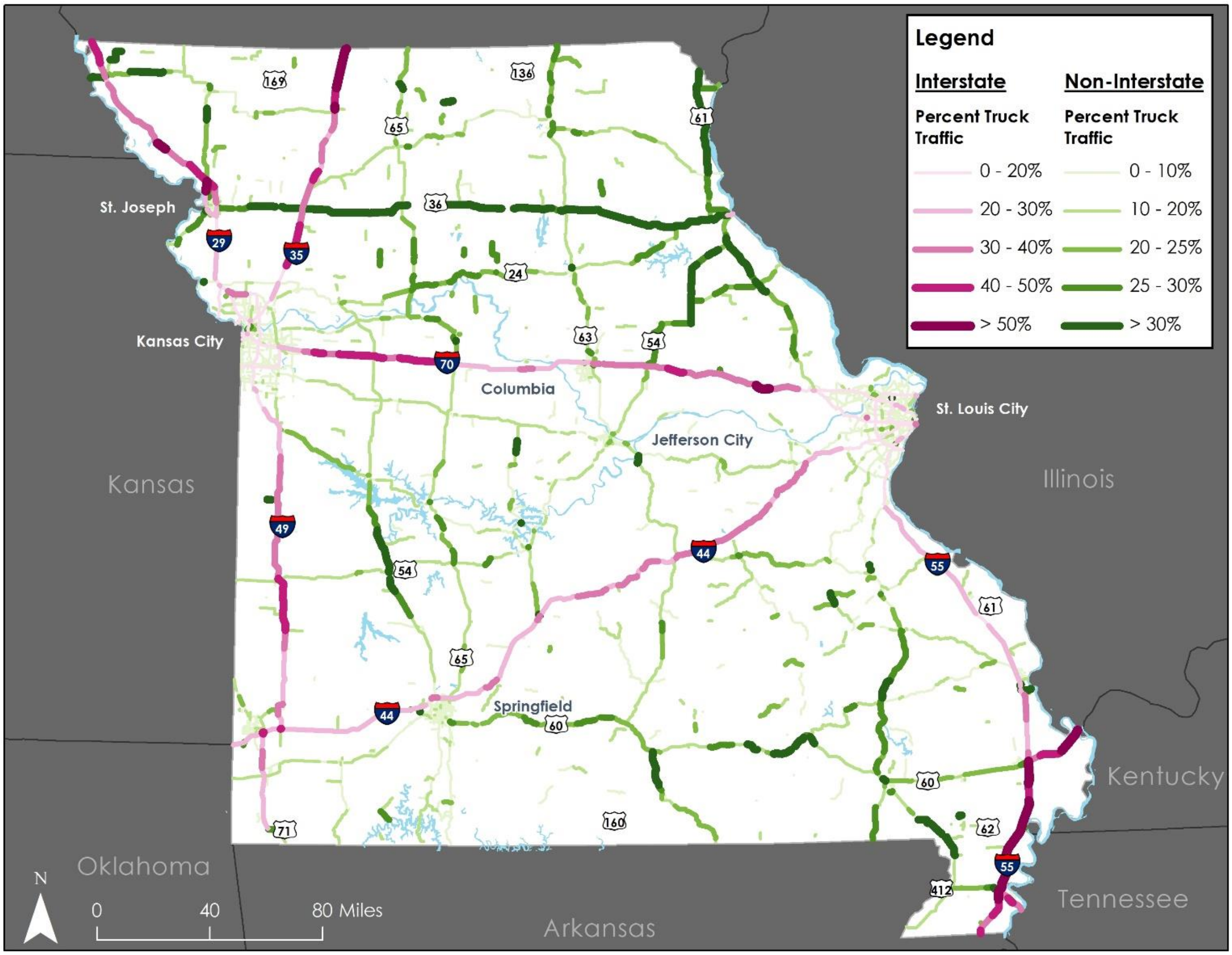
FIGURE 3.7 AVERAGE ANNUAL DAILY TRUCK TRAFFIC ON INTERSTATES AND NON-INTERSTATES IN URBAN AREAS



Note: *Routes with no truck traffic data have been excluded from this map.*

Source: *Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020*

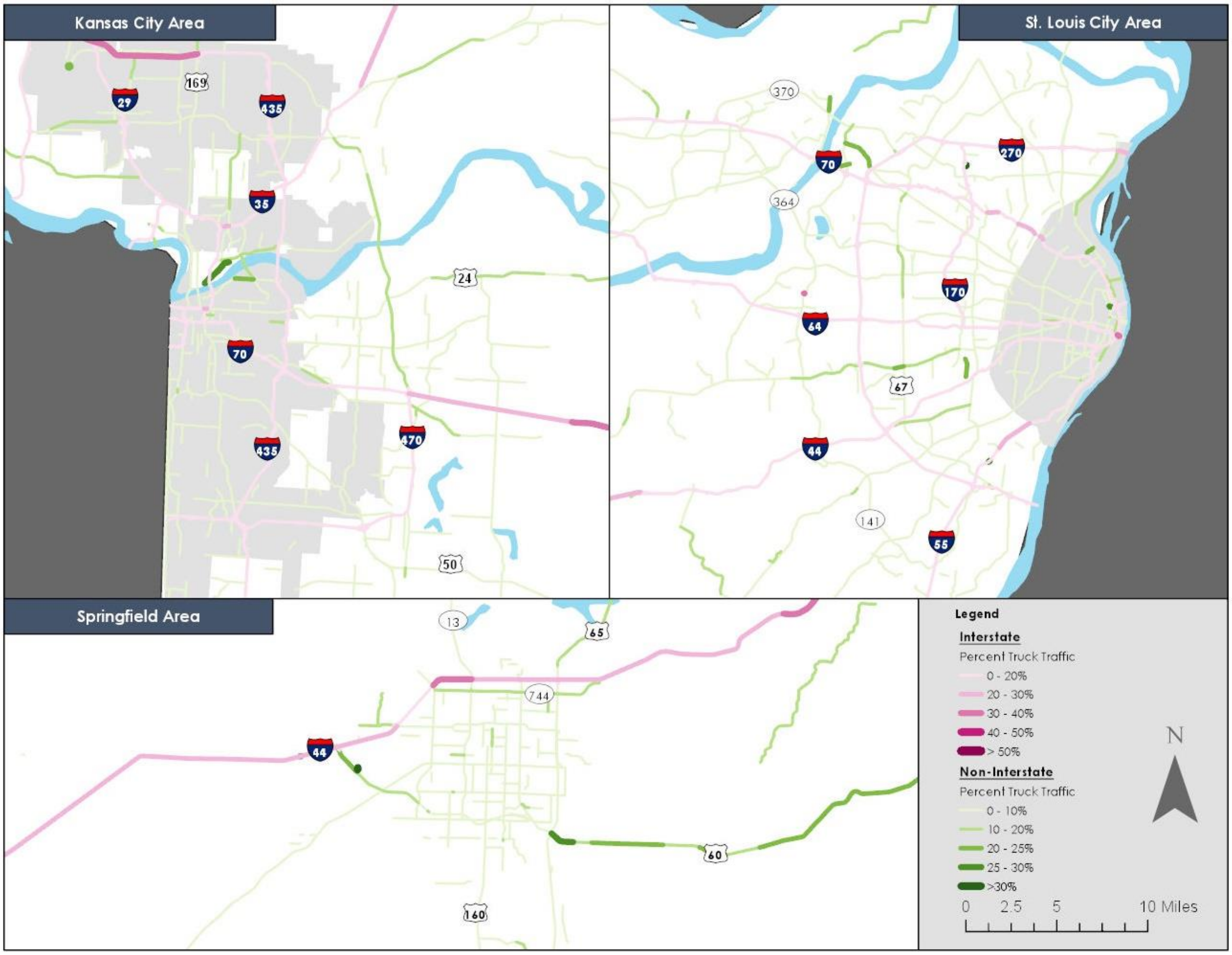
FIGURE 3.8 MISSOURI INTERSTATE AND NON-INTERSTATE AVERAGE ANNUAL DAILY TRUCK TRAFFIC AS A PERCENT OF AVERAGE ANNUAL DAILY TRAFFIC



Note: Routes with no truck traffic data have been excluded from this map.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

FIGURE 3.9 URBAN AREA INTERSTATE AND NON-INTERSTATE AVERAGE ANNUAL DAILY TRUCK TRAFFIC AS A PERCENT OF AVERAGE ANNUAL DAILY TRAFFIC



Note: Routes with no truck traffic data have been excluded from this map.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

3.2 Commodity Flow Analysis

In 2018, 32.5 million trucks transported more than 400 million tons of freight worth more than $495 billion on Missouri's highways. Table 3.3 summarizes the overall statistics about this freight activity. In terms of tonnage and value, by far the largest percent represented commodities that traveled through Missouri, which accounted for 37% of tons and 58% of value of all commodities. In terms of the number of trucks on the highways, freight was evenly split among trucks that were traveling into, out of, through and within Missouri. Each of those directions accounted for between 21% and 27% of the trucks traveling on the highways.

TABLE 3.3 SUMMARY OF FREIGHT TRANSPORTED BY TRUCKS ON MISSOURI HIGHWAYS, 2018

Direction	Tonnage (millions)	Percent of Total Tons	Value ($ billions)	Percent of Total Value	Trucks (millions)	Percent of Total Trucks
Inbound	82.7	20%	81.1	16%	8.3	26%
Intrastate	62.4	15%	23.3	5%	6.9	21%
Outbound	113.0	28%	101.8	21%	8.9	27%
Through	148.5	37%	289.4	58%	8.4	26%
Total	**406.6**	**100%**	**495.6**	**100%**	**32.5**	**100%**

Source: Transearch, 2018; analysis by Cambridge Systematics, 2020

Table 3.4 summarizes the top ten commodities transported on Missouri's highways in terms of tonnage. This table also includes the value of those commodities. Commodities are classified using the Standard Transportation Commodity Code at the 4-digit level. The largest commodity category is broken stone or riprap, which comprised just less than 18% of the total tonnage transported on Missouri's highways. The second highest commodity was grain, which accounted for more than 9% of the total tonnage. Of the top ten commodities based on tonnage, the highest value commodity was warehouse and distribution center goods, which accounted for more than $31 billion (or 6.4%) of the value of all commodities transported on the highways.

TABLE 3.4 TOP 10 COMMODITIES BY TONNAGE TRANSPORTED ON MISSOURI HIGHWAYS, 2018

Rank (based on tons)	Commodity (STCC 4)	Tonnage (millions)	Percent of Total Tons	Value ($ billions)	Percent of Total Value
1	Broken Stone or Riprap	72.7	17.9%	0.8	0.2%
2	Grain	37.7	9.3%	4.2	0.8%
3	Warehouse & Distribution Center	26.0	6.4%	31.8	6.4%
4	Oil Kernels, Nuts or Seeds	19.0	4.7%	6.5	1.3%
5	Gravel or Sand	18.5	4.6%	0.6	0.1%
6	Misc. Waste or Scrap	17.4	4.3%	4.4	0.9%
7	Petroleum Refining Products	15.8	3.9%	11.0	2.2%
8	Misc. Field Crops	13.2	3.2%	2.2	0.4%
9	Asphalt Paving Blocks or Mix	6.5	1.6%	0.7	0.1%
10	Dairy Farm Products	6.5	1.6%	2.1	0.4%

Source: Transearch, 2018; analysis by Cambridge Systematics, 2020

Table 3.5 lists the top ten commodities transported on Missouri's highways based on the value of those goods. This table also includes the tonnage of those goods. The highest value commodity was warehouse & distribution center goods, which represents goods moving from warehouses or distribution centers to a retailer or customer, reflecting the importance of these commodities in supply chains and home delivery through e-commerce businesses. Machinery, including farm machinery and motor vehicles, petroleum refining products and several agricultural products such as meat and oils also comprised some of the top-valued goods moved on Missouri's highways. In addition, pharmaceutical industry products like drugs had a high value yet made up only a small percentage of the total tonnage.

TABLE 3.5 TOP 10 COMMODITIES BY VALUE TRANSPORTED ON MISSOURI HIGHWAYS, 2018

Rank (based on value)	**Commodity** (STCC 4)	**Value** ($ billions)	**Percent of Total Value**	**Tonnage** (millions)	**Percent of Total Tons**
1	Warehouse & Distribution Center	31.9	6.4%	16.0	6.4%
2	Motor Vehicles	29.4	5.9%	2.9	0.7%
3	Misc. Plastic Products	19.0	3.8%	5.0	1.2%
4	Motor Vehicle Parts or Accessories	19.0	3.8%	2.2	0.5%
5	Farm Machinery or Equipment	11.3	2.3%	1.4	0.3%
6	Petroleum Refining Products	11.0	2.2%	15.8	3.9%
7	Drugs	10.5	2.1%	0.4	0.1%
8	Meat, Fresh or Chilled	7.2	1.4%	1.9	0.5%
9	Oil Kernels, Nuts or Seeds	6.5	1.3%	19.0	4.7%
10	Meat, Fresh or Frozen	6.3	1.3%	1.5	0.4%

Source: Transearch, 2018; analysis by Cambridge Systematics, 2020

More information about the commodities that are transported in Missouri can be found in the Commodity Flow Technical Memorandum of the 2021 Missouri State Freight and Rail Plan.

4.0 Highway Freight Network Condition and Performance

4

Highway infrastructure is critical to the safe and efficient movement of freight statewide. The condition of Missouri's pavement and bridge infrastructure affects not only the speed and reliability of freight deliveries, but also the wear and tear on trucks. The performance of the freight system also benefits the economy of the state overall. This section reviews the condition of Missouri's highway system and assesses how well the highway system is performing and efficiently moving goods.

4.1 Condition

This section examines the condition of pavement and bridge infrastructure on interstate and state routes in Missouri.

Pavement Conditions

MoDOT tracks pavement conditions based on the International Roughness Index. IRI is used by state DOTs as a standard to quantify road surface roughness and is useful for assessing overall pavement ride quality. A continuous profile of a highway is measured and analyzed to summarize qualities of pavement surface deviations that impact vehicle suspension movement. Reported in units of inches-per-mile, the IRI describes how much total vertical movement a standard passenger vehicle's body would experience if driven over a 1-mile segment of pavement at 50 mph. A higher IRI value indicates a rougher road surface.

MoDOT considers an IRI of less than 100 to indicate pavement in Good condition. An IRI greater than 100 indicates that the pavement is in Not Good condition. MoDOT measures IRI each year to assist in allocating resources and prioritizing resurfacing needs. It reports pavement condition in its Tracker performance management report –which also assesses safety, customer service, project delivery, reliability, managing assets, workforce and economic impacts.

This section reviews pavement conditions for major truck routes, defined as interstate routes, U.S. routes, state numbered routes and state lettered routes, for each mile and each direction statewide. This analysis is focused on the routes that are most likely to carry truck traffic.

NHS Route Pavement Conditions

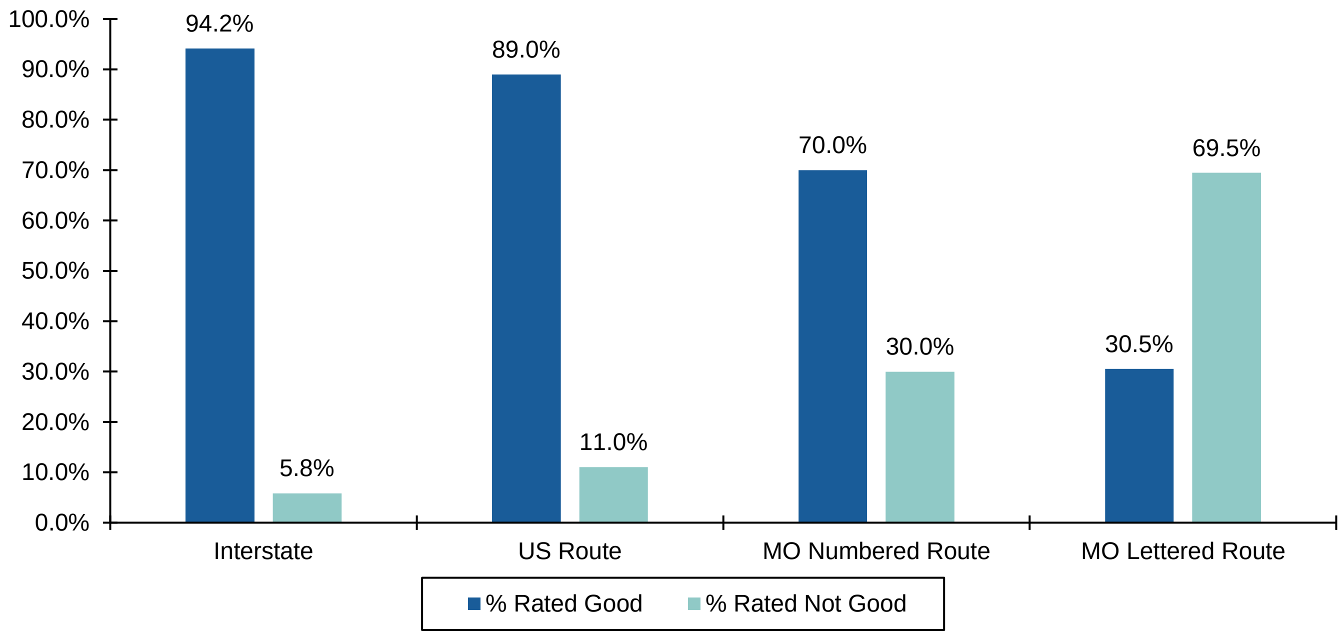
This analysis starts with an overview of pavement conditions on the National Highway System (discussed in Section 2.3 above). In total, there are 11,194 miles of the interstate routes, U.S. Routes, state numbered routes and state lettered routes reported in MoDOT's Tracker, which is based on the NHS. The pavement condition by mile of these truck routes is presented in Table 4.1. The percentage of Good and Not Good pavement by mile of these routes is presented in Figure 4.1. MoDOT's target for percentage of major highways in Good condition is 90%.

TABLE 4.1 PAVEMENT CONDITIONS BY MILE[18] ON MAJOR TRUCK ROUTES

Condition	Interstate	U.S. Route	MO Numbered Route	MO Lettered Route	Total
Good	2,627	4,433	2,228	73	9,361
Not Good	163	55	954	166	1,833
Total	**2,790**	**4,983**	**3,182**	**239**	**11,194**

Source: MoDOT, 2019

FIGURE 4.1 PAVEMENT CONDITION ON NATIONAL HIGHWAY SYSTEM ROUTES



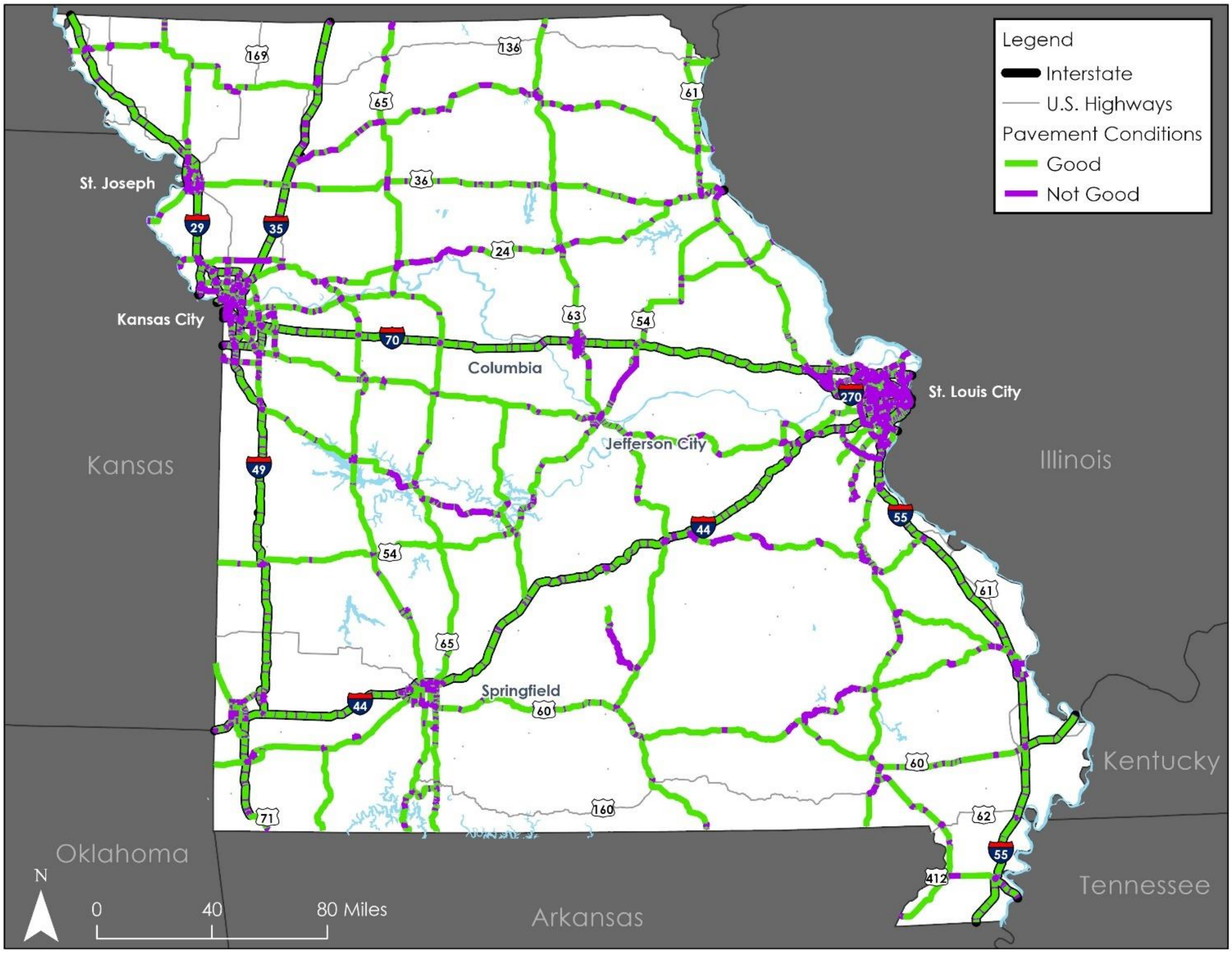
Source: MoDOT, 2019

As shown in Table 4.1 and Figure 4.1, the majority of interstate and U.S. Route pavements are in Good condition with 94.2% and 89.0%, respectively. In addition, 70% of state numbered routes are in Good condition. On state lettered routes, the majority of pavement, almost 70%, is in Not Good condition.

Figure 4.2 shows pavement conditions statewide for the major NHS truck routes shown in Figure 4.1. The figure shows that the majority of rural truck routes have pavement in Good condition with the majority of Not Good pavements occurring in the urban areas of St. Louis, Kansas City and Springfield. The figure also shows that interstate, U.S. Routes and state numbered routes have Good pavement conditions. Figure 4.3 shows NHS route pavement conditions in the urban areas of Kansas City, St. Louis and Springfield.

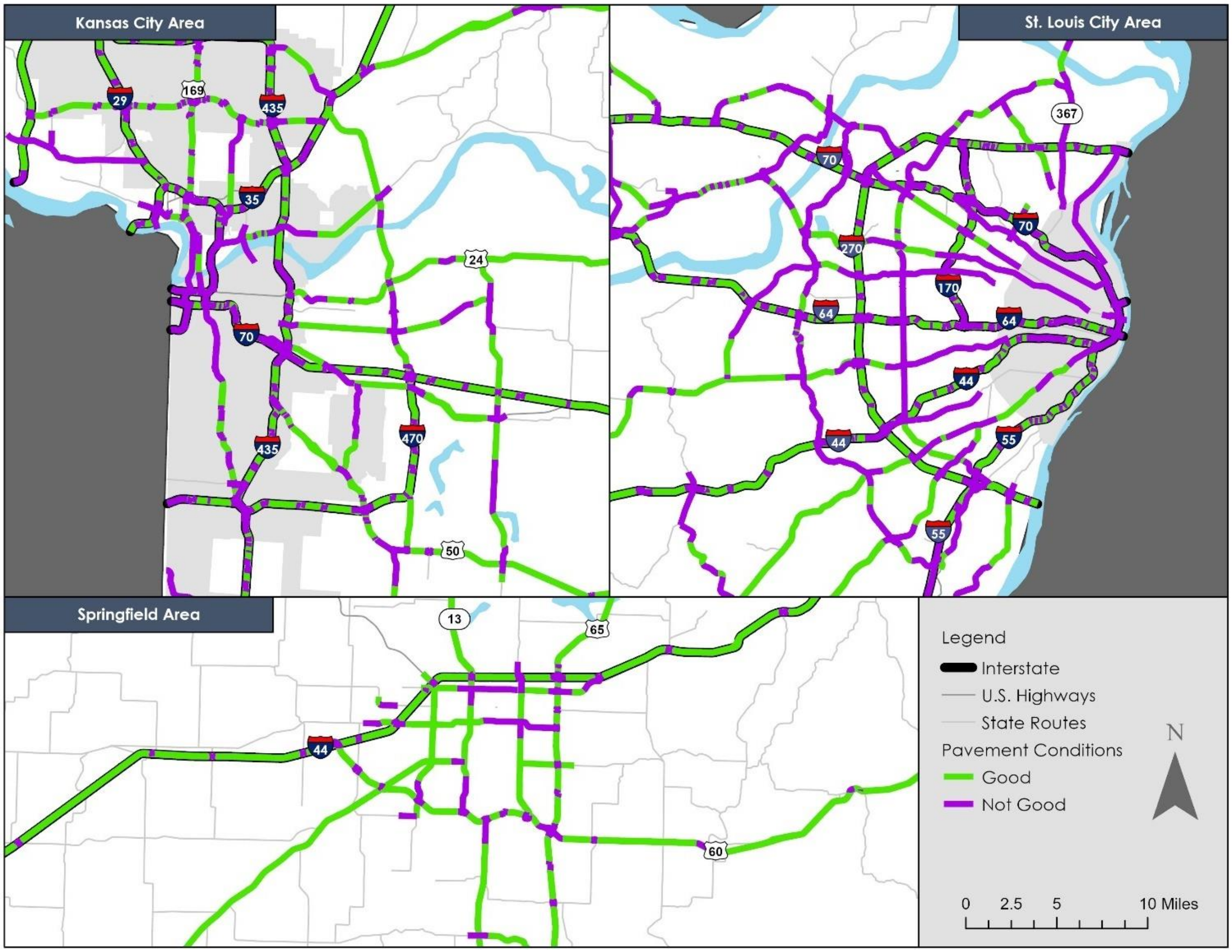
[18] Total miles of these roadways are twice the total lengths of these roadways as pavement condition is reported separately for each direction of travel.

FIGURE 4.2 PAVEMENT CONDITIONS ON NATIONAL HIGHWAY SYSTEM ROUTES



Source: MoDOT, 2019

FIGURE 4.3 PAVEMENT CONDITIONS ON MAJOR TRUCK ROUTES ON THE NHS IN URBAN AREAS



Source: MoDOT, 2019

Designated Highway Network Pavement Conditions

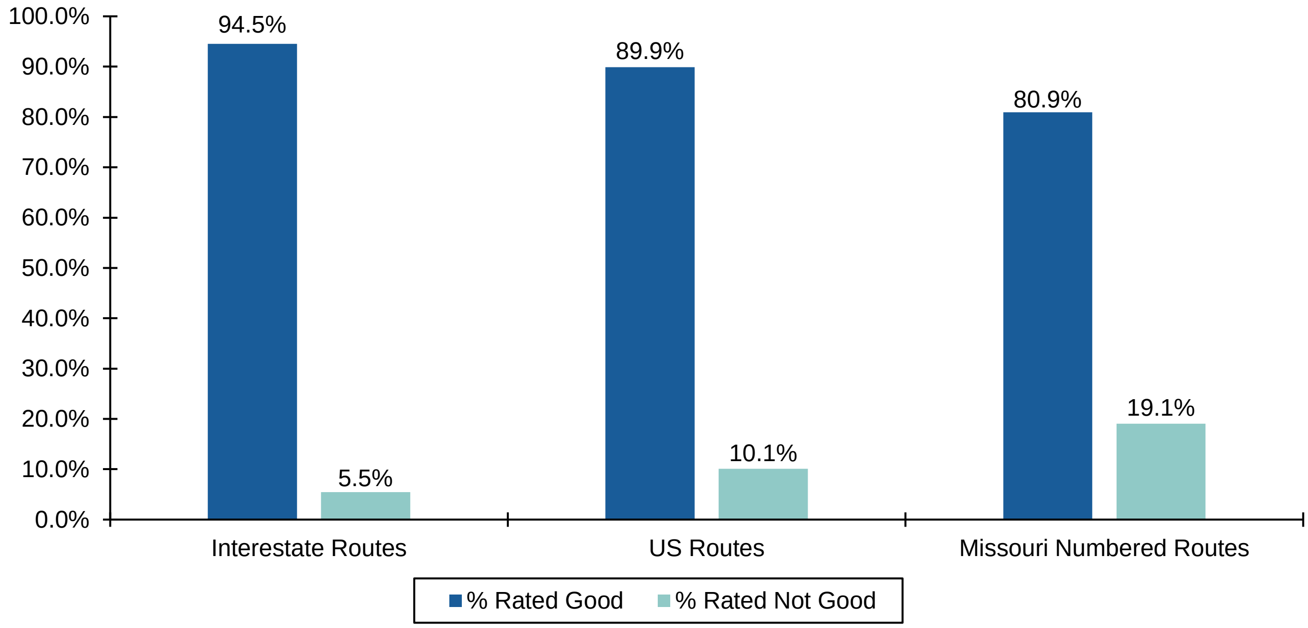
This section analyzes pavement conditions along DHN routes (discussed in Section 2.4). Figure 4.5 shows the DHN routes in Missouri sorted by Good and Not Good pavement condition. As shown in Table 4.2 and Figure 4.5, the majority of interstate and U.S. Routes on the DHN are in in Good condition with 94.5% and 89.9%, respectively. On state numbered routes on the DHN, 80.9% are in Good condition.

TABLE 4.2 PAVEMENT CONDITIONS BY MILE ON DHN ROUTES

Condition	Interstate	U.S. Route	Missouri Numbered Route	Total	Percentage
Good	1,799	2,811	721	5,331	90.0%
Not Good	104	316	170	590	10.0%
Total	**1,903**	**3,127**	**891**	**5,921**	**100.0%**

Source: MoDOT, 2019

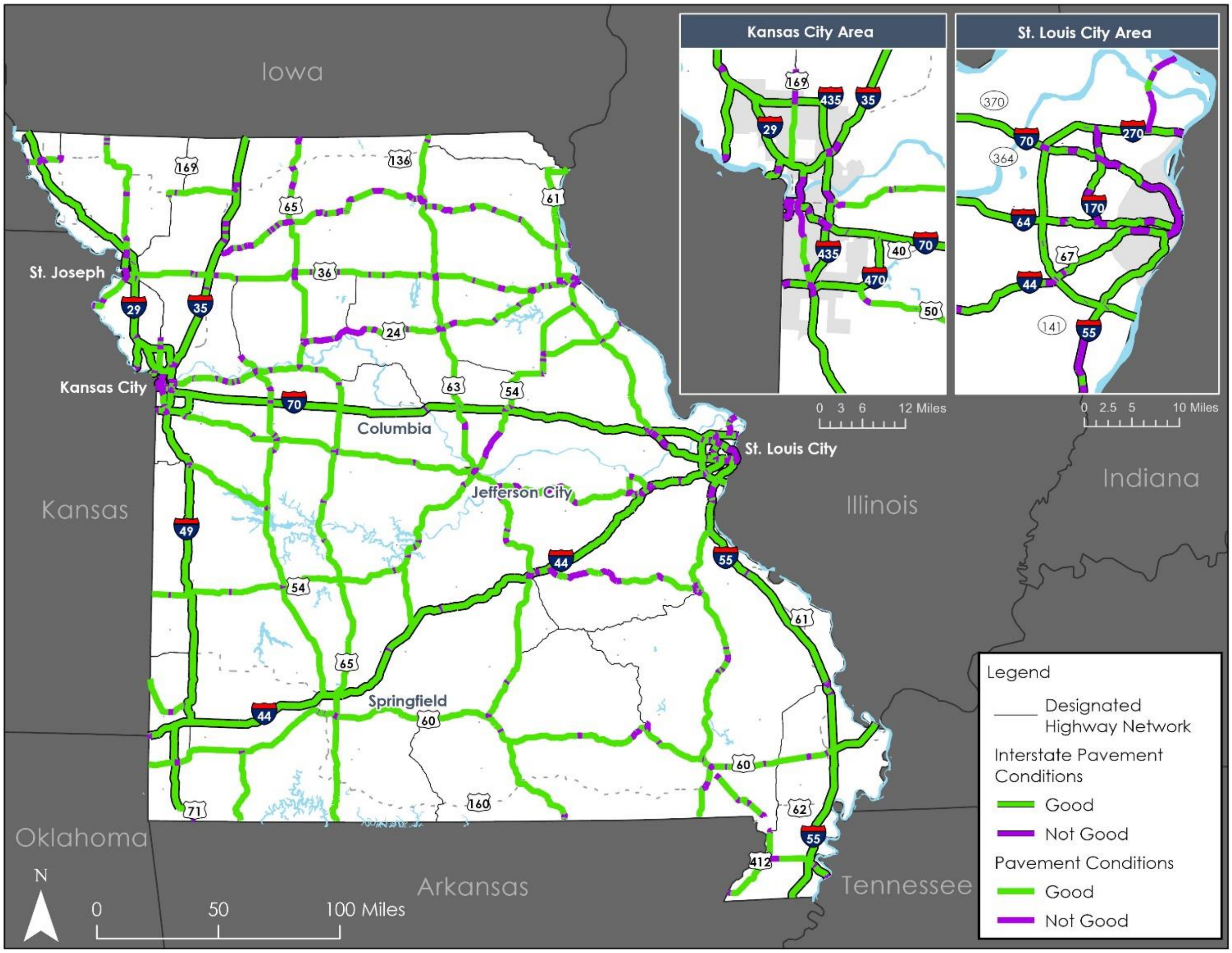
FIGURE 4.4 PAVEMENT CONDITIONS ON DHN ROUTES



Source: MoDOT, 2019

Figure 4.5 shows the DHN routes in Missouri sorted by Good and Not Good pavement condition.

FIGURE 4.5 PAVEMENT CONDITIONS ON DHN ROUTES



Source: MoDOT, 2019

Bridge Conditions

The condition of bridges also affects goods movement by trucks. Bridges with inadequate vertical clearances, posted load limits and/or substandard bridge ratings negatively affect freight movement and may result in trucks having to take detours to deliver their cargo. These detours negatively affect the timeliness and cost of moving trucked goods from origin to destination.

All National Highway System bridges in Missouri are inventoried by MoDOT each year and the results are displayed on its Tracker system. This analysis of that data focuses on bridges with substandard clearances, posted load limit bridges and the Federal Highway Administration bridge condition ratings.

There are 10,269 open state-owned bridges and culverts that carry a route over another route or feature statewide. Of this number, 3,519 (34.3%) are on the NHS while 6,750 (65.7%) are on non-NHS routes. In this section, bridges and culverts are combined and referred to as "bridges".

Bridge Vertical Clearances

According to the Missouri State Statutes, the maximum height of any vehicle outside of a commercial zone is 14 feet, including the truck's load. The maximum height of any vehicle within a commercial zone is 15 feet including the truck's load.

For vertical clearance, MoDOT's standard for routes with greater than 1,700 vehicles per day is 16 feet, 6 inches. Vertical clearances are based upon the American Association of State Highway Officials minimums with an additional six inches to accommodate future resurfacing of the route. Vertical clearances are also applicable when the facility under the bridge is being carried by a bridge (e.g., tri-level interchanges). Trucks with loads taller than 16.5 feet must obtain an Oversize Overweight permit from MoDOT to route safely within the state.

National Highway System Clearances

There are a total of 6,223 locations statewide where state-owned routes travel under another route or feature. Of this number, 5,235 NHS route locations cross under another route or feature. As shown in Table 4.3, 3,194 of these NHS route locations provide adequate vertical clearance defined as 16.5 feet or greater, while 2,041 do not provide adequate clearance. Figure 4.6 shows the locations statewide while Figure 4.7 shows the locations in the urban areas of Kansas City, St. Louis and Springfield.

TABLE 4.3 BRIDGE VERTICAL CLEARANCE ADEQUACY ON NHS ROUTES

Clearance	Number of NHS Route Locations	Percentage
Adequate (16.5' or greater)	3,194	61.0%
Inadequate (Less than 16.5')	2,041	39.0%
Total	**5,235**	**100.0%**

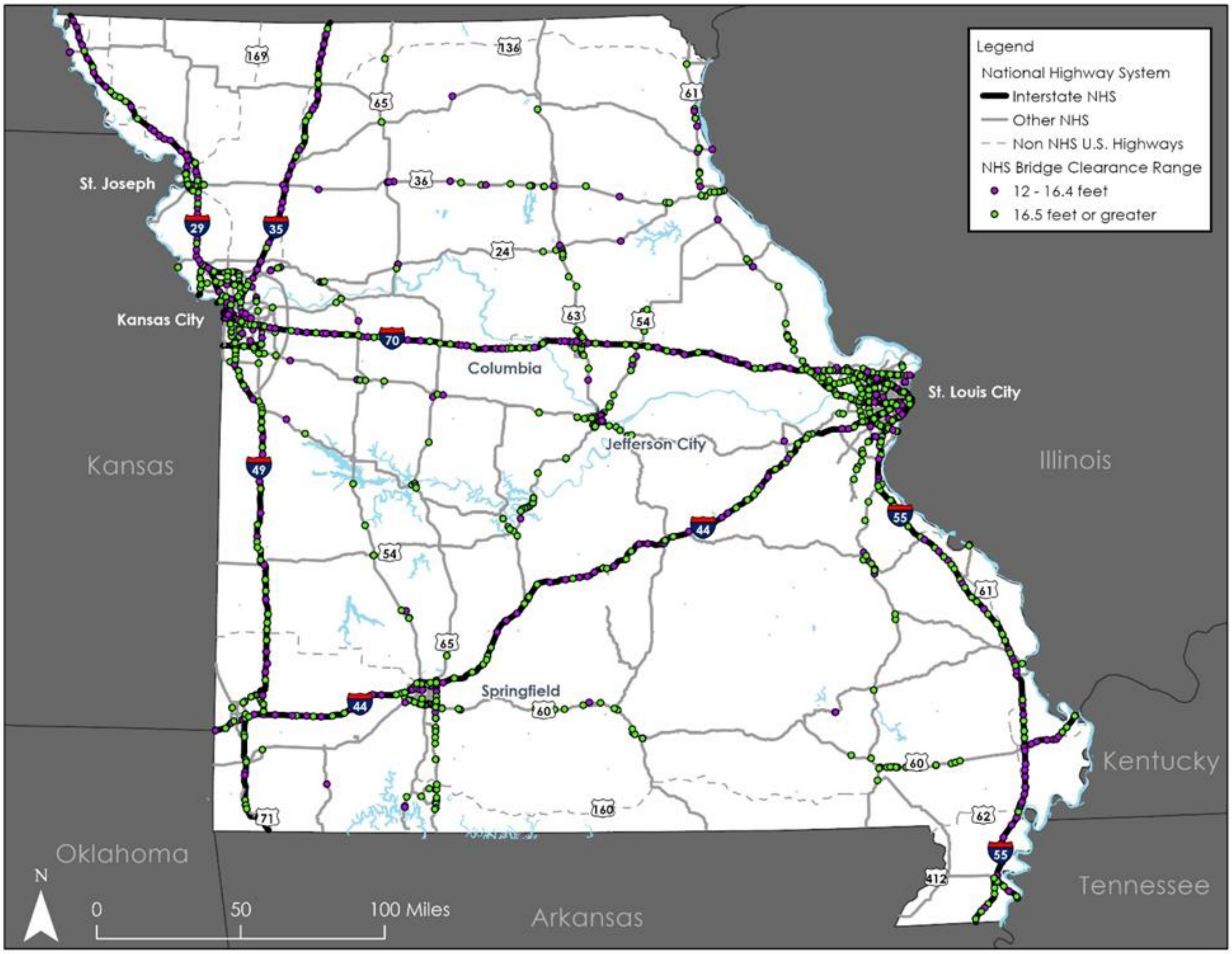
Note: Vertical clearance adequacy is based on the AASHTO minimums plus 6 inches for future resurfacing.

Source: MoDOT, 2019

Of the 2,041 NHS route locations that have inadequate clearance statewide, 1,212 (59.4%) occur within counties within the St. Louis (629 locations or 30.8%), Kansas City (507 locations or 24.8%) and Springfield (76 locations or 3.7%) regions of St. Louis County, St. Louis City, St. Charles County, Jackson County, Clay County and Greene County. In addition, Figure 4.6 and Figure 4.7 show NHS route locations with inadequate vertical clearances.

Of the 1,086 interstate route locations that cross under another route or feature, 795 (44.0%) do not provide at least 16.5 feet of clearance. Statewide, the 795 interstate route locations with inadequate clearance make up 39.0% of all inadequate clearance bridges (2,041) on NHS routes statewide.

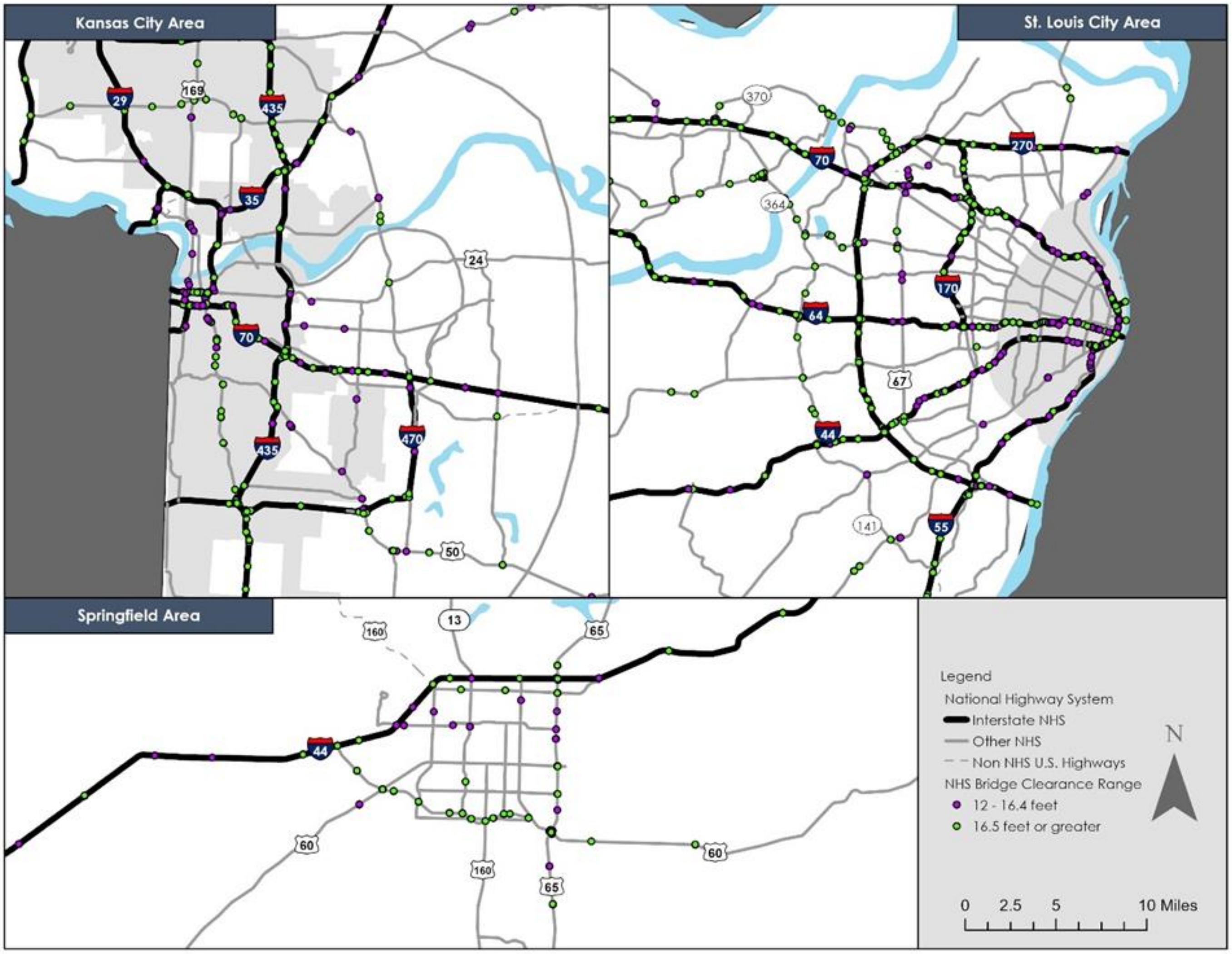
FIGURE 4.6 ADEQUATE AND INADEQUATE BRIDGE VERTICAL CLEARANCES ON THE NHS THAT TRAVEL UNDER ANOTHER ROUTE OR FEATURE



Note: *Vertical clearance adequacy is based on the AASHTO minimums plus 6 inches for future resurfacing*

Source: *MoDOT, 2019*

FIGURE 4.7 ADEQUATE AND INADEQUATE BRIDGE VERTICAL CLEARANCES ON THE NHS THAT TRAVEL UNDER ANOTHER ROUTE OR FEATURE



Note: Vertical clearance adequacy is based on the AASHTO minimums plus 6 inches for future resurfacing

Source: MoDOT, 2019

Designated Highway Network Clearances

Bridge clearances along the DHN were also analyzed. Figure 4.8 shows the location of DHN routes that travel under a roadway or feature statewide sorted by adequate clearance (16.5 feet or greater) and inadequate clearance (under 16.5 feet).

Of the 1,386 locations that carry a DHN route under another route or feature, 58.3% (808 locations) provide adequate clearance of 16.5 feet, while 41.7% (578 locations) do not provide adequate clearance (see Table 4.4). Related to interstates, 45.0% (375 locations) of the total 833 interstate DHN route locations crossing under another route or feature do not provide 16.5 feet of clearance. The 375 inadequate vertical clearance locations along interstates comprise 64.9% of all inadequate vertical clearances along DHN routes statewide.

Further analysis of inadequate clearance at DHN route locations in urban areas shows that 242, or 41.3% of all DHN route locations under another route or feature occur in the St. Louis region (147 bridges or 25.4%) and Kansas City region (95 bridges or 16.4%). Figure 4.8 shows these locations.

Related to interstates, 45.0% (375 locations) of the total 833 interstate DHN route locations crossing under another route or feature do not provide 16.5 feet of clearance. The 375 inadequate vertical clearance locations along interstates comprise 64.9% of all inadequate vertical clearances along DHN routes statewide.

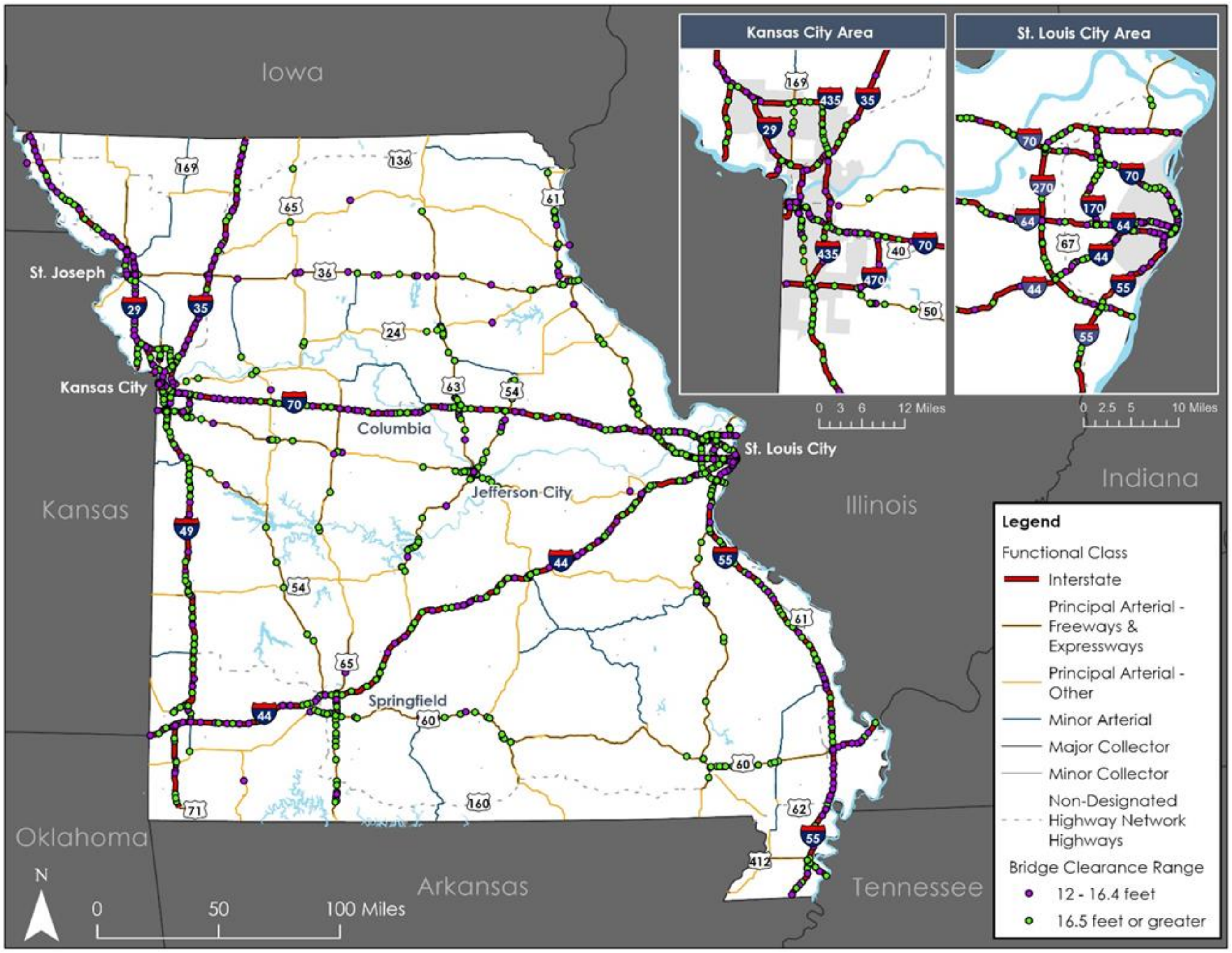
TABLE 4.4 VERTICAL CLEARANCE ADEQUACY OF NHS ROUTE BRIDGES

Clearance	Number of DHN Route Bridges	Percentage
Adequate (16.5’ or greater)	808	58.3%
Inadequate (Less than 16.5’)	578	41.7%
Total	**1,386**	**100.0%**

Note: Vertical clearance adequacy is based on the AASHTO minimum plus 6 inches for future resurfacing

Source: MoDOT

FIGURE 4.8 ADEQUATE AND INADEQUATE BRIDGE VERTICAL CLEARANCES ON THE DHN THAT TRAVEL UNDER ANOTHER ROUTE OR FEATURE



Note: Vertical clearance adequacy is based on the AASHTO minimum plus 6 inches for future resurfacing

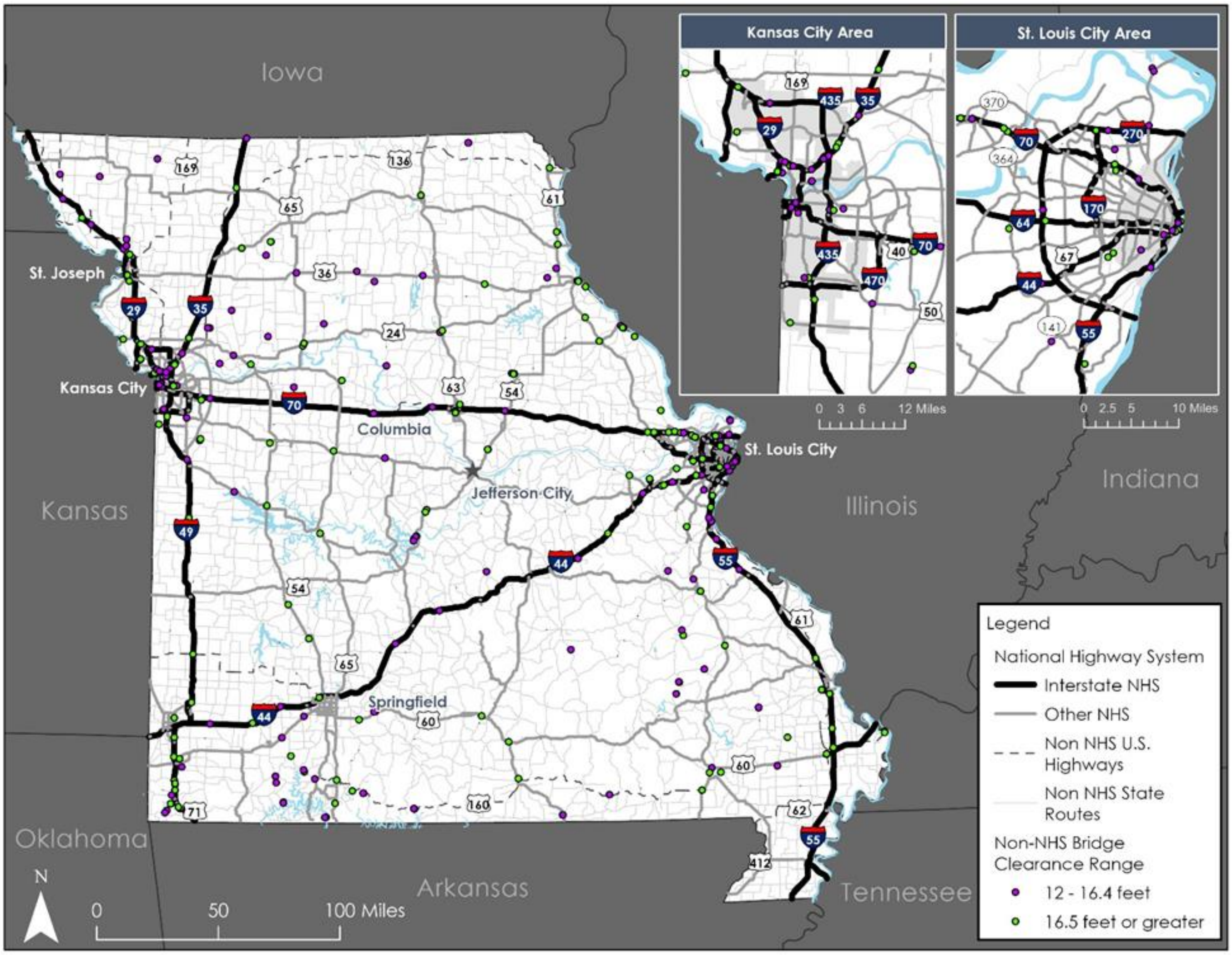
Source: MoDOT, 2019

Non-NHS Route Clearances

This section analyzes vertical clearances under state-owned bridges. This is especially important as much of the state is rural in nature, where agriculture is a significant freight movement contributor. While most crossings under these state-owned bridges are state routes, some are county routes and state-owned trails.

Of the 6,223 locations where a route travels under a state-owned bridge, 988 occur under non-NHS state-owned bridges. Of these 988 crossings under non-NHS state-owned bridges, 461 (46.7%) do not provide adequate vertical clearance of 16.5 feet. These inadequate clearance crossings of state-owned bridges represent 18.4% of all inadequate clearances statewide. The locations of state-owned non-NHS bridges is presented in Figure 4.9.

FIGURE 4.9 ADEQUATE AND INADEQUATE BRIDGE VERTICAL CLEARANCES ON NON-NHS ROUTES THAT TRAVEL UNDER ANOTHER ROUTE OR FEATURE



Note: Vertical clearance adequacy is based on the AASHTO minimum plus 6 inches for future resurfacing

Source: MoDOT, 2019

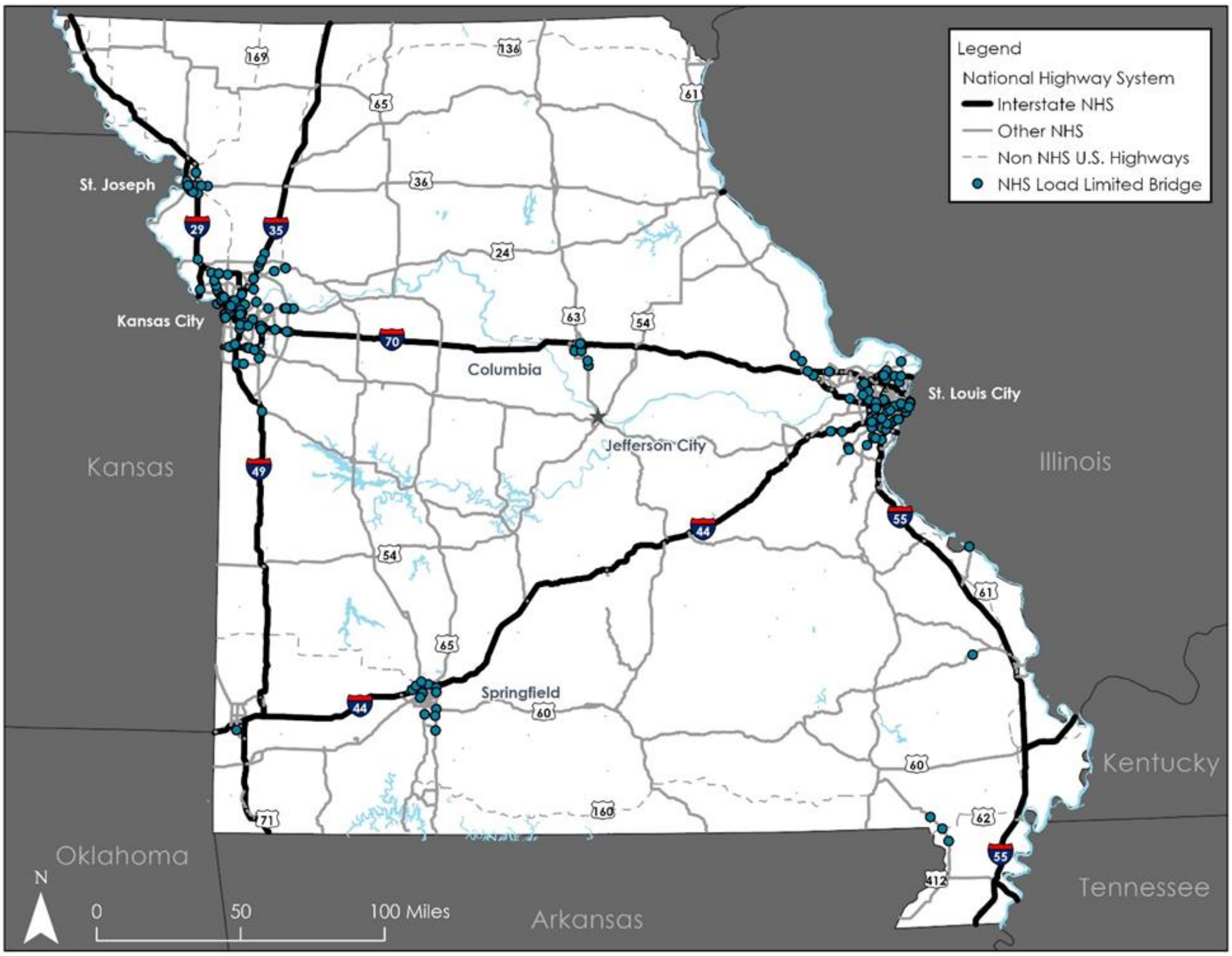
Posted Load Limit Bridges

Load limited bridges are those which post a load limit based on the structural capacity of the bridge. In Missouri, the gross vehicle weight limit for trucks is 80,000 pounds, which is the same as the national limit on interstates. Trucks heavier than this amount require an Oversize Overweight permit issued by MoDOT, as discussed in Section 2.5 above.

National Highway System Posted Load Limit Bridges

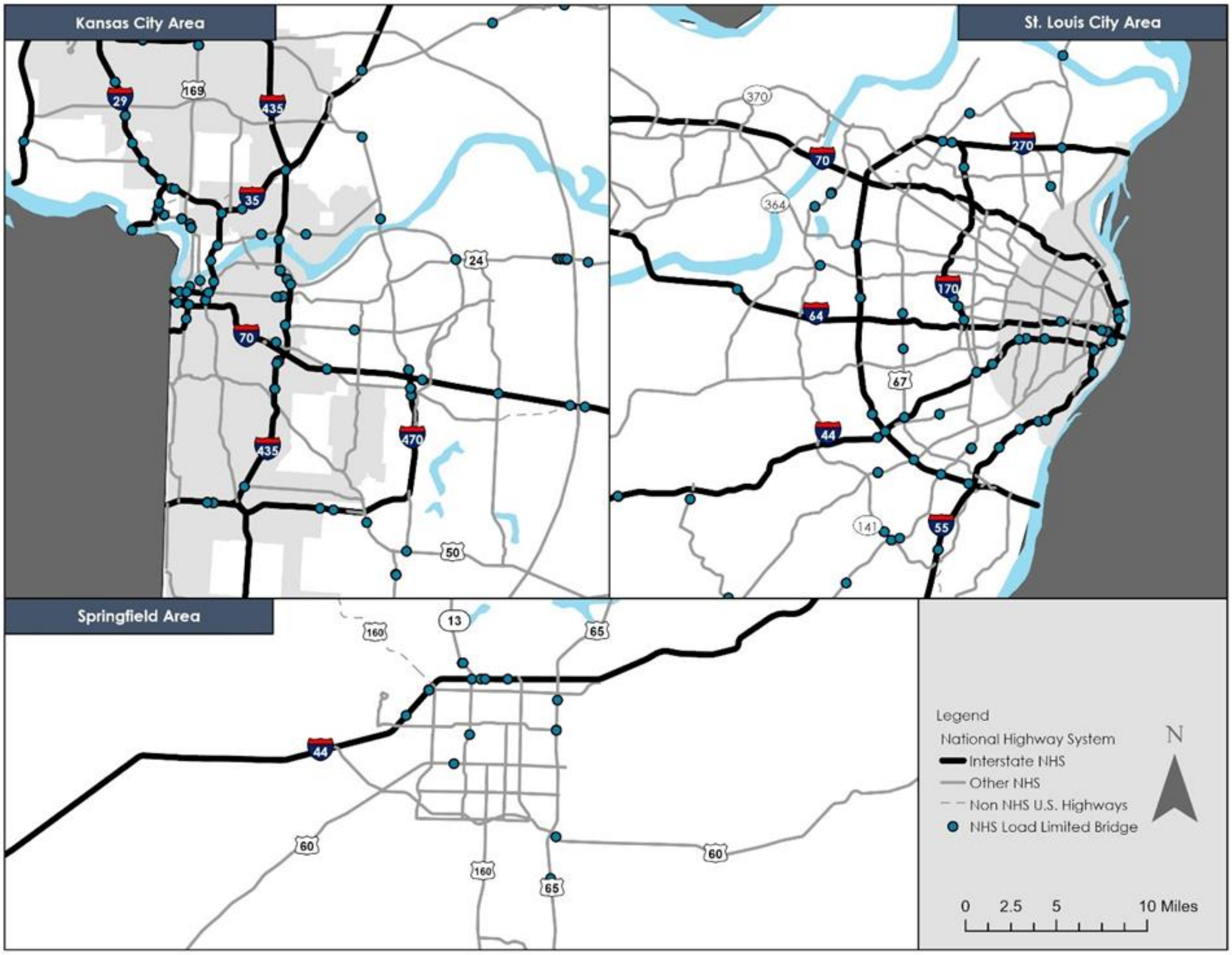
Statewide, there are a total of 10,269 open state-owned bridges that carry highways over other routes or features. Of these, 3,519 are located on NHS routes. A posted load limit is set on 285 (8.1%) of the 3,519 state-owned NHS bridges. The locations of these bridges are presented in Figure 4.10 and Figure 4.11. Trucks with a gross weight that exceeds posted load limits cannot use these routes, often resulting in longer delivery times and higher costs.

FIGURE 4.10 POSTED LOAD LIMITED BRIDGES ON THE NHS THAT TRAVEL OVER A ROUTE OR NATURAL FEATURE



Source: MoDOT, 2019

FIGURE 4.11 POSTED LOAD LIMITED BRIDGES ON THE NHS THAT TRAVEL OVER A ROUTE OR NATURAL FEATURE IN URBAN AREAS



Source: MoDOT, 2019

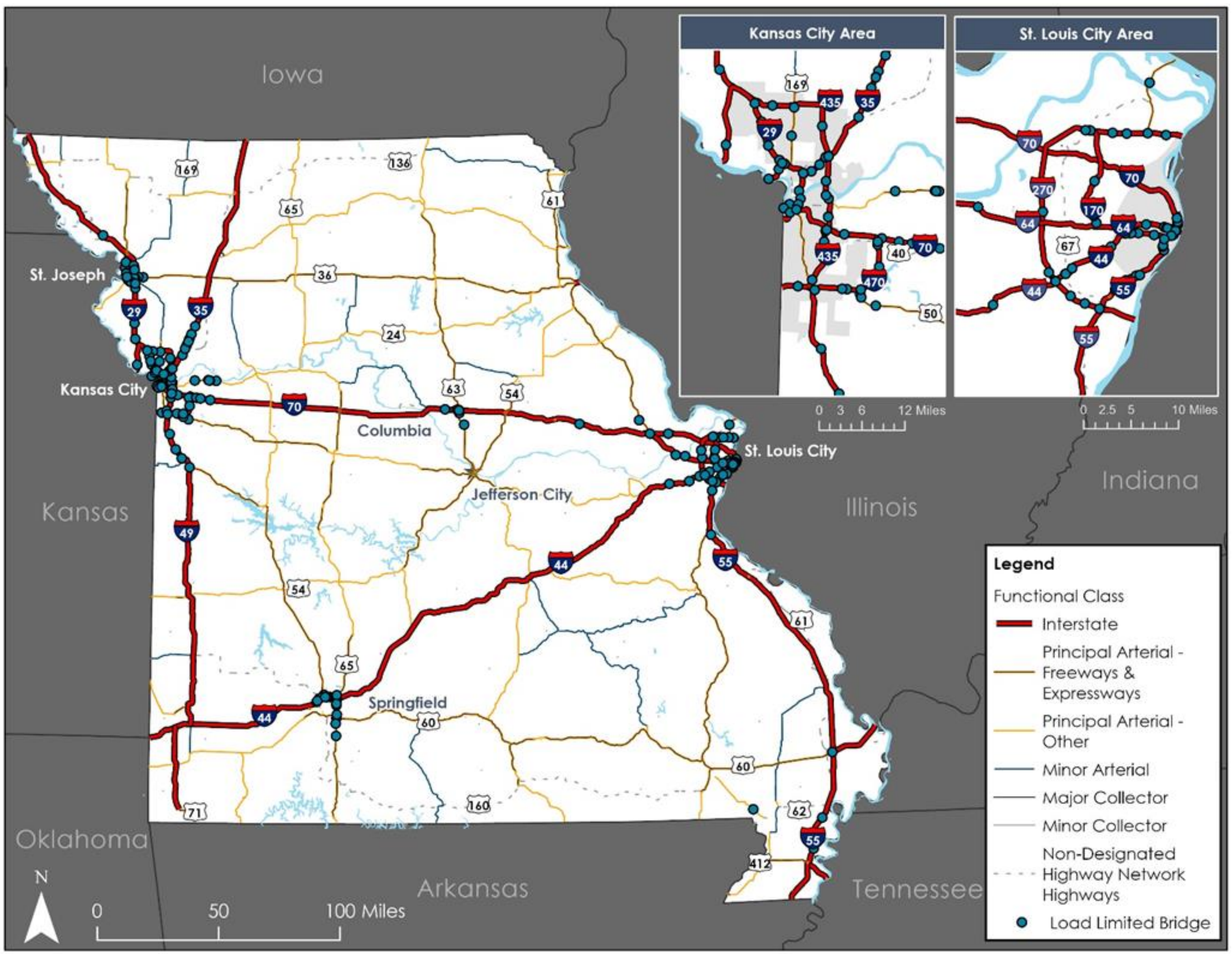
As seen in Figure 4.10 and Figure 4.11, most of the posted load bridges on the NHS system occur near the St. Louis, Kansas City and Springfield regions. Of the 285 posted load limited NHS route bridges in the state, 266 (93.3%) occur within Missouri's most populous areas. Specifically, the St. Louis (105 bridges or 36.8%), Kansas City (123 bridges or 43.2%) and Springfield (38 bridges or 13.3%) regions. The remainder of NHS route posted limited load bridges (19 bridges or 6.7%) are in rural areas.

Designated Highway Network Posted Load Limit Bridges

Of the 2,568 bridges on DHN routes in Missouri, 1,182 DHN route locations travel over another route or natural feature. A posted load limit is set for 106 (9.0%) of these bridges. The locations of these bridges are presented in Figure 4.12.

As shown in Figure 4.12, similar to posted load limit bridges on the NHS, most of the posted load limit bridges on the DHN occur near the St. Louis, Kansas City and Springfield regions. Of the 106 posted load limit DHN route bridges in Missouri, 75 (70.8%) occur within the St. Louis (30 bridges or 28.3%), Kansas City (35 bridges or 33.0%) and Springfield (10 bridges or 9.4%) regions. The remainder of posted load limit bridges (31 bridges or 29.2%) are in rural areas.

FIGURE 4.12 POSTED LOAD LIMITED BRIDGES ON DHN ROUTES THAT TRAVEL OVER ANOTHER ROUTE OR NATURAL FEATURE

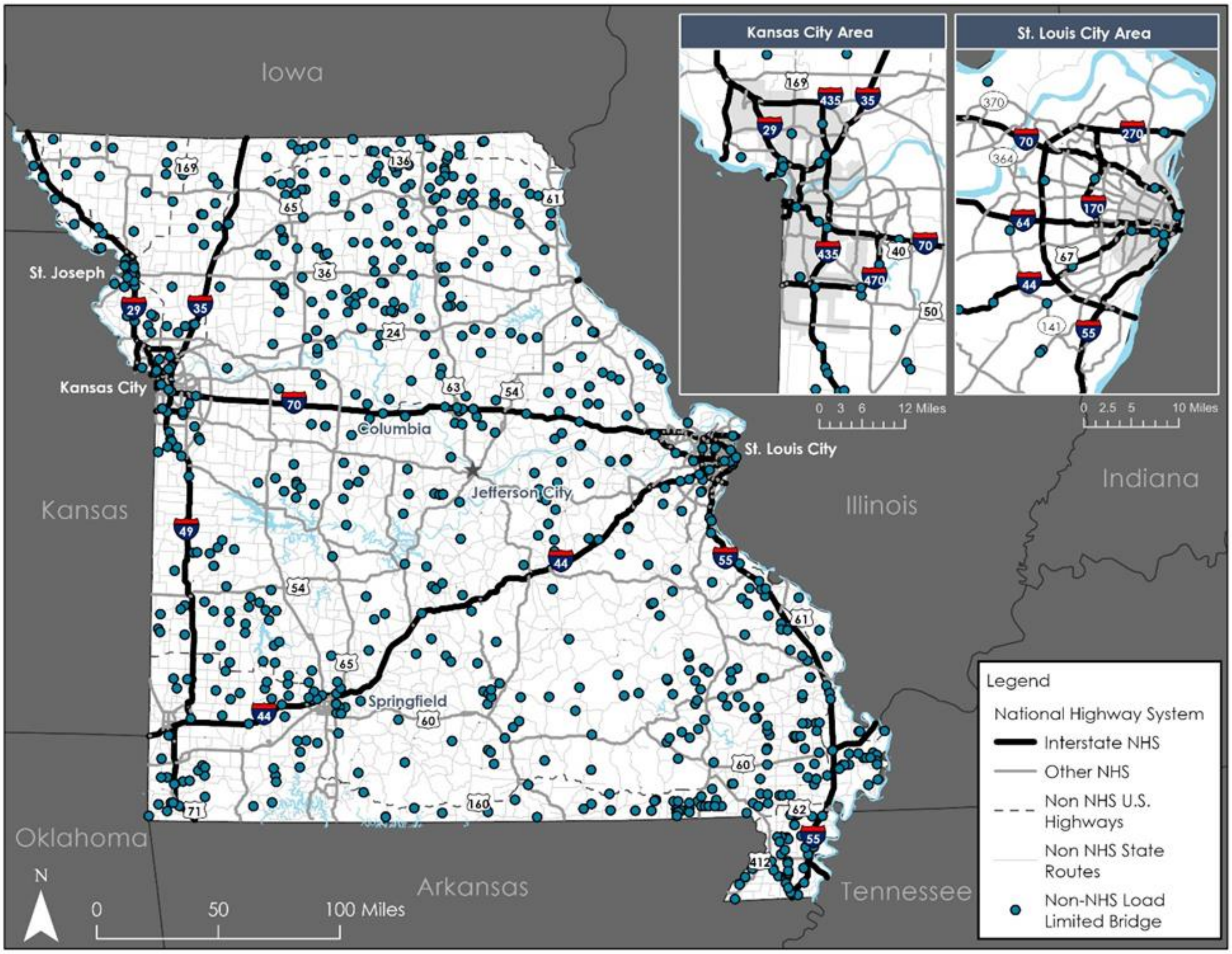


Source: MoDOT, 2019

Non-NHS Route Posted Load Bridges

Of the 10,269 open state-owned bridges, 6,750 are on non-NHS routes. Of these 6,750 bridges on non-NHS routes, 759 (11.2%) have a posted load limit. These posted load limit non-NHS route state-owned bridges represent 72.7% of all posted load limit bridges statewide. Figure 4.13 shows the location of non-NHS posted load limit bridges statewide.

FIGURE 4.13 POSTED LOAD LIMITED BRIDGES ON NON-NHS ROUTES THAT TRAVEL OVER ANOTHER ROUTE OR FEATURE



Source: MoDOT, 2019

FHWA Bridge Ratings

The final metric analyzed related to bridges in Missouri is the FHWA bridge rating. The National Bridge Inventory is updated annually with MoDOT bridge rating assessments. All NHS bridges in Missouri are rated on a 0 to 9 scale to each of the bridge's deck, superstructure and substructure. Table 4.5 defines each of the ten ratings.

TABLE 4.5 NATIONAL BRIDGE INVENTORY RATING SCALE

Rating	Definition
9	**Excellent Condition**
8	**Very Good Condition –** no problems noted
7	**Good Condition –** some minor problems
6	**Satisfactory Condition –** structural elements show minor deterioration
5	**Fair Condition –** all primary structural elements are sound but may have minor corrosion, cracking or chipping
4	**Poor Condition –** advanced corrosion, deterioration, cracking or chipping also significant erosion of concrete bridge piers
3	**Serious Condition –** corrosion, deterioration, cracking and chipping or erosion of concrete bridge piers
2	**Critical Condition –** advanced deterioration of deck, superstructure or substructure
1	**Imminent Failure Condition** – major deterioration or corrosion in deck, superstructure or substructure
0	**Failed Condition –** out of service, beyond corrective action

Source: MoDOT

National Highway System Bridge Ratings

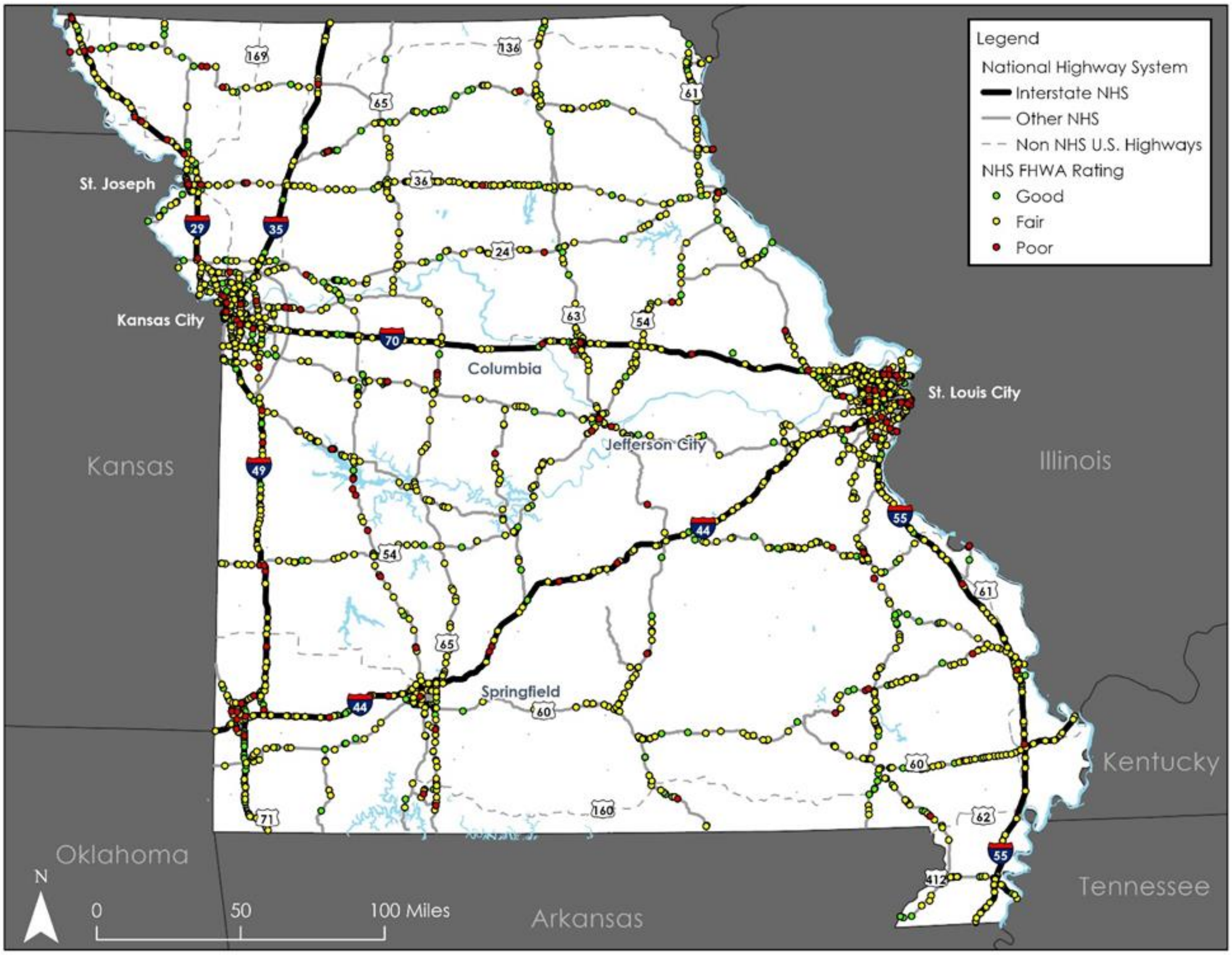
FHWA bridge ratings fall into three categories – Good, Fair and Poor. There are 10,269 open state-owned bridges with FHWA Ratings. NHS routes carry 3,519 of these bridges. Table 4.6 shows the rating, number and percentage of NHS route bridges in Missouri. Figure 4.14 and Figure 4.15 shows the three rating categories by location.

TABLE 4.6 FHWA BRIDGE RATINGS ON NHS ROUTES

Rating	Number	Percent
Good	1,072	30.5%
Fair	2,296	65.2%
Poor	151	4.3%
Total	**3,519**	**100.0%**

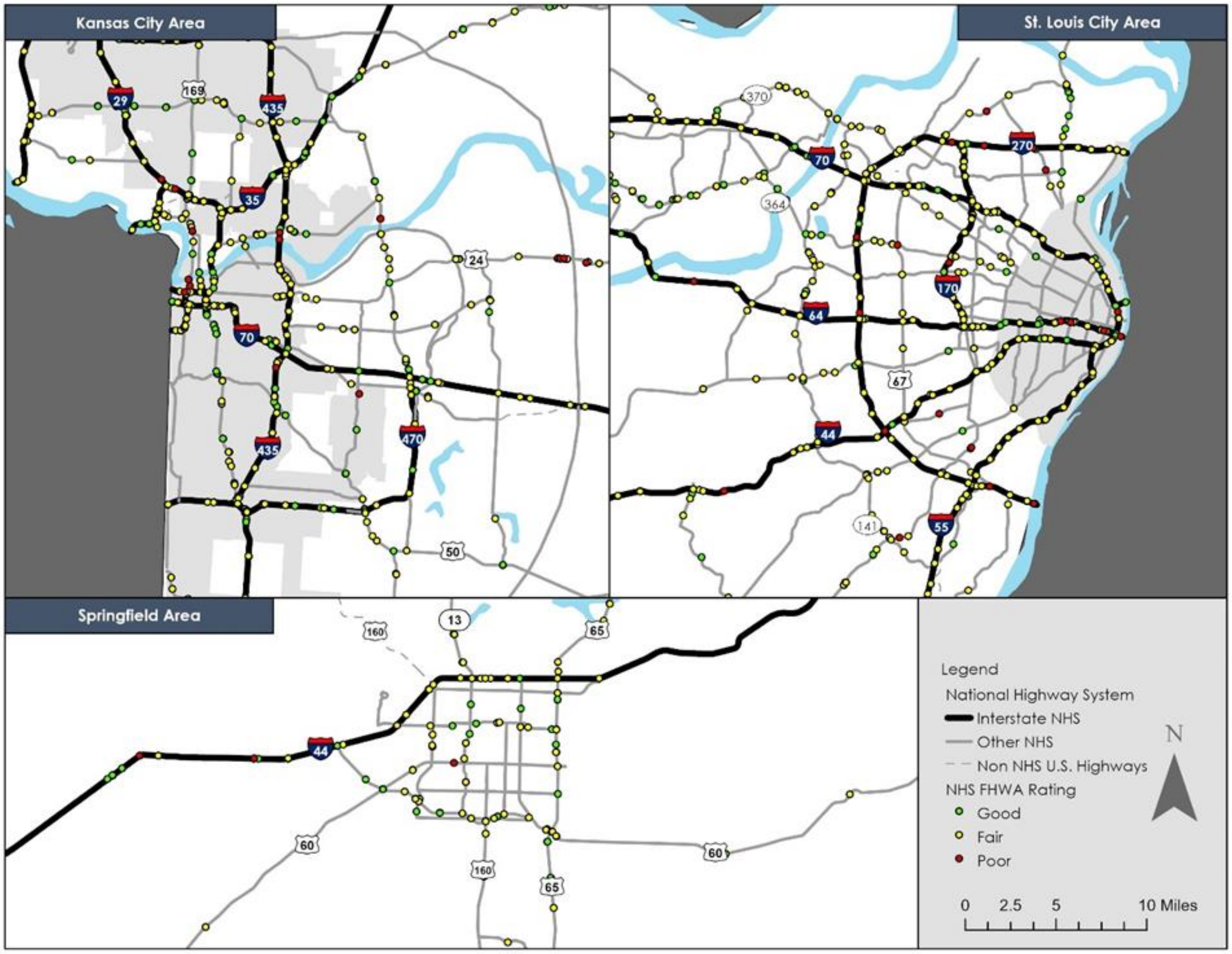
Source: MoDOT, 2019

FIGURE 4.14 FHWA BRIDGE RATINGS ON NHS ROUTES



Source: MoDOT, 2019

FIGURE 4.15 FHWA BRIDGE RATINGS ON NHS ROUTES IN URBAN AREAS



Source: MoDOT, 2019

As shown in Figure 4.14 and Figure 4.15, 827 of the 2,296 Fair rated NHS route bridges (36.0%) are located in the St. Louis (415 bridges or 18.1%), Kansas City (341 bridges or 14.9%) and Springfield (71 bridges or 3.1%) regions. In addition, 45 of the total 151 Poor rated bridges (29.8%) on the NHS are located in the St. Louis (27 bridges or 17.9%), Kansas City (16 bridges or 10.6%) and Springfield (2 bridges or 1.3%) regions. Table 4.7 shows the number of Good, Fair and Poor rated NHS bridges in these regions.

TABLE 4.7 FHWA BRIDGE RATINGS ON NHS ROUTES IN URBAN AREAS

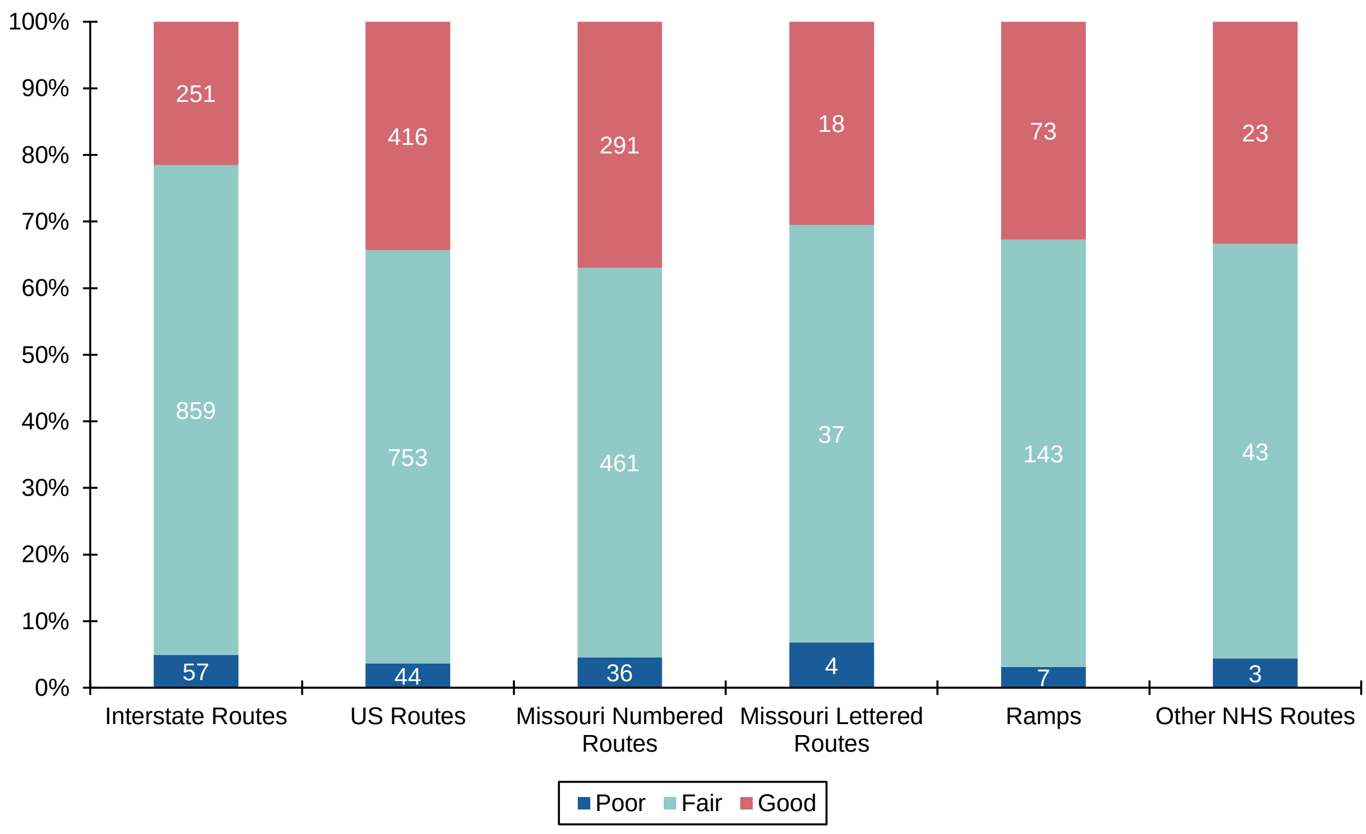
Region	Good	Fair	Poor	Total
St. Louis	142 (13.2%)	415 (18.1%)	27 (17.9%)	**584**
Kansas City	165 (15.4%)	341 (14.9%	16 (10.6%)	**522**
Springfield	42 (1.6%)	71 (3.1%)	2 (1.3%)	**115**
Total	**349 (32.6%)**	**827 (36.0%)**	**42 (29.8%)**	**1,221**

Source: MoDOT, 2019

As shown in Table 4.7, 29.8% of all Poor rated bridges and 36.0% of all Fair rated bridges on NHS routes are found in these three urban regions.

Finally, bridge ratings were broken down by types of roadways on NHS routes. Figure 4.16 shows a breakdown of FHWA NHS route bridge ratings by roadway type similar to MoDOT's Tracker.

FIGURE 4.16 FHWA BRIDGE RATINGS BY NHS ROADWAY TYPE



Source: MoDOT, 2019

Designated Highway Network FHWA Bridge Ratings

This section analyzes FHWA bridge condition ratings for bridges on DHN routes. There are 1,182 bridges with FHWA bridge ratings on DHN routes statewide as shown in Table 4.8.

TABLE 4.8 FHWA BRIDGE CONDITIONS ON DHN ROUTES

Rating	Number	Percent
Good	428	36.2%
Fair	681	57.6%
Poor	73	6.2%
Total	**1,182**	**100.0%**

Source: MoDOT, 2019

Table 4.9 shows the number and percentage of Good, Fair and Poor rated DHN route bridges statewide near the St. Louis, Kansas City and Springfield regions. Location statewide are shown in Figure 4.17.

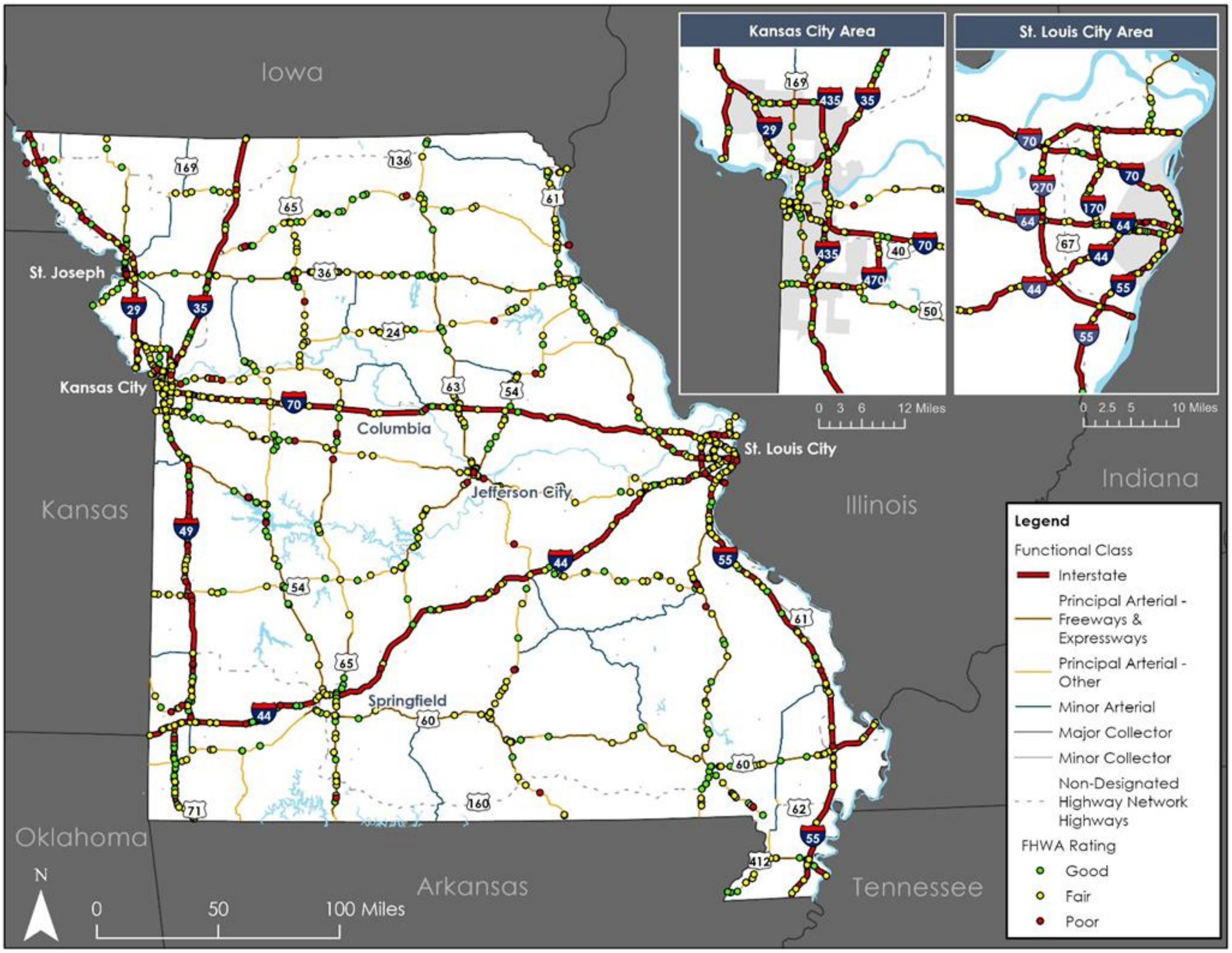
TABLE 4.9 FHWA BRIDGE CONDITIONS ON DHN ROUTES IN URBAN AREAS

Region	Good	Fair	Poor	Total
St. Louis	34 (7.9%)	111 (16.3%)	9 (12.3%)	**154**
Kansas City	44 (10.3%)	99 (14.5%)	4 (5.5%)	**147**
Springfield	15 (3.5%)	16 (2.3%)	0 (0.0%)	**31**
Total	**93 (21.7%)**	**226 (33.2%)**	**13 (17.8%)**	**332**

Source: MoDOT, 2019

As shown in Table 4.9**,** approximately one-third of DHN route bridges are rated Fair in these regions. These regions also contain 17.8% of all Poor rated bridges on DHN routes statewide.

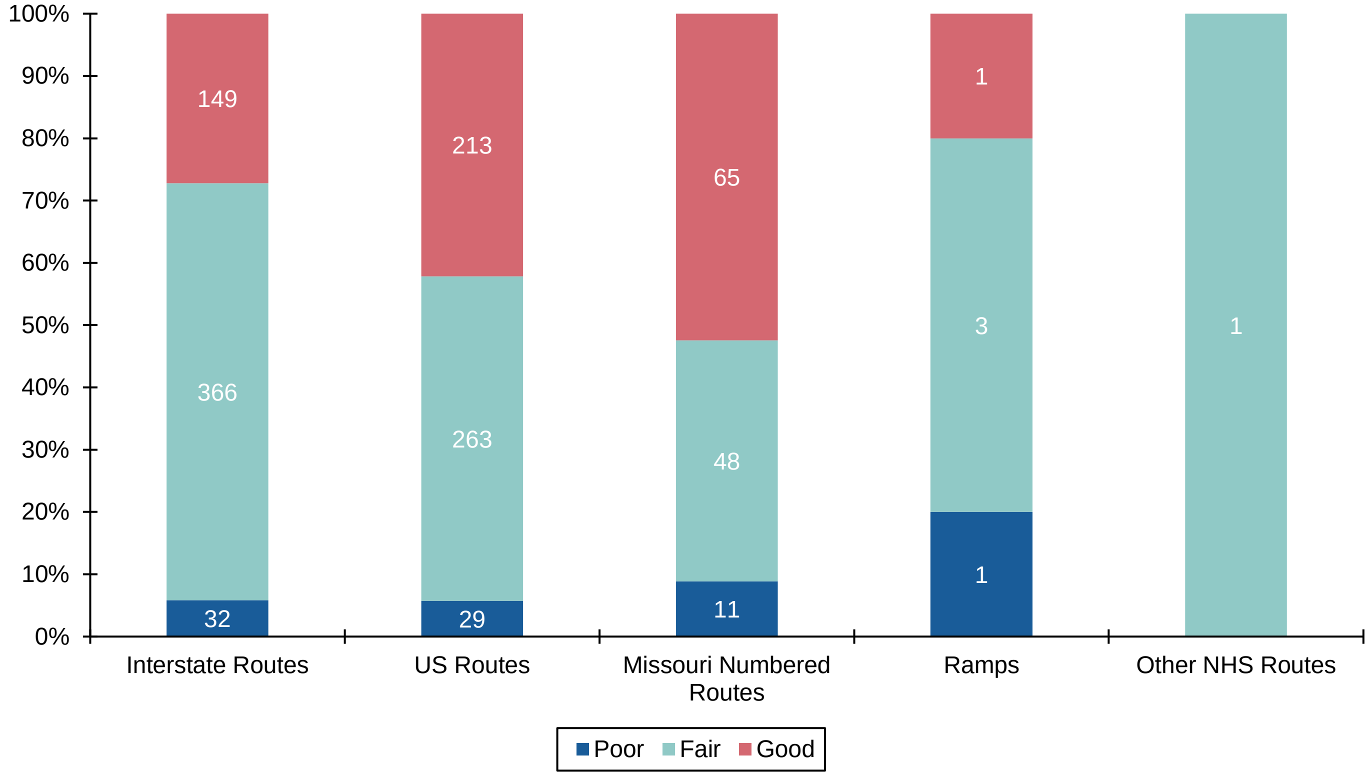
FIGURE 4.17 FHWA BRIDGE RATINGS ON DHN ROUTES



Source: MoDOT, 2019

Bridge ratings were assessed by route type on DHN routes. Figure 4.18 shows a breakdown of FHWA DHN route bridge ratings by route type similar to MoDOT's Tracker. There are no bridges on state lettered DHN routes in the state.

FIGURE 4.18 FHWA BRIDGE RATINGS BY NHS ROADWAY TYPE

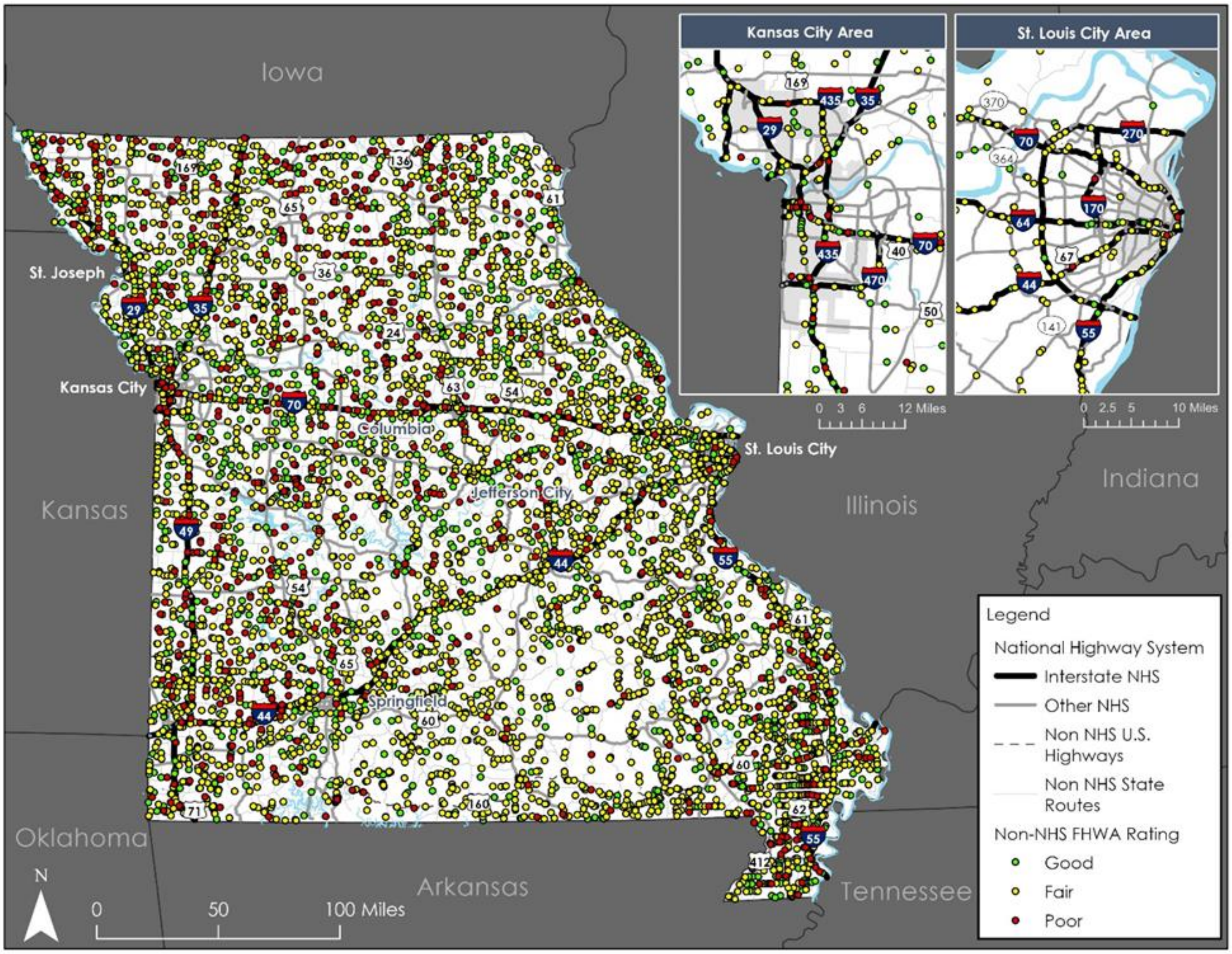


Source: MoDOT, 2019

Non-NHS Route FHWA Bridge Ratings

Of the 10,269 open state-owned bridges, 6,750 are on non-NHS route state-owned bridges. Of these 6,750 bridges, 1,920 (28.4%) are in Good condition, 4,176 (61.1%) are in Fair condition and 704 (10.4%) are in Poor condition. The locations of these non-NHS route bridges are shown in Figure 4.19.

FIGURE 4.19 FHWA BRIDGE RATINGS ON NON-NHS ROUTES



Source: MoDOT, 2019

4.2 Performance

To measure the performance of the state's highway system, this study uses truck travel data on highways from the National Performance Management Research Data Set. NPMRDS is used by federal, state and local agencies to understand travel time related metrics on the NHS. The travel time for all vehicles, passenger vehicles and freight trucks is recorded by segment, at five-minute intervals. The time travel data was subdivided into the following time periods:

- Morning Peak – from 6:00 a.m. – 10:00 a.m. on weekdays
- Midday Peak – from 10:00 a.m. to 4:00 p.m. on weekdays

- Evening Peak – from 4:00 p.m. to 8:00 p.m. on weekdays
- Nights – from 8:00 p.m. to 6:00 a.m. on both weekdays and weekends.
- Weekends – from 6:00 a.m. to 8:00 p.m. on weekends

This analysis focuses on truck data for the period from January 1, 2019 through December 31, 2019. Both truck speed and truck travel time reliability are discussed below.

Truck Speed

Truck speed is one measure of congestion on a route, focusing on how fast vehicles are moving. Measured truck speeds are compared to a threshold "free flow" speed. Those thresholds are listed in Table 4.10. They were chosen to approximate the posted speed limit based on the functional class of the route and whether the route is in an urban or rural area. When trucks are measured moving at or above this speed, the route is considered uncongested. When trucks are measured moving below this speed, the routes are considered to be congested. The sections below detail findings from the truck congestion analysis on both interstate and non-interstate roads.

TABLE 4.10 TRUCK SPEED THRESHOLDS

	Urban Routes	Rural Routes
Functional Class 1 – Interstate	60 mph	70 mph
Functional Class 2 – Primary Arterial Freeways & Expressways	50 mph	65 mph
All Other Functional Classes	40 mph	55 mph

Source: MoDOT

Interstates

On Missouri's interstates, threshold speeds of 60 mph (in urban areas) and 70 mph (in rural areas) were used to indicate free flow. Any speed below these are considered congested. Table 4.11 shows the percent of total interstate centerline miles which are at or above the speed threshold listed in Table 4.10. For context, this table also lists the percent of total interstate miles with average truck speeds that are at or above 10 mph below the threshold value. Between 23% and 30% of interstate miles see average truck speeds average truck that are above the threshold value. However, a large majority of interstate miles see average truck speeds that are close to the threshold, as 93% to 98% of centerline miles see average truck speeds that are within 10 mph of the threshold speed.

TABLE 4.11 SUMMARY OF AVERAGE TRUCK SPEEDS FOR INTERSTATE HIGHWAYS

Peak Period	Total Mileage >= Speed Threshold	Percent of Total Mileage >= Speed Threshold	Total Mileage >= 10 MPH Below Speed Threshold	Percent of Total Mileage >= 10 MPH Below Speed Threshold
Morning	743	27%	2,664	97%
Midday	762	28%	2,679	97%
Evening	646	23%	2,575	93%
Night	803	29%	2,706	98%
Weekend	840	30%	2,690	98%
Total Mileage (Both Directions)	**2,759**	**100%**	**2,759**	**100%**

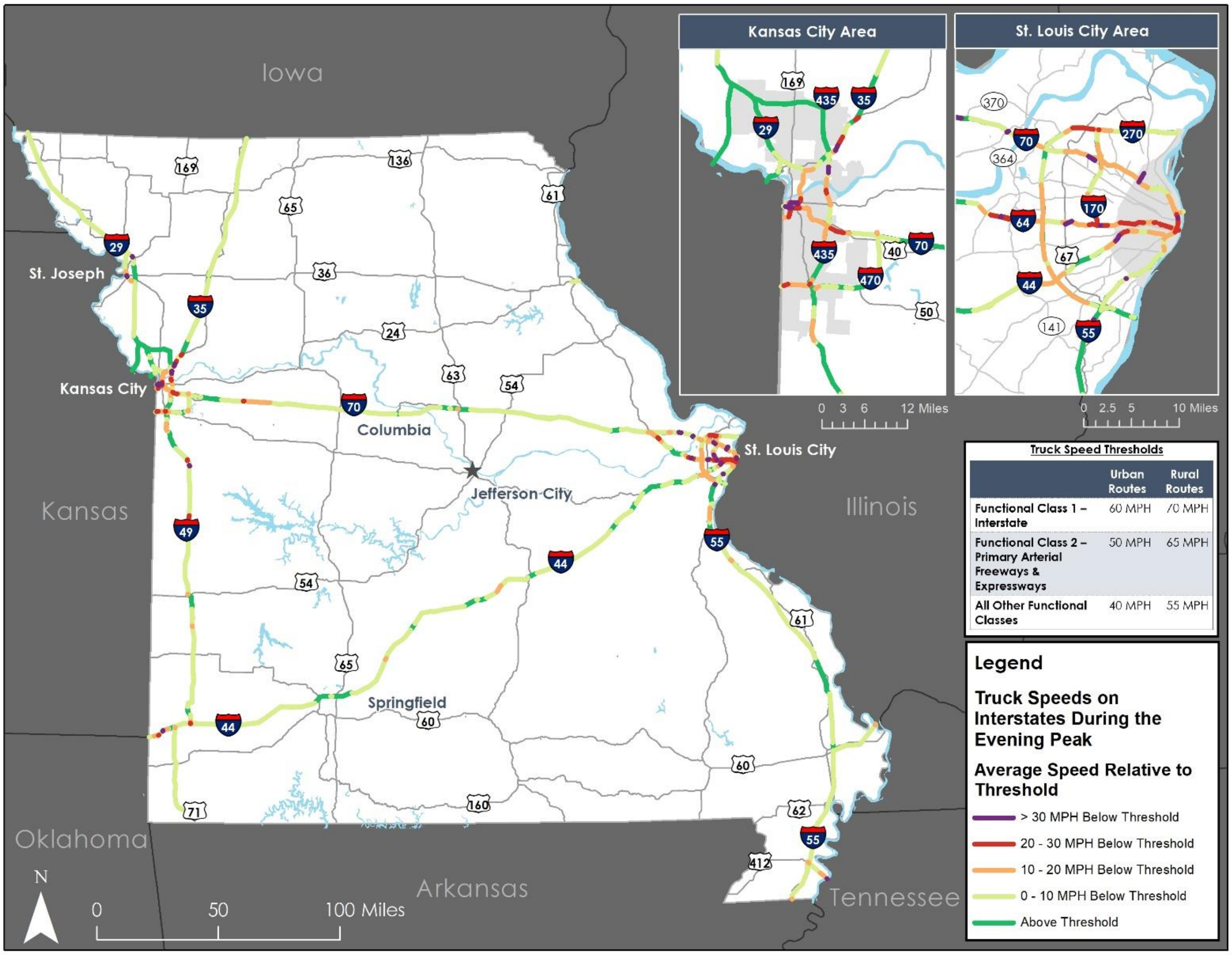
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Figure 4.20 shows the truck speeds across the state during the evening peak (maps of truck speeds statewide during all five time periods can be found in Appendix B.1). Outside of the urban areas, Missouri interstates show truck speeds that are above or within 10 mph of the speed threshold at all hours of the day. The slowest truck speeds happen almost entirely within the urban areas of the state, with St. Louis and Kansas City experiencing the slowest truck speeds. In St. Louis, there are congested segments during the evening on parts of I-64, I-270 and I-44. There is also congestion at the intersection of I-170 and I-64. In Kansas City, the area with the most congestion is where I-70, I-670, I-29 and I-35 loop downtown.

Though Missouri's urban areas experience congestion, it is relatively low compared to other large cities nationwide. In 2017, St. Louis ranked 25th and Kansas City ranked 37th in terms of the total person-hours of delay related to trucks.[19] For both cities, that is lower than their ranking in terms of population, meaning that there are cities with smaller populations that experience worse levels of truck delay.

[19] Texas A&M Transportation Institute 2019 Urban Mobility Report Base Statistics, https://mobility.tamu.edu/umr/report/

FIGURE 4.20 EVENING PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Non-Interstates

For non-interstates, the reference speed for uncongested roads is based on their functional class. The non-interstate roads tracked by the NPMRDS are those that are part of the NHS, and includes functional classes ranging from principal arterial freeways (Class 2) to major collectors (Class 5). Because Class 2 highways have separate entrance and exits, their speed thresholds are higher (50 mph in urban areas and 65 mph in rural areas). Routes classified as Class 3 or greater have speed thresholds of 40 mph (in urban areas) and 55 mph (in rural areas).

One of the limitations of the truck speed metric is that it does not account for traffic signals. That means that many city streets will show up as congested because, unlike on freeways, vehicles will wait for signals to change. In other words, the truck speed metric does not differentiate between vehicles that are stopped or slowed down due to congestion and those that are stopped or slowed down due to traffic signals.

Because of this limitation, a greater percentage of centerline miles on non-interstates are considered congested at all hours of the day. Table 4.12 shows the mileage of uncongested roads on non-interstates at different time periods. For context, this table also lists the percent of total non-interstate miles with average truck speeds that are at or above 10 mph below the threshold value. Between 31% and 40% of non-interstate miles see average truck speeds average truck that are above the threshold value. However, a significant amount of non-interstate miles see average truck speeds that are close to the threshold, as 75% to 81% of centerline miles see average truck speeds that are within 10 mph of the threshold speed. This is lower than the 93% to 98% of interstate centerline miles that are within 10 mph of the threshold, reflecting more variability in the average truck speeds on non-interstates as compared with interstates.

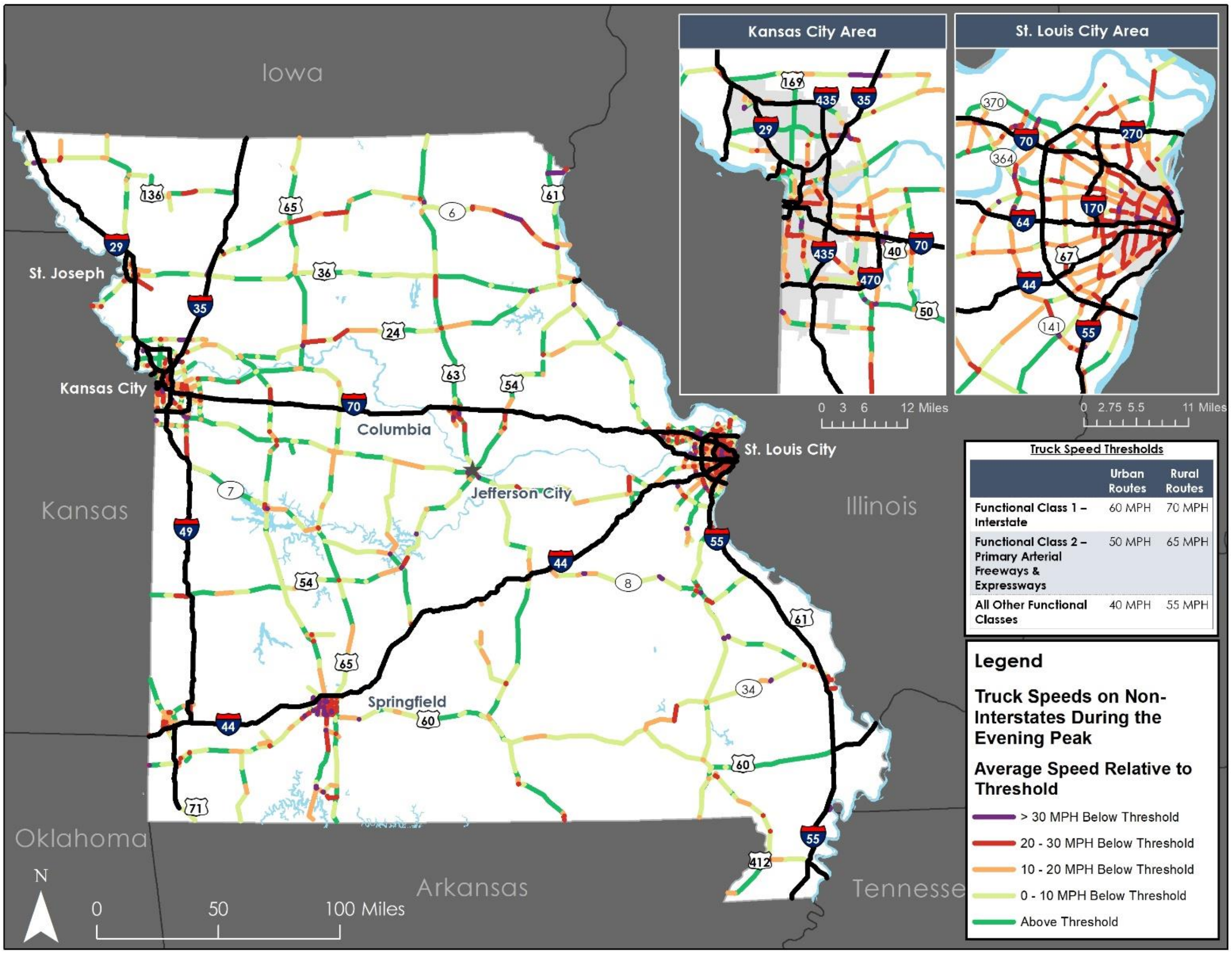
TABLE 4.12 SUMMARY OF AVERAGE TRUCK SPEEDS FOR NON-INTERSTATE HIGHWAYS

Peak Period	Total Mileage >= Speed Threshold	Percent of Total Mileage >= Speed Threshold	Total Mileage >= 10 MPH Below Speed Threshold	Percent of Total Mileage >= 10 MPH Below Speed Threshold
Morning	3,452	39%	6,539	77%
Midday	3,452	39%	6,609	76%
Evening	3,458	40%	6,606	75%
Night	2,701	31%	7,086	81%
Weekend	3,337	38%	6,787	78%
Total Mileage (Both Directions)	**8,750**	**100%**	**8,750**	**100%**

Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Figure 4.21 shows the average truck speeds during the evening time period, when the highest percentage of centerline miles see average truck speeds that are less than 10 mph relative to the speed threshold (maps of truck speeds across the state at all five different time periods can be found in Appendix B.1). The state's urban areas can be clearly shown on these maps, as this is where the large majority of congested roads are located, which is expected due to increased driveway density and the presence of traffic signals. In additional to the large urban areas of St. Louis and Kansas City, smaller urban areas such as St. Joseph, Columbia, Springfield and Joplin are all visible due to the slower truck speeds that occur in these areas. Outside of the urban areas, non-interstates are largely uncongested and allow for high truck speeds. There are some roads where slower speeds are observed, such as along MO-6 in the northeastern part of the state and portions of the roads in the Lake of the Ozarks area.

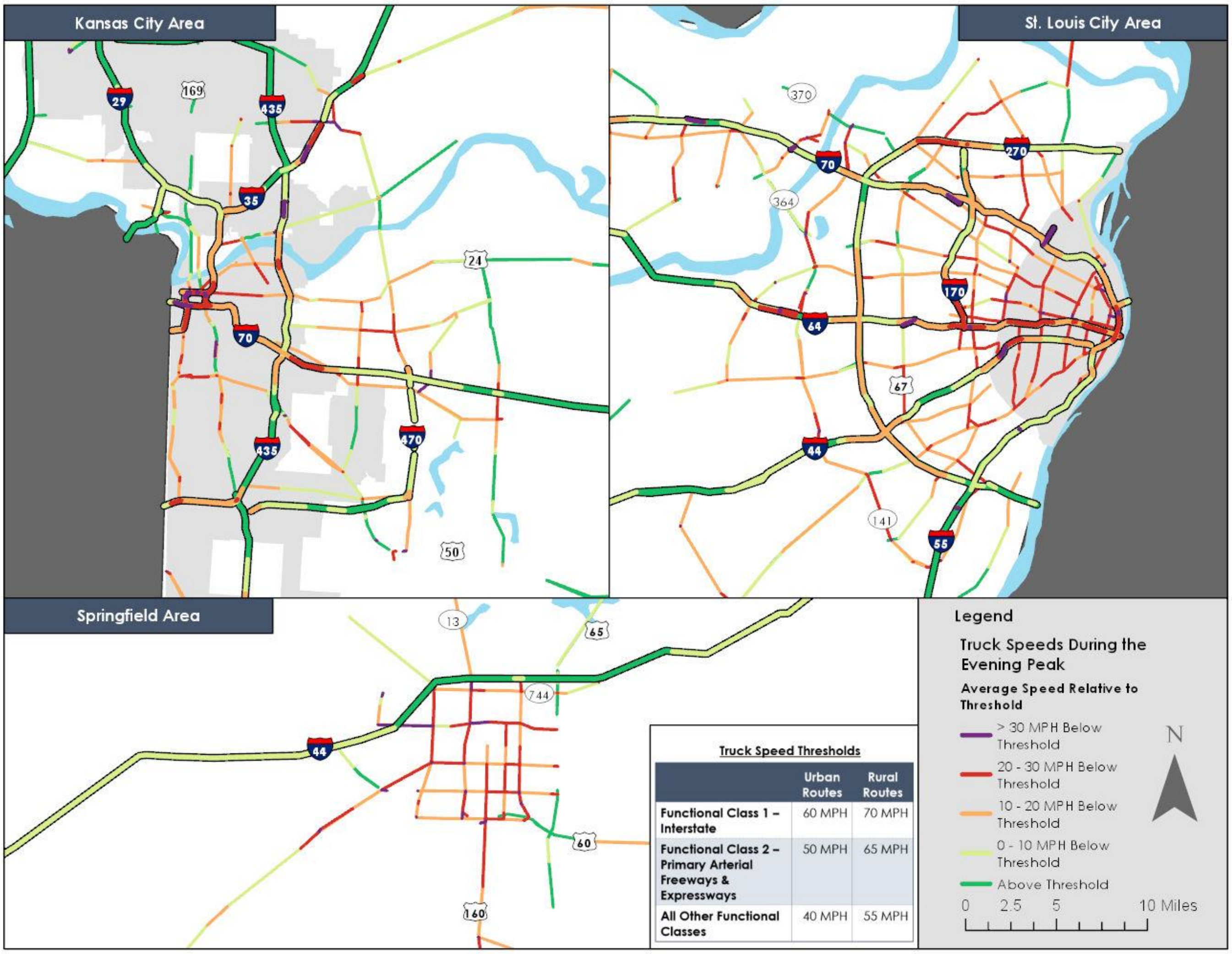
FIGURE 4.21 EVENING PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Finally, to provide more detail about the urban areas of St. Louis, Kansas City and Springfield, Figure 4.22 shows average truck speeds relative to the thresholds during the evening peak. This figure shows both interstates and non-interstates.

FIGURE 4.22 AVERAGE TRUCK SPEEDS DURING THE EVENING PEAK IN ST. LOUIS, KANSAS CITY AND SPRINGFIELD



Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Truck Travel Time Reliability

The second metric used to measure performance on highways is reliability. This measures the variability of travel time within the five different time periods. Reliability is a metric that is particularly important for freight as it is closely tied to motor carrier's decision making and operating costs. When travel times are not reliable, motor carriers must build additional time into their schedules to compensate for the uncertainty in travel times. This can lead to increased shipping costs due either to the wasted time that needs to be included in the schedule but is not used or due to the increased time that results from the delay experienced by the driver.

This analysis measures reliability through the truck travel time reliability index. This is the ratio of truck travel times at the 95th percentile to the 50th percentile over an individual segment of road. The greater the difference between the 95th percentile and the 50th percentile of travel times, the higher the TTTR, and the less reliable that stretch of road is during that time period. For example, a TTTR value of 2 means that travel times can be up to twice as long as the median travel time. For this analysis, reliable roads were determined using a cutoff TTTR of 1.45, which is the target that MoDOT has set for 2021. Roads at or below 1.45 are considered reliable, and roads above that value are considered unreliable. The TTTR on interstates is a performance metric that states are required to submit periodically to FHWA to monitor national freight performance.

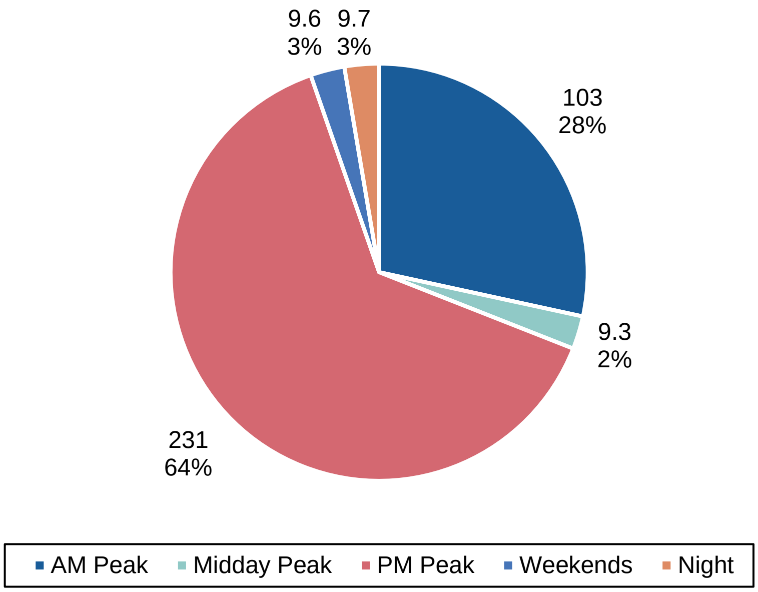
Interstates

One measure of overall interstate reliability across the state is to calculate the TTTR index. The TTTR index is a weighted average of truck congestion in the state. The 2017 baseline TTTR value was 1.25, and a lower number means that congestion is decreasing. The TTTR for 2019 is slightly higher than in 2017, with a value of 1.27 across the state.

Approximately 13% (363 of 2,759 highway miles) of Missouri's interstates are unreliable at any time period, i.e., have a TTTR greater than 1.45 during one or more of the five time periods. To give an idea of when the roads are least reliable, Figure 4.23 shows within what time period the maximum TTTR measurement occurs among the five time periods. The majority (64%) of the maximum TTTR measurements occur during the evening peak; this is followed by the morning peak, where 28% of maximum TTTR measurements are observed.

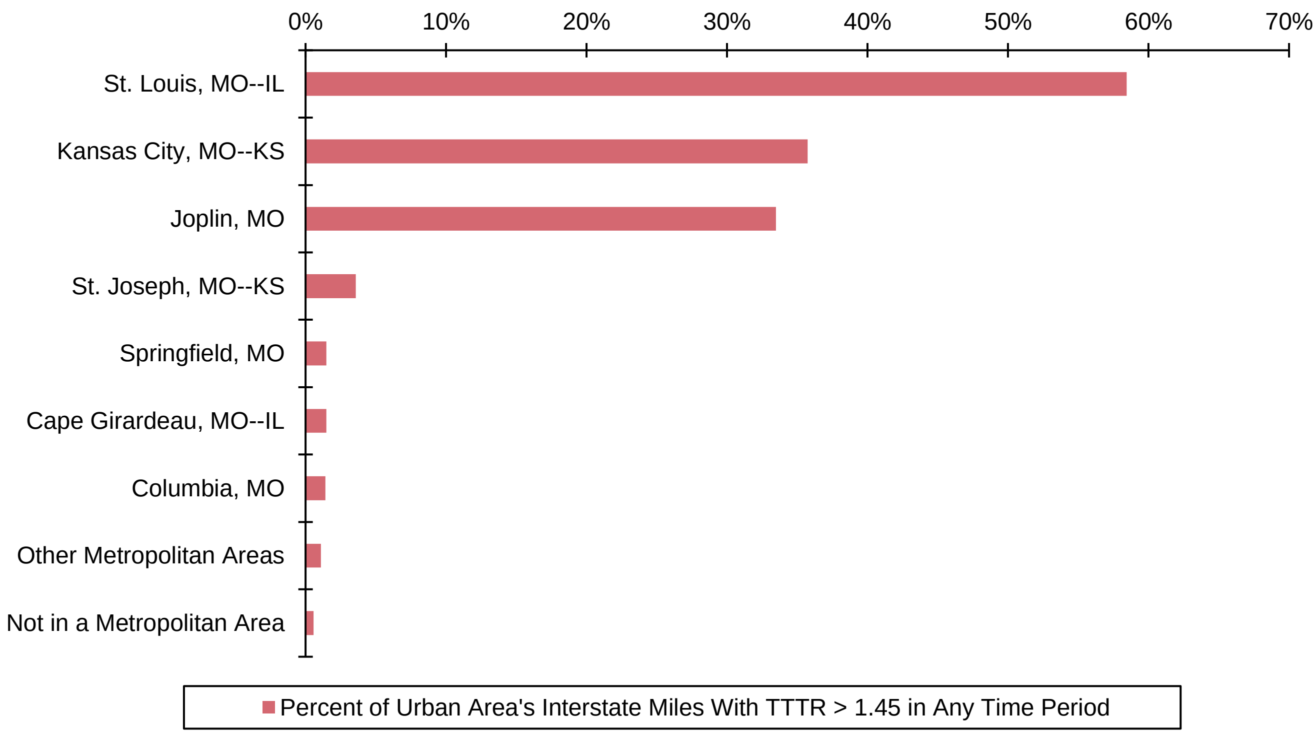
Most of the interstate miles that are unreliable happen within urban areas of the state. Figure 4.24 shows the percentage of interstate centerline miles in Missouri's urban areas that have a TTTR greater than 1.45 in any time period. It uses the total number of interstate centerline miles in each urban area as the denominator of the percent. It also combines miles of unreliable roads across different time periods, meaning, in other words, that it combines congestion in the morning peak with congestion in the evening peak, the midday peak, etc. St. Louis has the highest percentage of unreliable interstate miles (232 of 397 miles, or 58%), followed by Kansas City (109 of 305 miles, or 36%), Joplin (7.5 of 22 miles, or 33%) and St. Joseph (1 of 31 miles, or 4%). 99% of interstate miles not in a metropolitan area are reliable across all time periods.

FIGURE 4.23 MILES OF UNRELIABLE INTERSTATE, CATEGORIZED BY TIME PERIOD WHERE THE MAXIMUM TTTR OCCURS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE 4.24 PERCENT OF AN URBAN AREA'S INTERSTATE MILES THAT ARE ABOVE A TTTR OF 1.45 IN ANY TIME PERIOD



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Table 4.13 shows a breakdown of the percentage of interstate miles that are reliable across the five different time periods. This provides a percent, in each of the time periods, of the number of centerline miles that have a TTTR value greater than 1.45 compared to the total interstate centerline miles statewide.[20] The evening peak has the lowest number of highway miles that are reliable, at 90%. This is followed by the morning peak, where 94% of interstate miles are reliable. Nights and weekends have the highest percentage of highway miles that are reliable, at 99% for both.

TABLE 4.13 SUMMARY OF INTERSTATE CENTERLINE MILES WITH TTTR <= 1.45

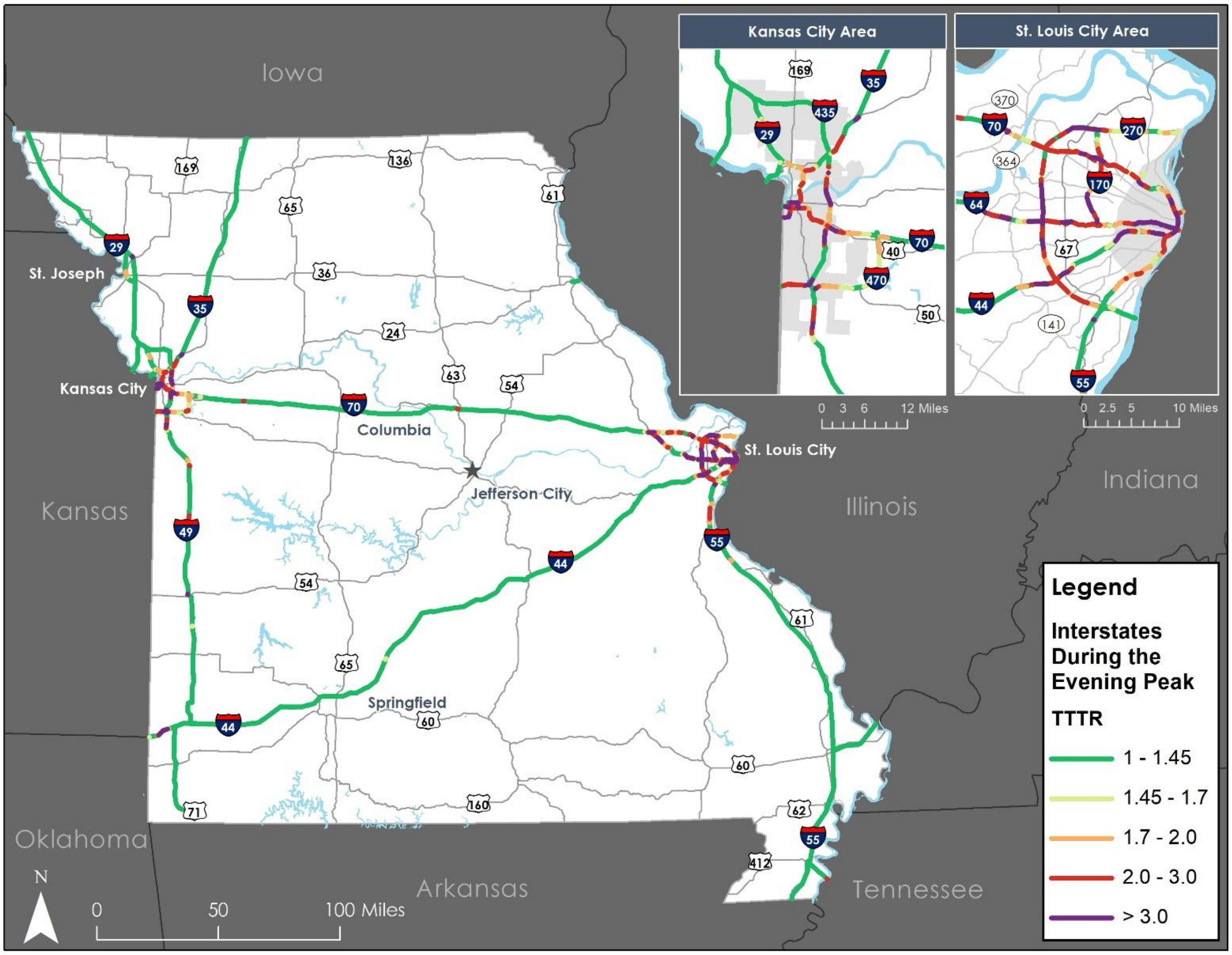
Peak Period	Total Miles with TTTR <= 1.45	Percent of Total Miles with TTTR <= 1.45
Morning	2,592	94%
Midday	2,658	96%
Evening	2,486	90%
Night	2,732	99%
Weekend	2,720	99%
Total Interstate Centerline Miles (Both Directions)	**2,759**	**100%**

Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Figure 4.25 shows a map of Missouri's interstates during the evening peak, when there are there is the greatest percent of unreliable interstate highway miles (maps of TTTR statewide at all five different time periods can be found in Appendix B.2). It reiterates that most of the unreliable interstate miles happen within the state's urban centers, particularly in the city centers of St. Louis and Kansas City. There are also some small portions of unreliable interstate in St. Joseph and Joplin. Aside from these areas, this map shows that the interstates outside of the urban areas are reliable.

[20] The total interstate mileage in Table 4.13 is twice the mileage listed in Table 2.1 because it accounts for centerline miles in both directions.

FIGURE 4.25 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Non-Interstates

Non-interstates are less reliable than the interstates, in large part because they are not designed to provide the same level of efficiency in terms of the free flow of traffic. Reliability on non-interstate roads is largely a function of the functional class of the road, where roads that are designed with limited access and exit/entrance ramps (such as Functional Class 2, primary arterial freeways and expressways) are more efficient than those that do not have limited access (such as Functional Class 3, other primary arterial).

The effects of the difference in design on reliability can be shown by comparing the percent of total miles of unreliable road with the breakdown of unreliable roads by functional class. Table 4.14 shows the variation in reliable miles for non-interstates during the five different time periods. The percent of reliable miles are similar throughout all five time periods, at around 69%. Table 4.15 breaks down the number of reliable miles by functional class during the evening peak, which has the lowest number of reliable miles among all the time periods. 85% of

Functional Class 2 are reliable, yet only 56% of Functional Class 3 are reliable. Thus, even though the percent of miles that are reliable is significantly lower than for interstates, this difference is largely due to the differences in functional class and therefore the design of those roads.

TABLE 4.14 SUMMARY OF RELIABLE NON-INTERSTATE HIGHWAY MILES

Peak Period	Total Miles with TTTR <= 1.45	Percent of Total Miles with TTTR <= 1.45
Morning	5,996	68%
Midday	5,965	68%
Evening	5,909	68%
Night	6,178	71%
Weekend	6,023	69%
Total Non-Interstate NHS Centerline Miles (Both Directions)	**8,749**	**100%**

Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

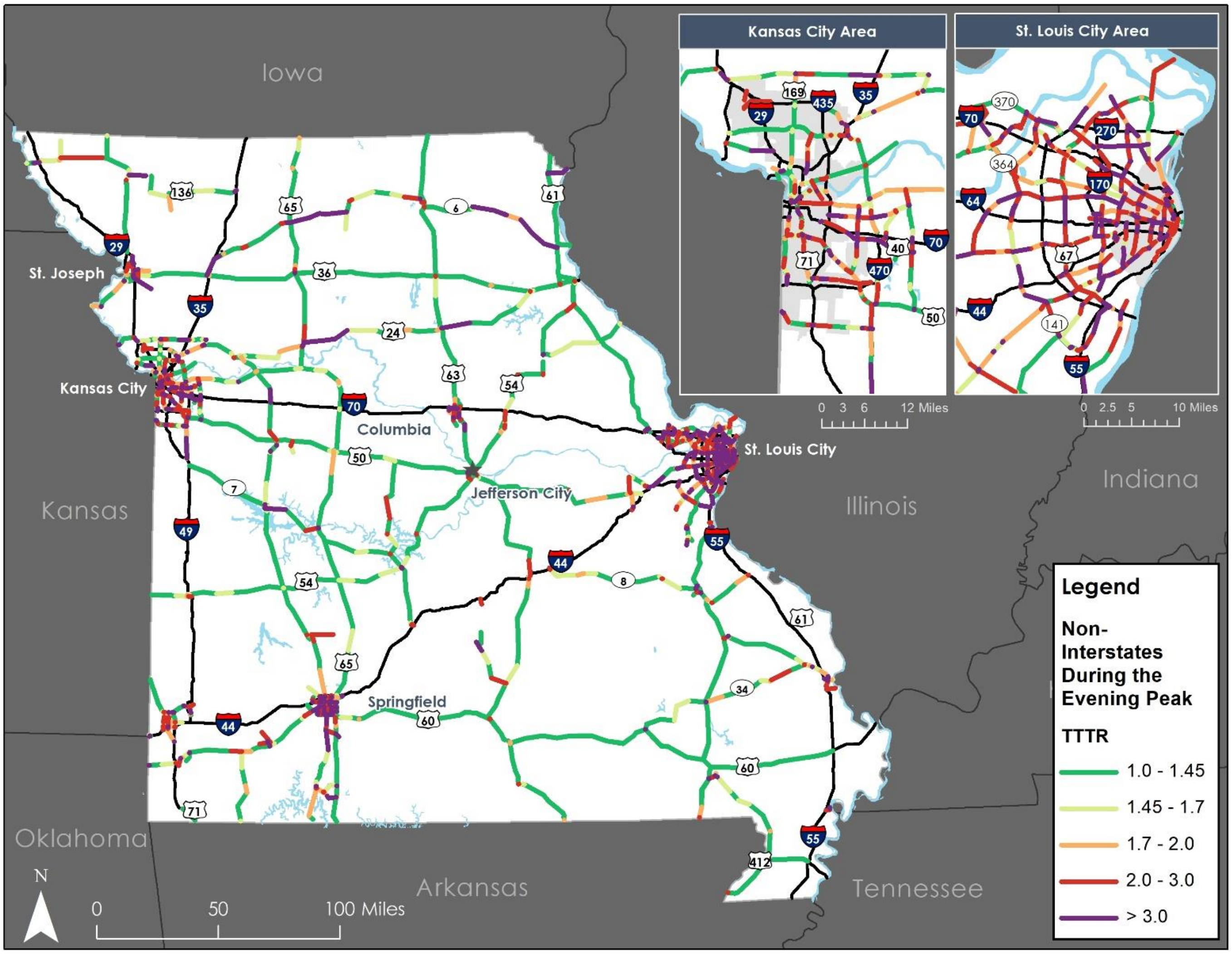
TABLE 4.15 RELIABLE NON-INTERSTATE HIGHWAY MILES DURING THE EVENING PEAK BY FUNCTIONAL CLASS

FWHA Functional Classification	Total Miles with TTTR <= 1.45	Total Mileage in the NHS	Percent of Total Miles with TTTR <= 1.45
2 – Principal Arterial – Other Freeways & Expressways	2,914	3,400	85%
3 – Principal Arterial – Other	2,947	5,258	56%
4 – Minor Arterial	46	82	56%
5 – Major Collector	2	9	21%
Total Non-Interstate NHS Mileage (Both Directions)	**5,909**	**8,749**	**68%**

Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Figure 4.26 shows a map of TTTR on non-interstates across the state during the evening peak (maps of TTTR on non-interstates statewide at all five different time periods can be found in Appendix B.2). Overall, reliability is higher in more rural areas and lower in the urban areas. There are certain roads that show higher unreliability, such as MO-6 in the northeastern part of the state and U.S. 136 in the northwestern part of the states. Non-interstates are, in general, less uniformly reliable than interstates. Roads that are reliable in one part of the state may become less reliable in other parts. For instance, U.S. 36, in the northern part of the state, is reliable throughout most of its eastern segments, but has parts that are unreliable in the western part of the road near St. Joseph.

FIGURE 4.26 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATES

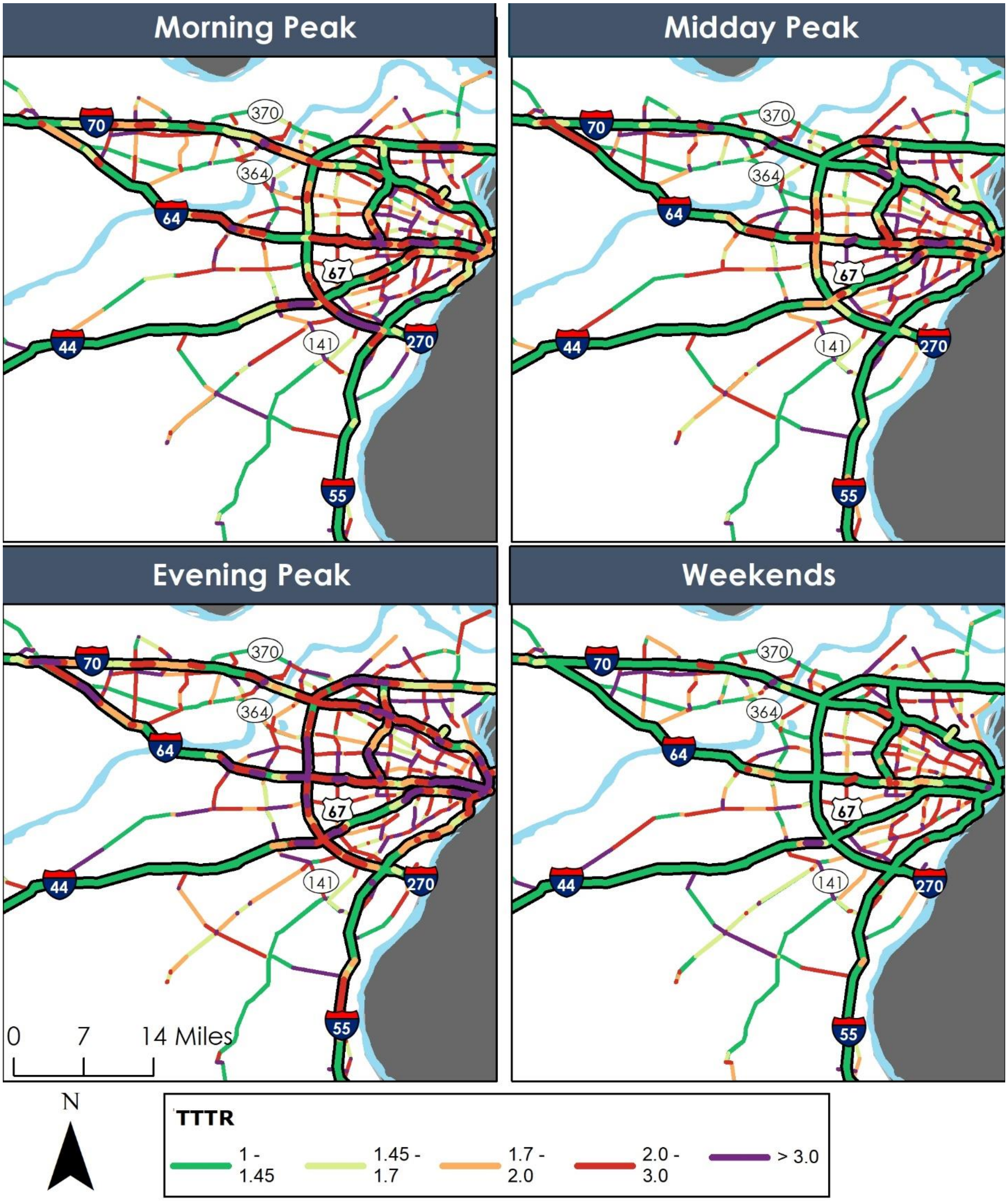


Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Urban Areas

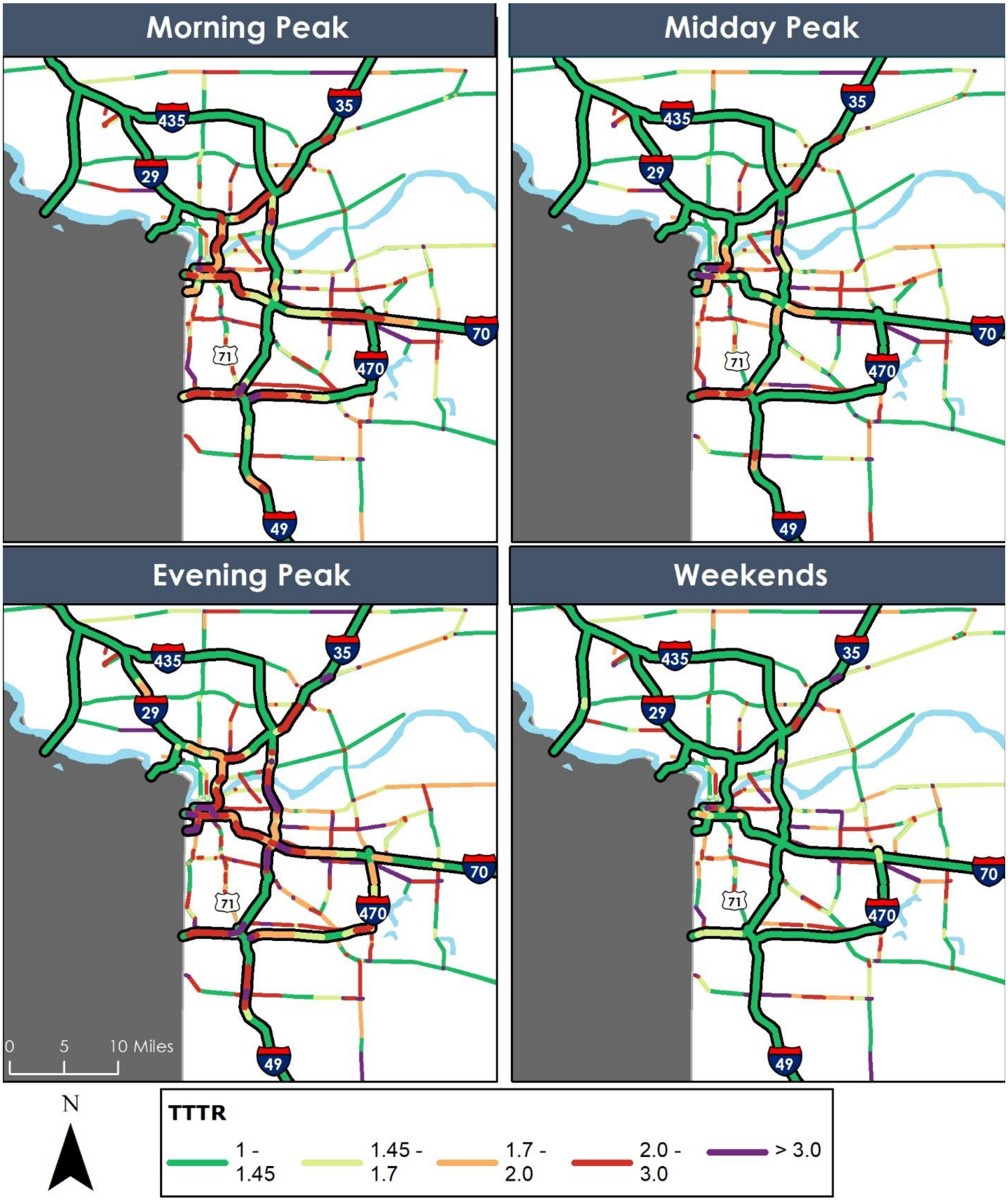
Because the reliability of the roads varies greatly in the urban areas, Figure 4.27, Figure 4.28 and Figure 4.29 map out the TTTR measurements in the St. Louis, Kansas City and Springfield areas, respectively. In St. Louis, there is some variability in where unreliable roads show up during the morning and evening peaks. In the morning, I-270 in the southern part of the city is less reliable; in the evening, I-64 and I-70 in the northwest part of the area are less reliable. In the Kansas City area, the downtown interchanges between I-29, I-35, I- 670 and I-70 are less reliable during both the morning and evening peaks. Outside of this area, in the mornings, I-70 is less reliable, while in the evenings I-35 and I-435 have portions that are less reliable. The roads in Springfield are generally reliable, though the non-interstates can see significant variations in travel time, notably U.S. 160 to the south, U.S. 60 in the west and MO-744 which runs parallel with I-44.

FIGURE 4.27 TRUCK TRAVEL TIME RELIABILITY FOR THE ST. LOUIS AREA



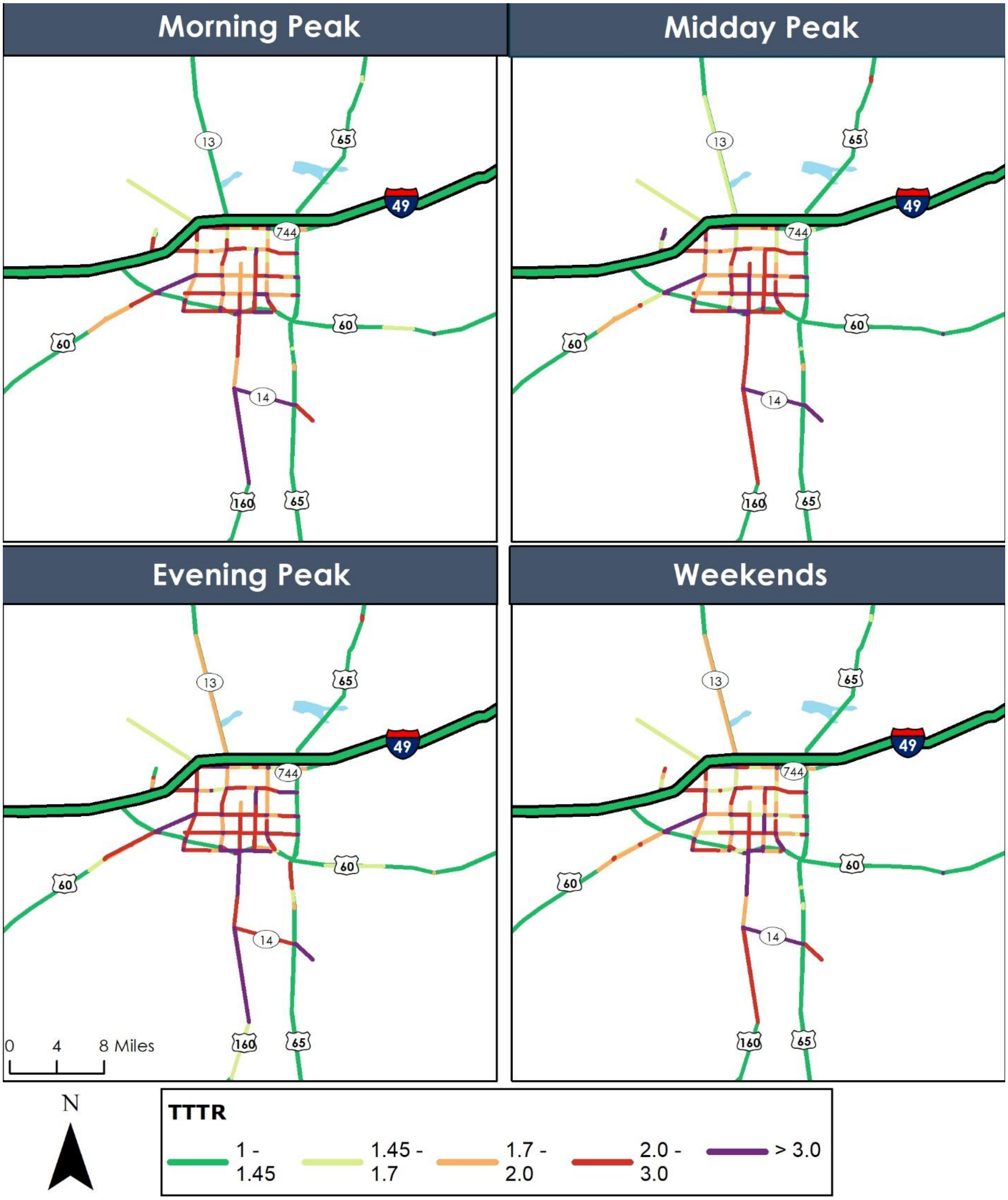
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE 4.28 TRUCK TRAVEL TIME RELIABILITY FOR THE KANSAS CITY AREA



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE 4.29 TRUCK TRAVEL TIME RELIABILITY FOR THE SPRINGFIELD AREA



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Bottlenecks

In looking at the performance of the highways in Missouri, it is important to focus on truck bottlenecks where persistent delays occur. Citing 23 CFR 490.101, the FHWA defines a bottleneck as “a segment of roadway identified by the state DOT as having constraints that cause a significant impact on freight mobility and reliability.”[21]

The FHWA emphasizes the importance of identifying bottlenecks on interstates, which are primary highways for freight movement and thus a high priority to reduce any bottlenecks. The process of identifying bottlenecks relies in part on using data and metrics to pinpoint areas of persistent congestion and/or unreliability and in part on working with freight stakeholders to incorporate feedback based on their experience of where and why delays occur. As of 2020, MoDOT has identified three freight bottlenecks of particular interest:

1. The interchange of I-55, I-64 and I-44 near the Poplar Street Bridge (known officially as the William L. Clay Sr. Bridge) in St. Louis

2. The interchange between I-64 and I-270 in western St. Louis County

3. The Downtown Loop interchange between I-70, I-670 and US-71 in downtown Kansas City

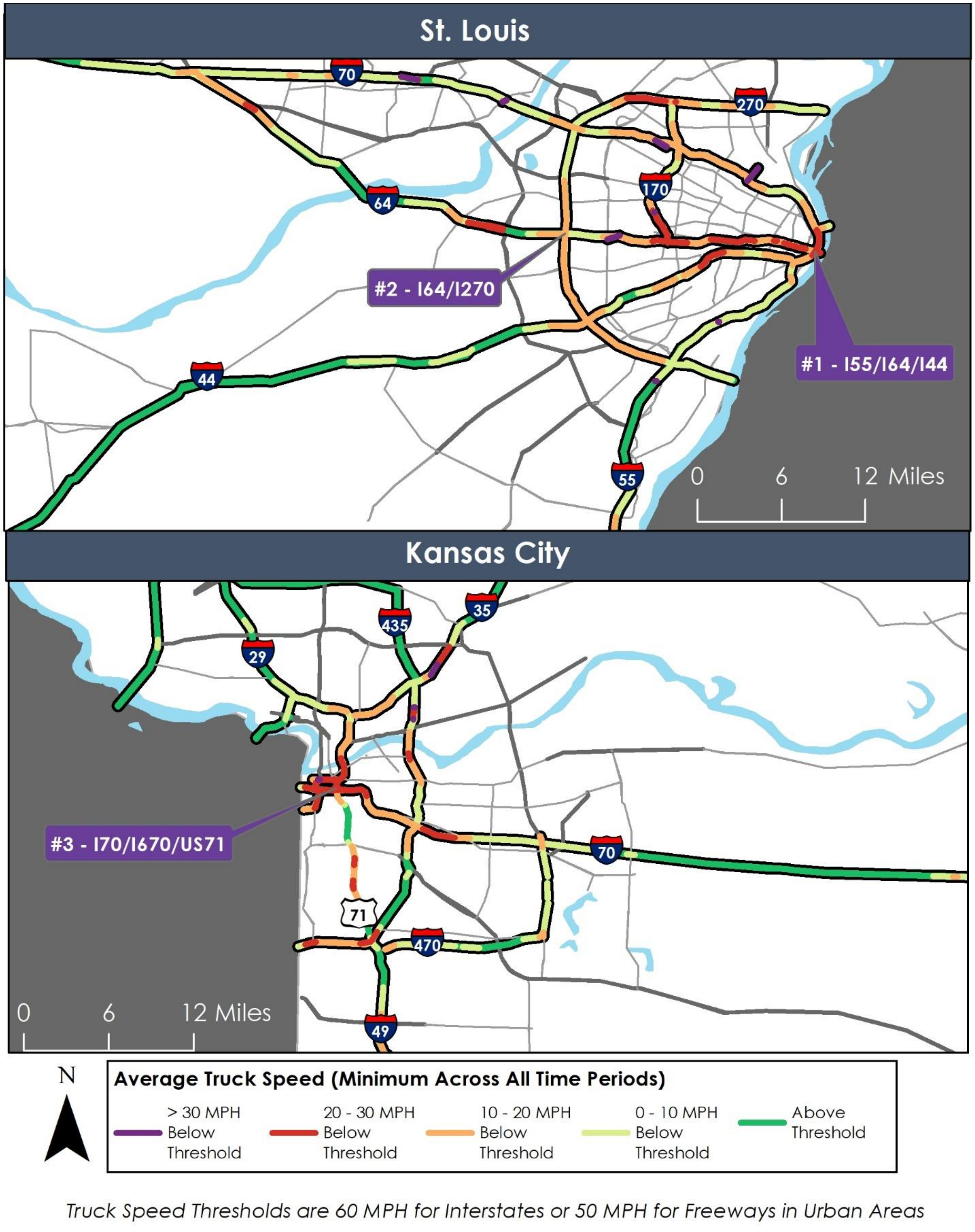
The first and third bottlenecks have also been listed as two of the top 100 truck bottlenecks in the country for the year 2019 by the American Transportation Research Institute.[22] These three bottlenecks are shown in Figure 4.30 and Figure 4.31. Figure 4.30 shows the minimum average truck speed that is found among any of the five time periods, and Figure 4.31 shows the highest TTTR.

Table 4.16 shows the traffic volume and performance measurement values (i.e. minimum average truck speed and maximum TTTR) for the roads near the bottlenecks. These numbers give a sense of which segments of road within the bottleneck are the most congested and the least reliable. In the first bottleneck, the roads that lead into the Poplar Street Bridge (i.e. I-55/I-44 going north, I-44 going south and I-64 going east) have the highest TTTR values and the lowest average truck speeds. In the second bottleneck, I-270 going south and I-64 going east have the lowest average truck speeds and the highest TTTR values. Finally, in the third bottleneck, all the roads involved have low truck speeds and high TTTR values except for southbound US-71.

[21] https://www.fhwa.dot.gov/tpm/guidance/hop18070.pdf

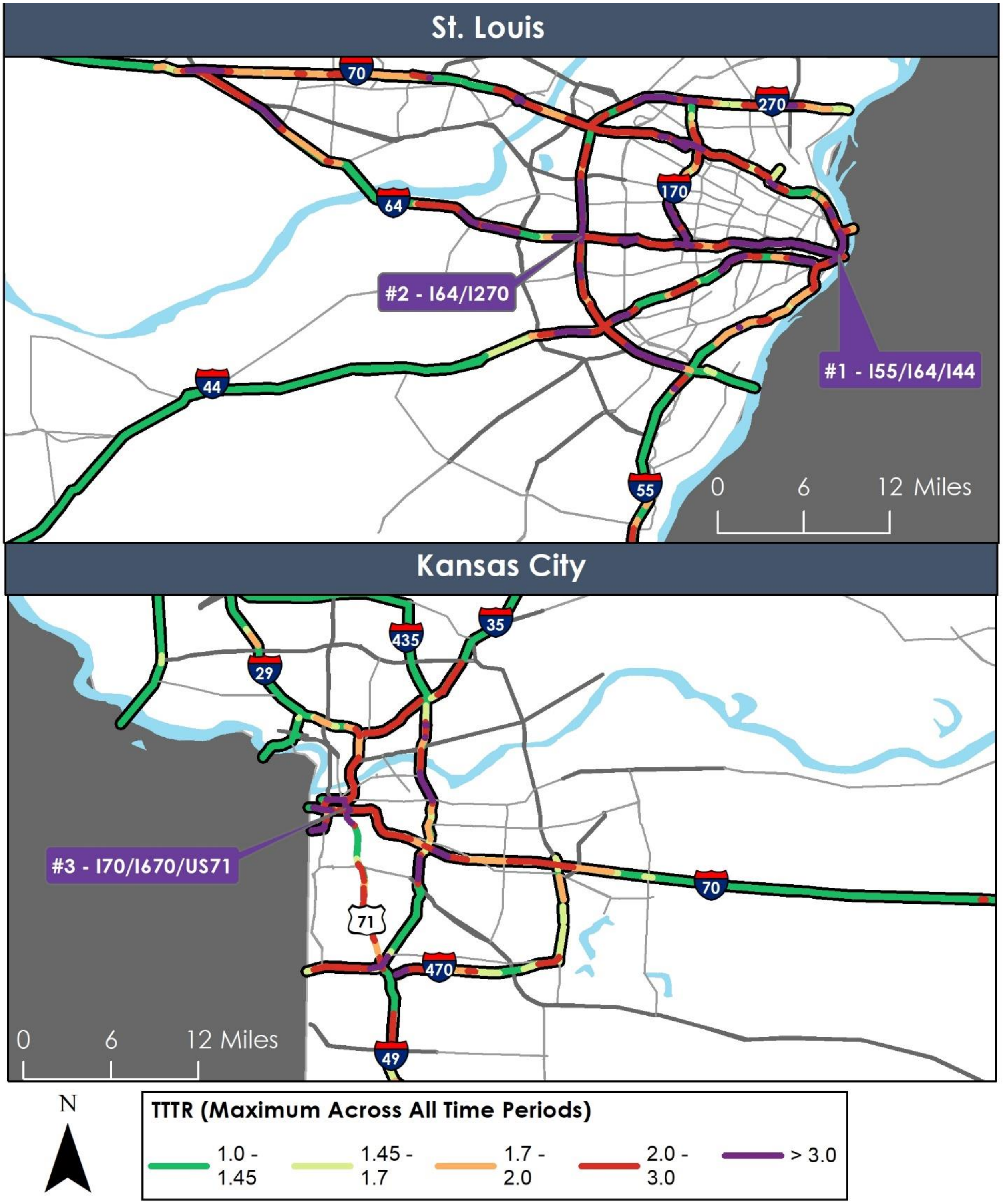
[22] https://truckingresearch.org/2019/02/06/atri-2019-truck-bottlenecks/

FIGURE 4.30 AVERAGE TRUCK SPEED FOR THREE TRUCK BOTTLENECK LOCATIONS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE 4.31 TRUCK TRAVEL TIME RELIABILITY FOR THREE TRUCK BOTTLENECK LOCATIONS



Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020*

TABLE 4.16 VOLUME AND PERFORMANCE MEASURES FOR ROADS IN MISSOURI'S BOTTLENECKS

Highway	Length-Weighted AADT	Length-Weighted AADTT	Length-Weighted Average Truck Speed* (Minimum among all time periods)	Length-Weighted Average TTTR * (Maximum among all time periods)
Bottleneck 1 – The interchange of I-55, I-64 and I-44 near the Poplar Street Bridge in St. Louis				
I-44 Eastbound	99,593	17,253	47 MPH	1.88
I-44 Westbound	97,356	17,253	32 MPH	3.73
I-55/I-44 Northbound	126,383	24,105	49 MPH	3.08
I-55/I-44 Southbound	127,260	24,564	44 MPH	1.52
I-55/I-64 Eastbound	48,888	17,670	45 MPH	2.13
I-55/I-64 Westbound	57,597	20,794	36 MPH	1.43
I-64 Eastbound	96,503	9,569	43 MPH	3.56
I-64 Westbound	92,619	10,041	50 MPH	1.27
Bottleneck 2 – The interchange between I-64 and I-270 in west St. Louis County				
I-270 Northbound	199,353	32,264	56 MPH	1.41
I-270 Southbound	199,539	31,873	43 MPH	3.19
I-64 Eastbound	170,897	19,876	50 MPH	2.67
I-64 Westbound	170,785	19,928	57 MPH	1.60
Bottleneck 3 – The Downtown Loop interchange between I-70, I-670 and US-71 in downtown Kansas City.				
I-35 Northbound	75,423	9,657	37 MPH	2.56
I-35 Southbound	80,800	11,107	36 MPH	2.24
I-35/I-70 Eastbound	69,939	12,665	31 MPH	2.02
I-35/I-70 Westbound	69,954	12,669	41 MPH	2.02
I-670 Eastbound	65,124	10,002	37 MPH	2.15
I-670 Westbound	64,896	9,973	40 MPH	1.97
I-70 Eastbound	74,914	13,899	43 MPH	1.72
I-70 Westbound	74,056	13,673	37 MPH	2.65
US-71 Northbound	86,581	5,319	34 MPH	4.44
US-71 Southbound	86,156	5,294	51 MPH	1.20

Note: Colors are matched with the legends of Figure 4.30 (for Length-Weighted Average Truck Speed) and Figure 4.31 (for Length-Weighted Average TTTR). Major construction activities such as on I-44 may impact analysis.

Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020*

Bottlenecks can also occur due to traffic incidents that block travel lanes and temporarily reduce the number of vehicles that can travel on a route. MoDOT tracks the speed at which it clears these incidents and returns the highway to normal conditions.[23] Specifically, MoDOT tracks how long it takes to clear incidents in St. Louis, Kansas City, Springfield, rural portions if I-70 and rural portions of I-44. As of July 2020, the time to clear incidents in

[23] MoDOT Tracker metric 4c – Average Time to Clear Traffic Incidents

Kansas City and rural portions of I-44 consistently improved, while clearance times were more variable in the other areas.

Additionally, though the roads outside of the urban areas show consistent numbers in terms of reliability and truck speed, this can mask the potential for delays when the highway system is overwhelmed. For instance, a reduction in speed due to a crash, inclement weather, a work zone or a large influx of recreational vehicles heading to areas like Lake of the Ozarks, can lead to significant backups that do not show up in the overall truck speed and TTTR performance measures.

Therefore, in addition to these three bottlenecks identified by MoDOT, it is helpful to map the highest TTTRs and lowest average truck speed measurements across all five time periods. Doing so identifies other parts of the state where there is potential for severe congestion and unreliability. These are mapped out, respectively, in Figure 4.32 and Figure 4.33. Note that Figure 4.33 only includes average truck speed measurements on roads of Functional Classes 1 (Interstates) and 2 (Principal Arterial – Freeways & Expressways) to avoid capturing slow truck speeds that result from roads not designed to provide consistent truck speeds. In both figures, four points have been labeled for road segments that appear on both maps, i.e. road segments that have measured both the highest unreliability and the slowest average truck speed in the state. These four segments include (information about traffic volumes on those segments are included in parentheses):

1. MO-13 Southbound at the intersection with MO-7/MO-13-BR in Clinton. (AADT of 10,276 with AADTT of 1,915)

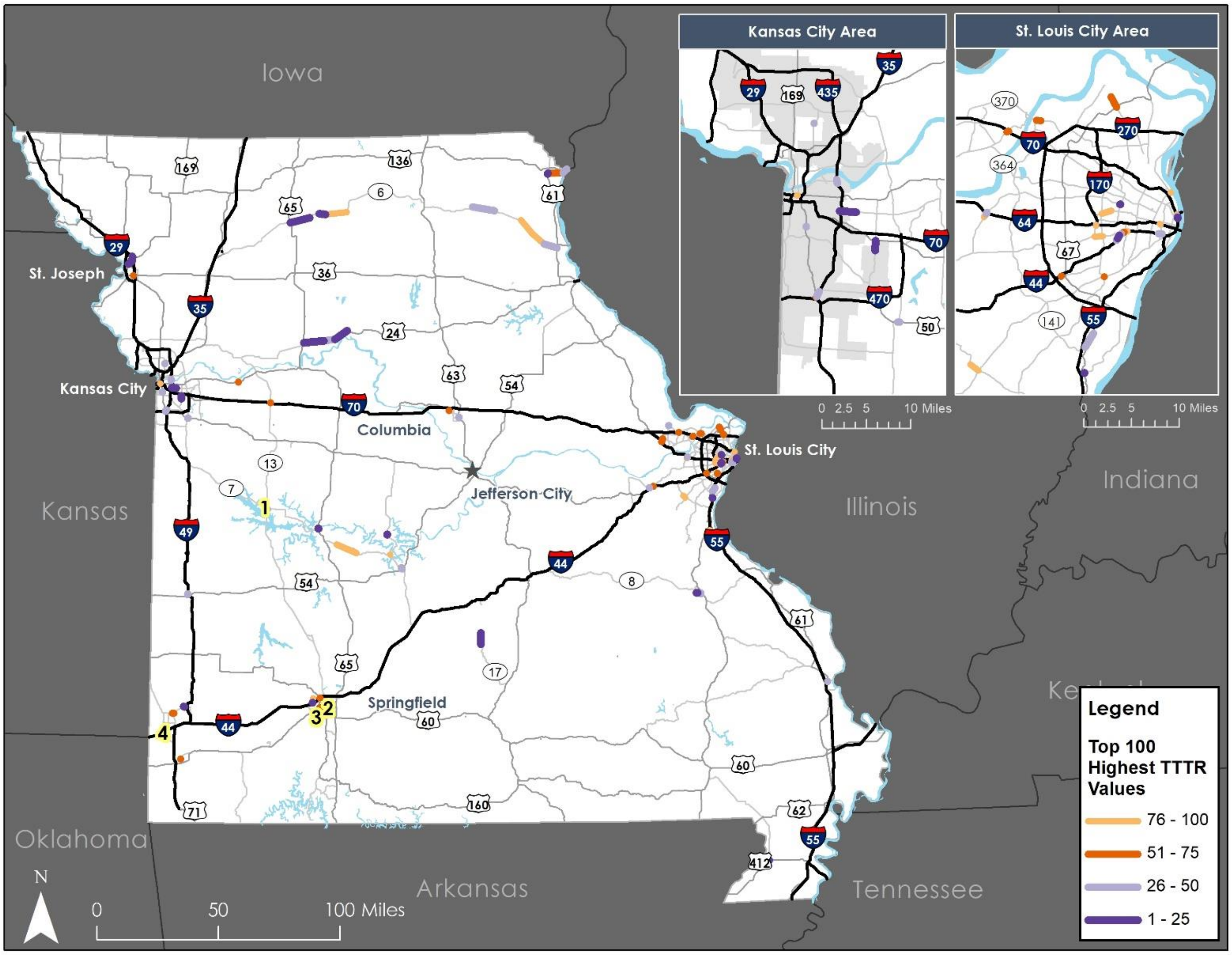
2. MO-13 Northbound at the intersection with W. Battlefield Road in Springfield. (AADT of 29,863 with AADTT of 1,293)

3. MO-FF Southbound at the intersection of S. Republic Road in Springfield. (AADT of 14,889 with AADTT of 404)

4. MO-43 Southbound at the interchange with I-44, MO-86 and S. Main Street in Joplin. (AADT of 2,124 with AADTT of 238)

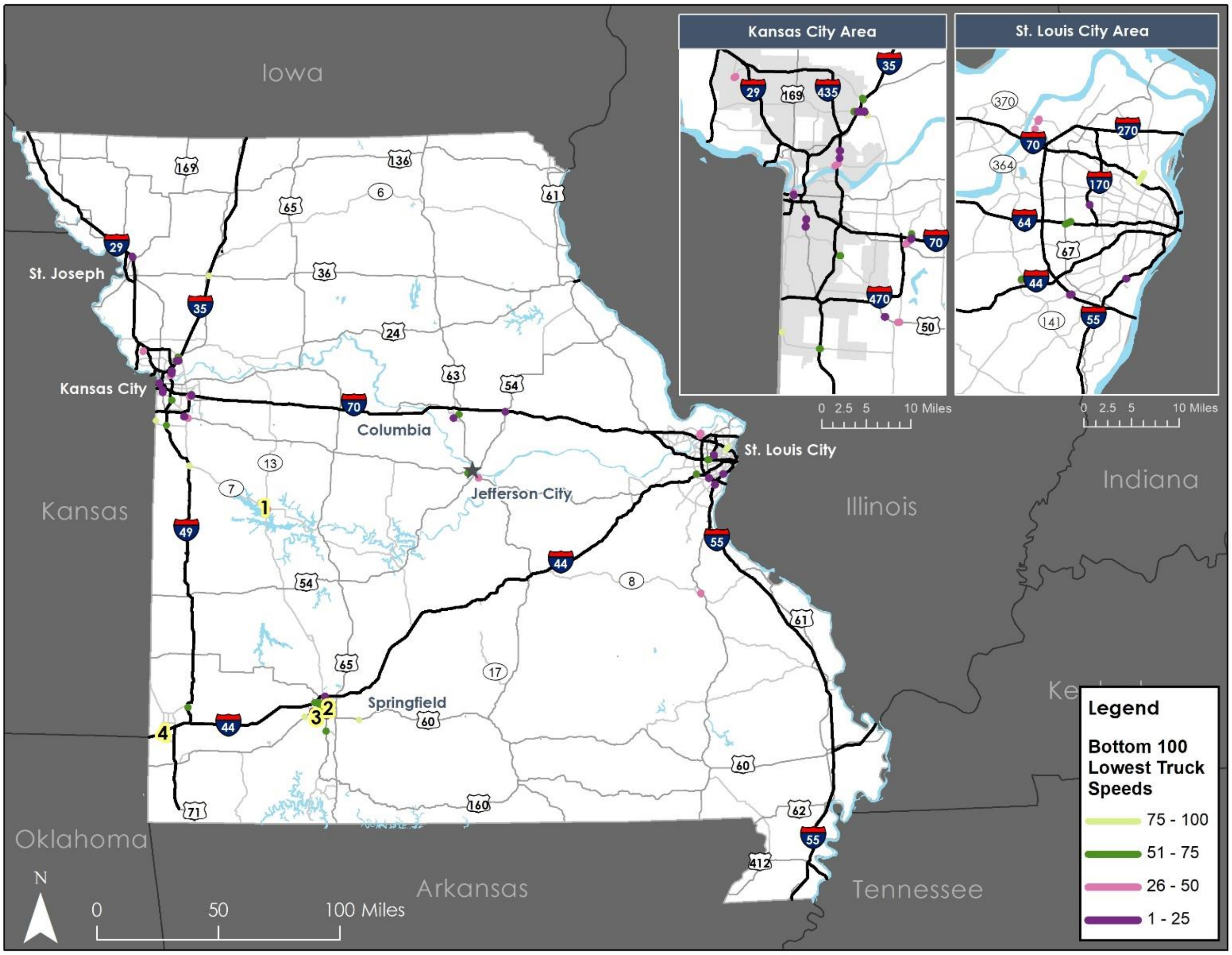
The identification of these roads provides additional information about bottlenecks that occur outside of the interstates and outside of the urban areas of St. Louis and Kansas City. Each of these four points show consistently high unreliability and consistently slow truck speeds in smaller urban areas, including two points in Springfield.

FIGURE 4.32 HIGHEST 100 MEASURES OF TRUCK TRAVEL TIME RELIABILITY IN MISSOURI



Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020. Major construction activities such as on I-44 may impact analysis.*

FIGURE 4.33 LOWEST 100 SLOWEST AVERAGE TRUCK SPEEDS IN MISSOURI



Note: *This map limits average truck speed measurements to roads of Functional Class 1 (interstates) and 2 (Primary Arterial – Freeways & Expressways).*

Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020*

5.0 Safety

5

Safety for all roadway users is MoDOT's top value. This section will present information on crashes involving trucks in Missouri as well as the contributing circumstances to those crashes. Data for crashes involving trucks in Missouri include information about human factors such as driver fatigue, distraction, impairment or other behaviors, as well as roadway conditions, including pavement and bridge conditions and vehicle operations.

5.1 Trucks Involved in Crashes

Data on truck crashes, including date, route, location, severity and contributing factors for the 5-year period between 2015 and 2019 was obtained from MoDOT through the Missouri Highway Safety Patrol (MHSP) Statewide Traffic Accident Records System (STARS) database and analyzed in this section.

Truck crash data is reported in two manners in the STARS database – truck crashes, or the overall number of crashes involving trucks, and trucks involved in crashes, which represents the total number of trucks involved in all truck crashes. The latter accounts for multiple trucks involved in the same crash. Both truck crashes and trucks involved in crashes were analyzed in this section; truck crashes are used when discussing overall truck crash numbers, and trucks involved in crashes is used when discussing truck crash severity and contributing factors as this captures all severity types and contributing circumstances when multiple trucks are involved in the same crash. Note that these terms do not mean that a truck driver is at fault or that the truck crashed into another vehicle; crashes can result from the behavior of an automobile driver, a truck driver or both.

Statewide Statistics on Trucks Involved in Crashes

Between 2015 and 2019, there were 72,144 truck-involved crashes in Missouri. There were a total of 83,522 trucks involved in those crashes, indicating that some crashes involved multiple trucks.[24] The number of truck crashes was relatively consistent from year to year, ranging from 13,402 in 2015 to 15,370 in 2019.

Trucks comprised 10.8 percent of all vehicle-involved in crashes in Missouri over these five years. Table 5.1 shows the annual number of truck crashes, the number of trucks involved in crashes and the severity of those crashes.[25]

[24] Note that this includes all trucks involved in crashes whether the truck driver was at fault or not.

[25] Note that statistics presented on truck involved crash injuries and fatalities includes data on all vehicles involved in the crash, including passenger and other non-commercial vehicles.

TABLE 5.1 TRUCK INVOLVED CRASHES BY SEVERITY AND YEAR

Year	Truck Involved Crashes	Trucks Involved in Crashes*	Property Damage Only (PDO)	Minor Injury	Disabling Injury	Suspected Serious Injury **	Fatal
2015	13,402	15,481	12,566	2,412	365	--	138
2016	14,393	16,690	13,293	2,815	438	--	144
2017	14,052	16,268	12,996	2,761	361	--	150
2018	14,927	17,305	13,849	2,890	393	--	173
2019	15,370	17,778	14,270	2,907	--	444	157
Total	**72,144**	**83,522**	**66,974**	**13,785**	**1,557**	**444**	**762**

**Data on crash severity is based on each truck involved in a crash. Therefore, columns four through eight sum up to column three (Trucks Involved in Crashes) and not column two (Truck Involved Crashes).*

*** MoDOT began using Suspected Serious Injury in lieu of Disabling Injury beginning in 2019.*

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

At the MoDOT District level, the breakdown of crashes by severity is shown in Table 5.2. More than 57% of the trucks involved in crashes were in the St. Louis (35.2%) and Kansas City (22.0%) Districts.

TABLE 5.2 TRUCKS INVOLVED IN CRASHES BY MODOT DISTRICT AND SEVERITY

MoDOT District	Fatal	Disabling/ Suspected Serious Injury	Minor Injury	PDO	Total Trucks Involved in Crashes	Percentage
Northeast	50	172	664	3,674	4,500	5.5%
Northwest	40	159	716	3,261	4,176	5.0%
Kansas City	135	385	3,156	14,606	18,282	22.0%
Central	137	260	1,267	6,882	8,546	10.3%
St. Louis	135	437	4,607	24,090	29,269	35.2%
Southwest	167	347	2,016	8,107	10,637	12.8%
Southeast	98	241	1,325	5,922	7,586	9.1%
Total	**762**	**2,001**	**13,751**	**66,542**	**83,056***	**100.0%****

** Crash reports for 466 truck involved crashes did not include location information.*

*** Percentages may not add up to 100% due to rounding.*

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

Table 5.2 lists the number of trucks involved in crashes but does not factor in the actual lane miles of the routes on which the truck crashes occurred. To normalize this data, the lanes miles in each of the MoDOT Districts was factored into the crashes by severity and is presented in Table 5.3. Lane miles consider not only the length of the roadway but also the number of lanes along that length. Therefore, a 10-mile long roadway with four lanes would have 40 lane miles.

TABLE 5.3 TRUCKS INVOLVED IN CRASHES BY MODOT DISTRICT AND SEVERITY NORMALIZED BY LANE MILES

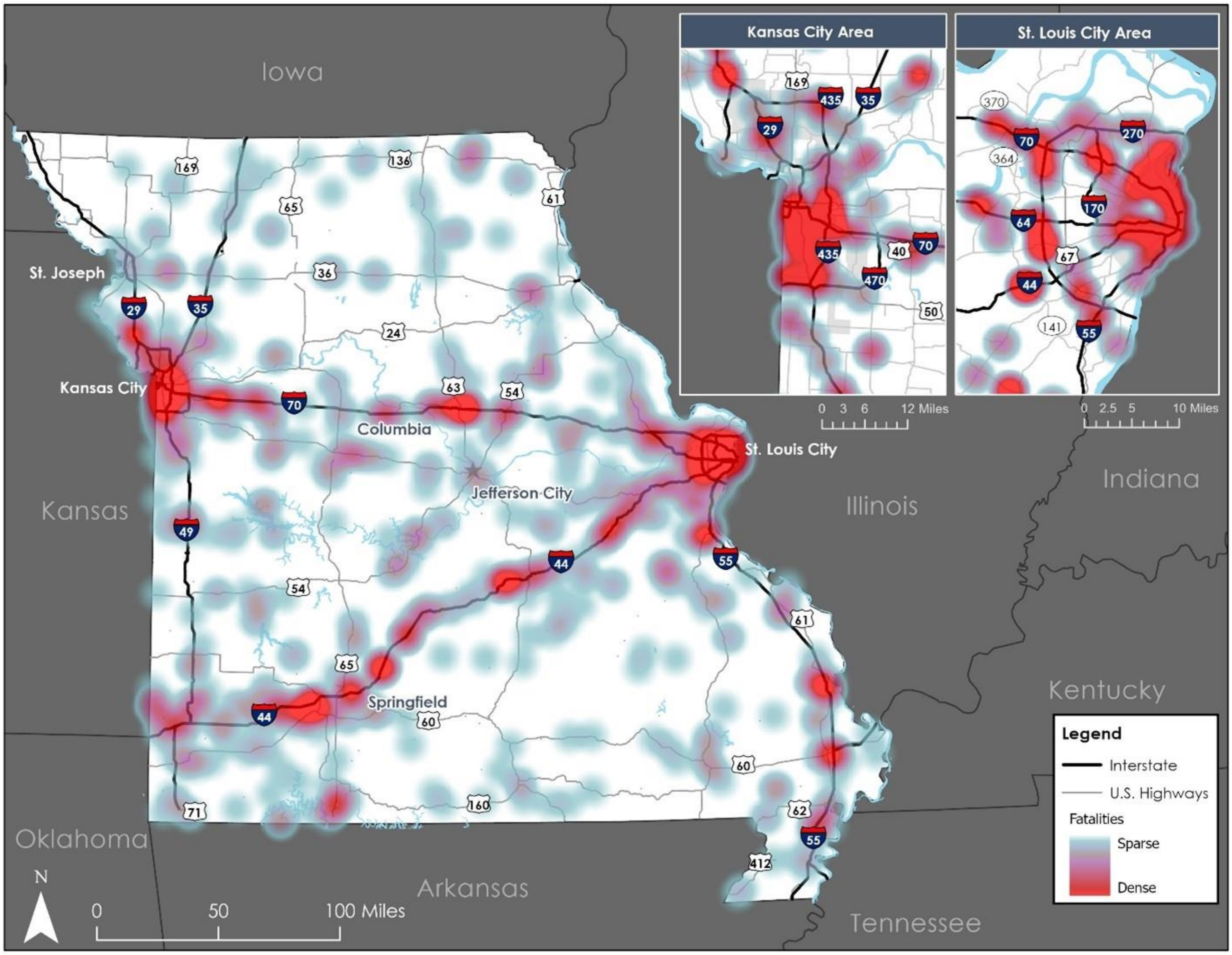
MoDOT District	Lane Miles	Fatal	Disabling/ Suspected Serious Injury	Minor Injury	PDO	Total All Categories
Northeast	2,224	0.07	0.23	0.89	4.95	6.15
Northwest	1,863	0.07	0.26	1.19	5.41	6.93
Kansas City	3,474	0.16	0.44	3.64	16.85	21.09
Central	2,547	0.18	0.35	1.71	9.29	11.53
St. Louis	4,060	0.17	0.55	5.82	30.44	36.99
Southwest	3,646	0.16	0.33	1.90	7.63	10.01
Southeast	3,073	0.11	0.27	1.46	6.53	8.36

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

As shown in Table 5.3, the Kansas City and St. Louis MoDOT Districts have the highest normalized crash severity types when compared to the other five MoDOT Districts, although the Central District has a slightly higher level of fatal crashes.

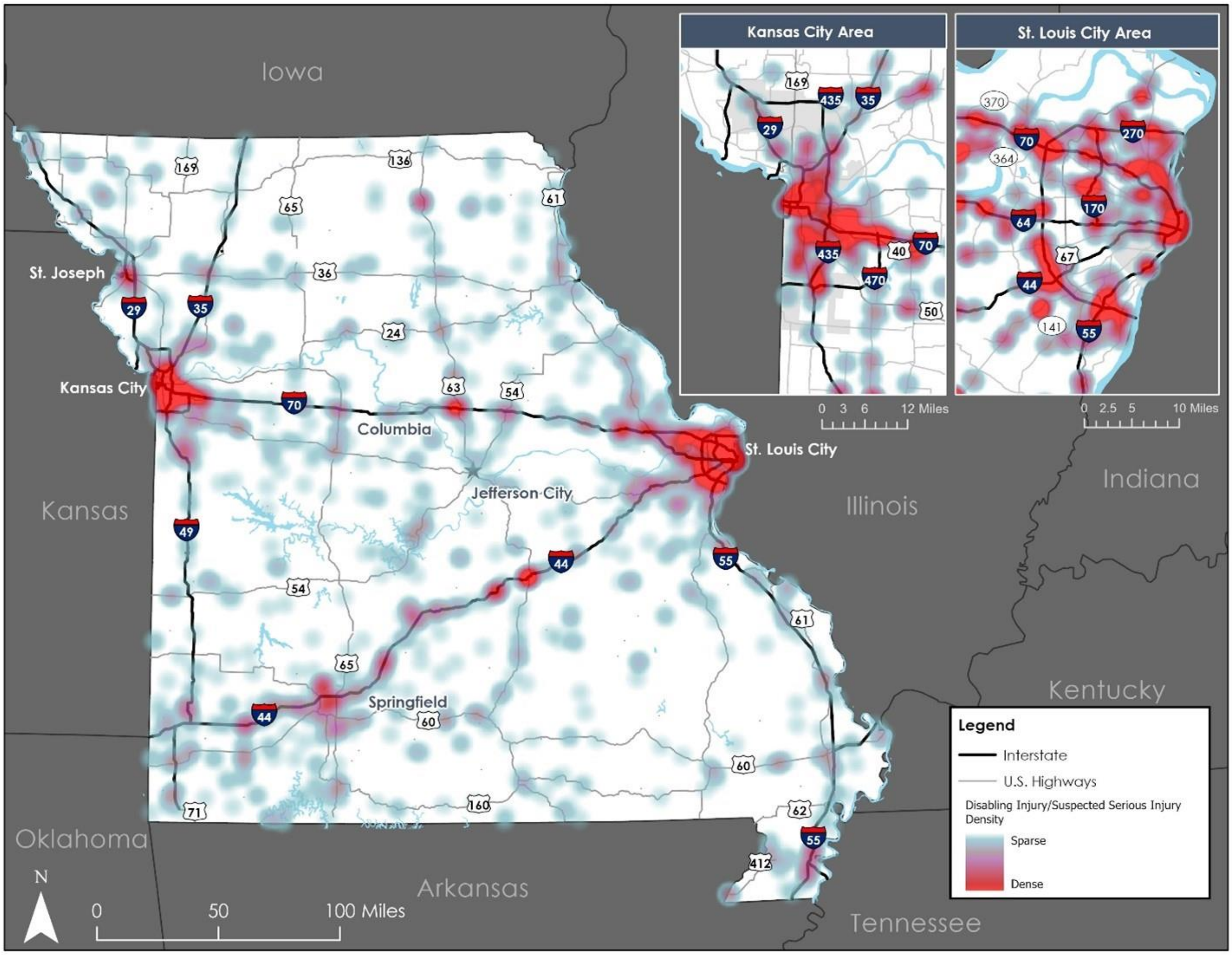
Statewide truck-involved crash heat maps for fatal and disabling injury/suspected serious injury severities for the 5-year period are shown in Figure 5.1 and Figure 5.2, respectively. Clusters are found along interstate routes, U.S. routes and state numbered and lettered routes and are most concentrated in the urban centers of St. Louis, Kansas City and Springfield/Joplin.

FIGURE 5.1 STATEWIDE TRUCK FATAL CRASH HEAT MAP



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

FIGURE 5.2 STATEWIDE TRUCK DISABLING INJURY/SUSPECTED SERIOUS INJURY CRASH HEAT MAP



Source: MoDOT (2015 – 2019)

Statewide Statistics on Non-Commercial Vehicles Involved in Crashes with Trucks

Data for non-commercial vehicles involved in crashes with trucks was obtained from MoDOT for the years 2015 – 2019. MoDOT's NCV vehicle type includes 18 categories ranging from ATVs to passenger vehicles to farm implements. For reporting purposes, the 18 vehicle types were combined into six main categories defined as follows:

- **Passenger Vehicles** – Passenger car, motorcycle, pickup, SUV and vans with fewer than nine passengers.
- **Recreational Vehicles** – ATV, motor home, motorized bicycle and pedal cycle.
- **Farm/Construction Vehicles** – Farm implement and construction equipment.

- **Commercial Vehicles** – Cargo van, limousine and vans with more than nine passengers.
- **Other Trucks** – Other heavy truck and single unit truck.
- **Other/Unknown**

In total, there were 34,641 NCVs involved in crashes with trucks with a total of 49,786 NCV occupants including 34,641 drivers and 15,145 passengers. Table 5.4 presents the number of vehicles/drivers and passengers traveling in a NCV that crashed with a truck.

TABLE 5.4 STATEWIDE TOTAL VEHICLES/DRIVERS AND PASSENGERS INVOLVED IN CRASHES WITH TRUCKS

NCV Category	2015	2016	2017	2018	2019	Total
Vehicles/Drivers	4,996	5,957	6,946	7,735	9,007	34,641
Passengers	2,362	2,649	3,112	3,317	3,705	15,145
Total	**7,358**	**8,606**	**10,058**	**11,052**	**12,712**	**49,786**

Source: MoDOT (2015 – 2019)

As shown in Table 5.4, the number of vehicles/drivers and passengers traveling in NCV that were involved in crashes with trucks increased each year from 2015 to 2019.

The breakdown of total injuries by NCV categories is provided in Table 5.5. The number of passenger vehicle injuries and total injuries increased every year between 2015 – 2019 and NCV passenger vehicle injuries comprise 98.64% of all injuries in NCVs involved in crashes with trucks over the five-year period. Injury severity by NCV categories is provided in Table 5.6.

TABLE 5.5 STATEWIDE TOTAL INJURIES FOR NCVS INVOLVED IN CRASHES WITH TRUCKS

NCV Category	2015	2016	2017	2018	2019	Total	Percent of All NCV Crashes
Passenger	1,314	1,617	1,802	1,889	2,232	8,854	98.6%
Recreational	5	3	4	8	1	21	0.2%
Farm/ Construction	0	4	4	2	5	15	0.0%
Commercial	14	9	9	20	23	75	0.8%
Other Trucks	0	0	1	1	0	2	0.0%
Other/Unknown	0	1	4	1	3	9	0.2%
Total	**7,358**	**8,606**	**10,058**	**11,052**	**12,712**	**49,786**	**100.0%**

Source: MoDOT (2015 – 2019)

TABLE 5.6 STATEWIDE TOTAL INJURY SEVERITY FOR NCVS INVOLVED IN CRASHES WITH TRUCKS

NCV Category	PDO	Minor Injury	Serious Injury	Fatal	None/ Unknown/ Blank	Total	Percent of All NCV Crashes
Passenger	39,729	7,365	1,089	400	261	48,844	98.1%
Recreational	149	14	3	4	3	174	0.4%
Farm/ Construction	124	8	3	4	1	140	0.3%
Commercial	435	62	13	0	3	513	1.0%
Other Trucks	49	2	0	0	3	54	0.1%
Other/Unknown	44	5	3	1	8	61	0.1%
Total	**40,530**	**7,456**	**1,111**	**409**	**280**	**49,786**	**100.0%**
Percentage	**81.4%**	**14.9%**	**2.2%**	**0.8%**	**0.6%**	**--**	**--**

Source: MoDOT (2015 – 2019)

Table 5.6 shows that PDO severity was by far the highest injury severity type with 40,530 PDO, equaling 81.4% of all injury severities. Fatalities occurred in only 409 (0.8%) of all NCV occupants involved in crashes with trucks.

Data for contributing circumstances was also analyzed for the NCVs involved in crashes with trucks. As some of the 34,641 NCVs involved in crashes with trucks include multiple contributing circumstances, MoDOT reported 39,720 total contributing circumstances. Most contributing circumstances were less than three percent of all contributing circumstances. “None” was the top contributing circumstance in NCVs involved crashes with trucks totaling 16,746 (42.2%). The top six contributing circumstances for NCVs involved in truck crashes is provided in Table 5.7.

TABLE 5.7 STATEWIDE TOP CONTRIBUTING CIRCUMSTANCES FOR NCVS INVOLVED IN CRASHES WITH TRUCKS

Contributing Circumstance	2015	2016	2017	2018	2019	Total	Percent of All Contributing Circumstances
None	2,445	2,872	3,323	3,718	4,388	16,746	42.2%
Improper Lane Usage/Change	613	678	762	819	983	3,855	9.7%
Failed to Yield	414	482	682	734	788	3,100	7.8%
Distracted/Inattentive	412	524	587	602	634	2,759	1.0%
Following too Close	401	485	579	580	675	2,720	6.9%
Too Fast for Conditions	343	387	359	431	733	2,353	5.9%
Total	4,628	5,428	6,292	6,984	8,201	31,533	100.0%

Source: MoDOT (2015 – 2019)

5.2 Truck-Involved Crashes by Roadway Type

A detailed analysis of truck-involved crashes was conducted on the routes that carry high volumes of truck trips and on ramps where trucks may park when authorized parking locations/spaces are not available. These major truck routes/locations include interstates, U.S. routes, state numbered and state lettered routes and ramps. Statewide total, fatal and disabling injury/suspected serious injuries for trucks involved in crashes on major truck routes is presented in Table 5.8. The table shows values from two datasets with columns two and three referring to truck crashes (any crash involving a truck) and columns three through seven referring to trucks involved in crashes (factors in truck crashes involving more than on truck).

TABLE 5.8 STATEWIDE TOTAL TRUCK CRASHES AND TRUCKS INVOLVED IN CRASHES BY SEVERITY

Roadway Type	Total 5-Year Truck Crashes	Percent of Truck Crashes	Number of Trucks Involved in Crashes	Number of Trucks Involved in Fatal Crashes	Percent of Trucks Involved in Fatal Crashes	Number of Trucks Involved in Disabling Injury/ SSI Crashes	Percent of Trucks Involved in Disabling injury /SSI Crashes
Interstates	19,808	27.5%	23,678	280	36.7%	601	30.0%
U.S. Highways	7,908	11.0%	9,278	155	20.3%	399	19.9%
State Numbered Routes	10,275	14.3%	11,999	168	22.0%	406	20.3%
Ramps	1,665	2.3%	1,914	4	0.5%	24	1.2%
Total Major Truck Routes	**39,656**	**55.1%**	**46,869**	**607**	**79.7%**	**1,430**	**71.5%***
All other roadways	32,488	44.9%	36,653	155	20.3%	571	28.5%
Total	**72,144**	**100.0%**	**83,522**	**762**	**100.0%****	**2,001**	**100.0%**

** Does not total to 71.5% due to rounding.*

*** Percentages may not add up to 100% due to rounding.*

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

As shown in Table 5.8, crashes on major truck routes account for more than 55% of the number of truck crashes, with the interstate system comprising the single largest road type with 27.5% of the total crashes.

Almost 80% of the trucks involved in fatal crashes were located on major truck routes in Missouri, with more than one-third occurring on interstates. These roadway types have higher travel speeds and higher traffic volumes.

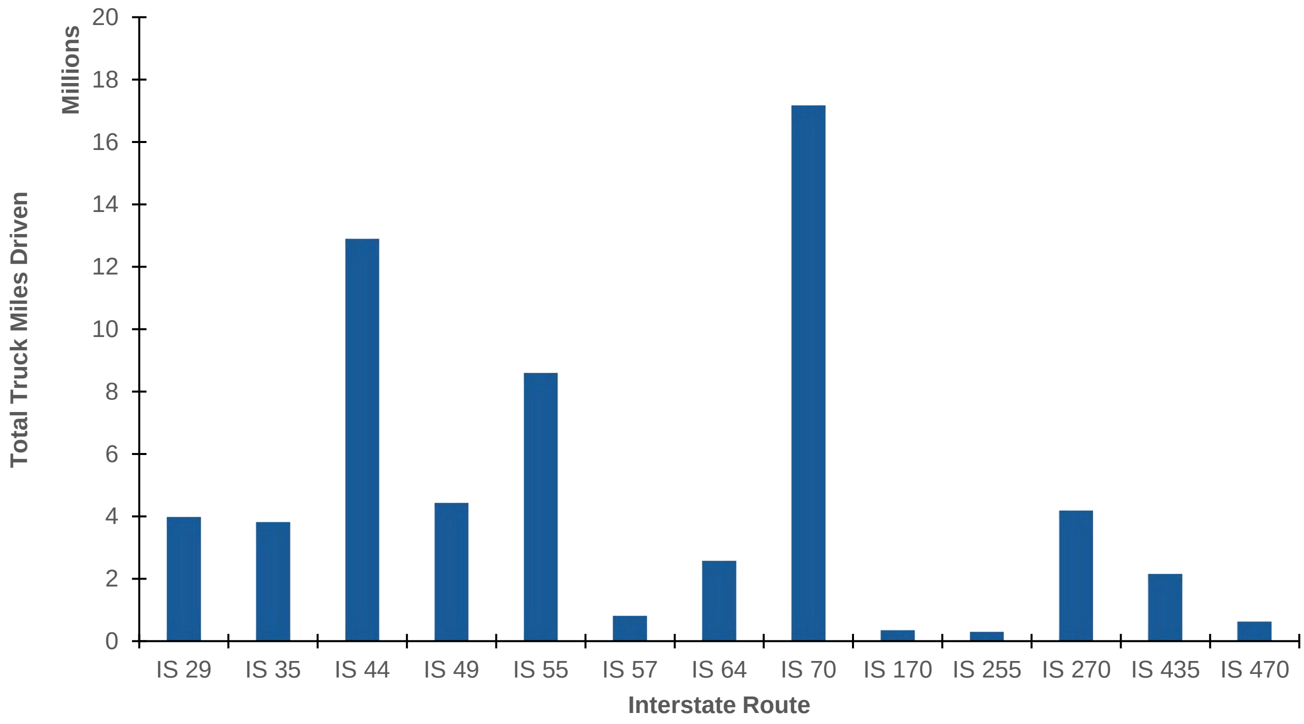
Also as shown in Table 5.8, more than 70% of the trucks involved in disabling injury/suspected serious injury crashes were traveling on major truck routes and ramps within Missouri. Almost 50% of trucks involved in disabling injury/suspected serious injury crashes were on the interstate system or U.S. Highway system, with an additional 20% on the state numbered system.

A more detailed analysis was conducted for trucks involved in crashes on the interstate and U.S. route systems that carried high volumes of truck traffic (at least 225,000 of truck miles traveled) between 2015 – 2019. Detailed calculations are included in Appendix C. Data was compiled along interstates for the following categories:

- Total truck miles driven
- Trucks involved in crashes rate per million truck miles traveled

Figure 5.3 below shows the total truck miles driven on the Missouri interstate system between 2015 and 2019. As shown in Figure 5.3, I-70 has the highest amount of truck mileage of 17,167,402 miles, or an average of 3.4 million miles per year. The second highest truck mileage is I-44, which had 12,889,080 miles during the five-year period. This results in an average of 2.6 million miles per year. I-255 (295,978 miles over five years) and I-170 (342,182) had the lowest truck miles driven over the five-year period. This can be attributed, in part to the short lengths of these interstate routes, 5.3 miles and 10.9 miles, respectively.

FIGURE 5.3 INTERSTATE FIVE-YEAR TRUCK MILES DRIVEN (2015 – 2019)

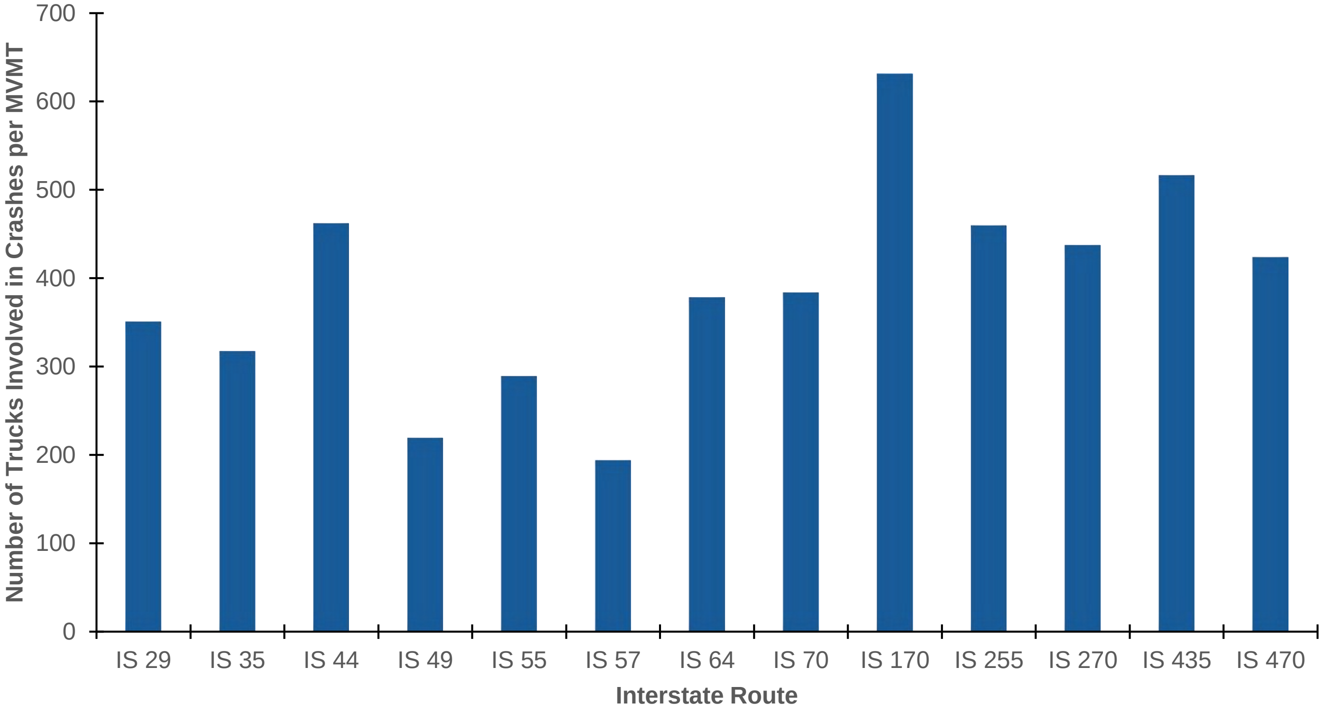


Source: MoDOT through the MSHP STARS Database (2015 – 2019)

Crash rates are traditionally presented as a five-year rate of crashes per million vehicle (truck) miles traveled. For this analysis, actual truck miles driven in 2018 were obtained from the MSHP STARS database. To determine five-year truck miles traveled, this number of truck miles was multiplied by five to obtain an estimate of truck miles traveled over the five-year analysis period. The number of trucks involved in crashes for the five year period was also obtained from the MSHP STARS database and was used, in conjunction with the estimated truck miles traveled, to develop crash rates for all interstates and U.S. routes that carried more than 225,000 truck miles between 2015 and 2019.

Figure 5.4 shows interstate five-year trucks involved in crashes rates. As these rates are based on approximated five-year truck miles driven, they should be used for comparative purposes only.

FIGURE 5.4 INTERSTATE FIVE-YEAR TRUCK CRASH RATES PER MVMT (2015 – 2019)

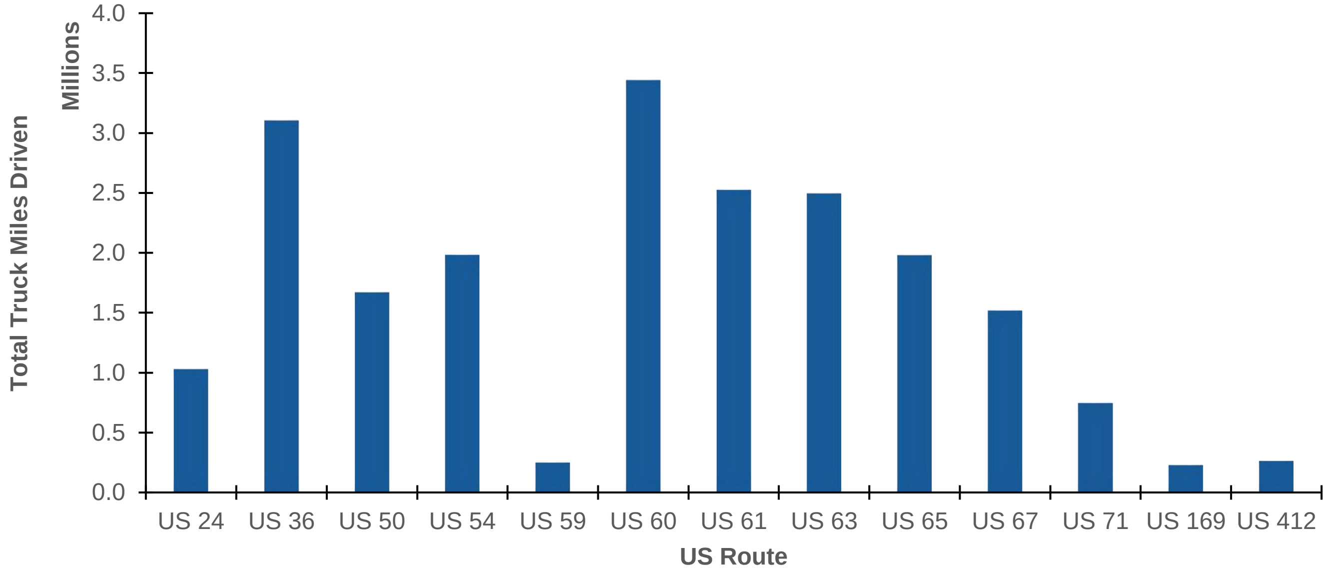


Source: MoDOT through the MSHP STARS Database (2015 – 2019)

From a crash rate perspective, as shown in Figure 5.4, I-170 has the highest rate of trucks involved in crashes of 631 trucks involved in crashes per million vehicle (truck) miles traveled. I-70, which had the most truck miles driven, has the seventh highest trucks involved in crashes rate per MVMT.

A similar analysis of the number of truck volumes and trucks involved in crashes was performed for all U.S. routes in Missouri (see detailed calculations in Appendix C) that carried over 225,000 truck miles over the five-year period. Figure 5.5 shows the truck miles driven on U.S. routes between 2015 - 2019.

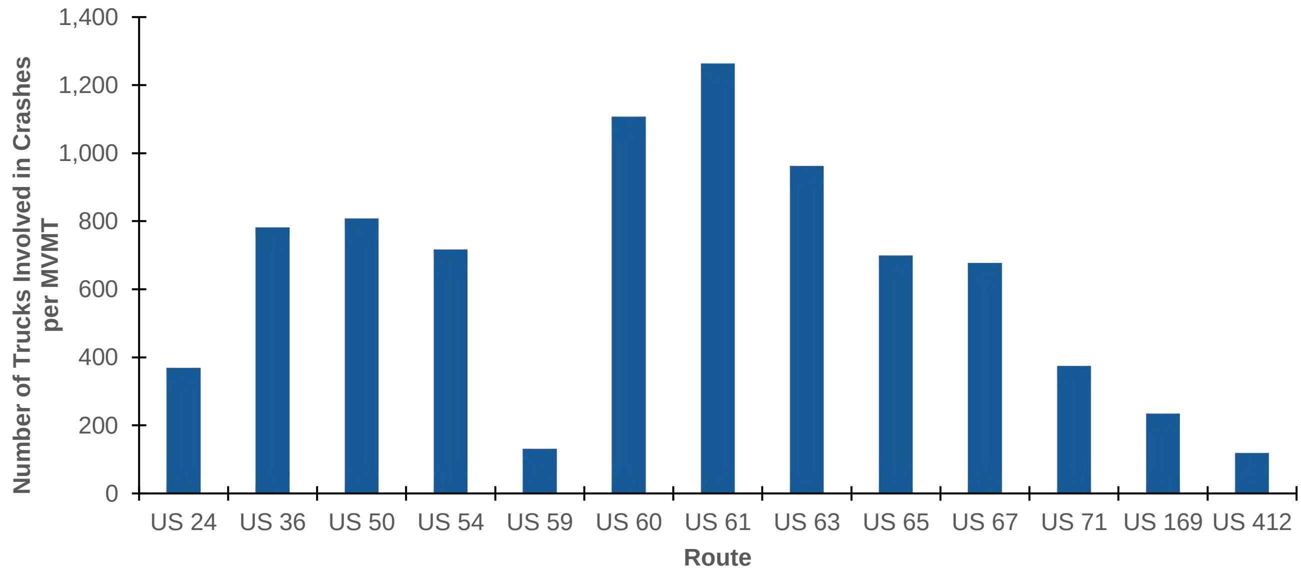
FIGURE 5.5 U.S. ROUTE FIVE YEAR TRUCK MILES DRIVEN (2015 – 2019)



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

When analyzing these U.S. routes by crash rates as shown in Figure 5.6, U.S. 61 had the highest five-year rate of trucks involved in crashes per MVMT, with a rate of more than 1,200 trucks invovled in crashes per MVMT. US-60 also had a trucks involved in crashes rate more than 1,100 crashes per MVMT. In contrast, U.S 36 which had the 2nd highest MVMT has the 5th highest crash rate.

FIGURE 5.6 U.S. ROUTE TRUCKS INVOLVED IN CRASHES RATE (2015 – 2019)



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

Contributing Circumstances

In addition to the total number of trucks involved in crashes and crashes by severity, the MoDOT truck involved crash database also includes information related to contributing circumstances. Contributing circumstances are factors that "contributed" to a crash as determined by the investigating or responding agency. These contributing circumstances include items such as alcohol, animals, distracted driver, improperly parked, improperly stopped and driver fatigue. A total of 33 contributing circumstances were reported in the truck involved crash database. It is important to note that the circumstances and behavior that contributed to a truck-involved crash can be attributed to one or more of the drivers involved. Truck-involved crashes can result from the behavior of an automobile driver, a truck driver or both.

The top ten contributing circumstances for crashes involving trucks over the 5-year period, with the exception of "Other", "None" and "Unknown", which totaled 39,435, are presented in Table 5.9. Driving errors were a factor in more than 39% of crashes and represent eight of the top ten contributing circumstances for trucks involved in crashes.

TABLE 5.9 STATEWIDE TRUCK INVOLVED CRASHES BY CONTRIBUTING CIRCUMSTANCES

Contributing Circumstance	Total 5-Year Crashes	Percentage of All Crashes
Improper Lane Use[26]	8,608	10.3%
Distracted	4,699	5.6%
Improper Turn	3,974	4.8%
Following too Close	3,962	4.7%
Too Fast for Conditions	3,842	4.6%
Failed to Yield	3,476	4.2%
Improper Backing Up	2,478	3.0%
Vehicle Defects	2,461	2.9%
Failed to Secure Load	1,674	2.0%
Vision Obstructed	1,565	1.9%

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

5.3 Crashes Associated with Parked Trucks

Due to several factors including commercial vehicle driver hours of service limits, "just in time delivery" requirements, and the sheer number of commercial trucks using Missouri's roadways, Missouri's designated truck parking capacity is heavily utilized. Of the 142 designated truck parking sites within a half-mile of the interstate system, 87 (61%) are at or over capacity and another 23 are at more than 80% capacity between 2-3 a.m. which is the peak hour of demand in the state. A lack of available spaces or even a perceived lack of available spaces can

[26] Defined by MoDOT as follows: "Improper lane usage or an improper lane change contributed to the crash. This does not include instances where the vehicle is making a turning movement. Includes changing lanes and striking another vehicle, going straight in a turn-only lane, etc."

result in commercial vehicles creating safety concerns by parking on ramps, shoulders and/or other undesignated locations.

To assess the number of trucks involved in crashes related to parked trucks, an analysis of trucks involved in crashes occurring along interstates, and those located at, or near, truck stops or truck parking sites was performed. Of the 33 contributing circumstances in the truck involved crash database, three are most directly related to parked trucks. These are “Improperly Parked”, “Improperly Stopped on Roadway” and “Improper Start from Park”. In total, 614 crashes were contributed to one of these three factors. Table 5.10 provides a breakdown of these crashes. Figure 5.7 depicts these crash types on a statewide map. Figure 5.8 shows these types of crashes statewide by severity. Like the overall trends discussed above, clusters of these types of crashes are found along most of interstate system and in the urban areas near St. Louis, Kansas City and Springfield/Joplin.

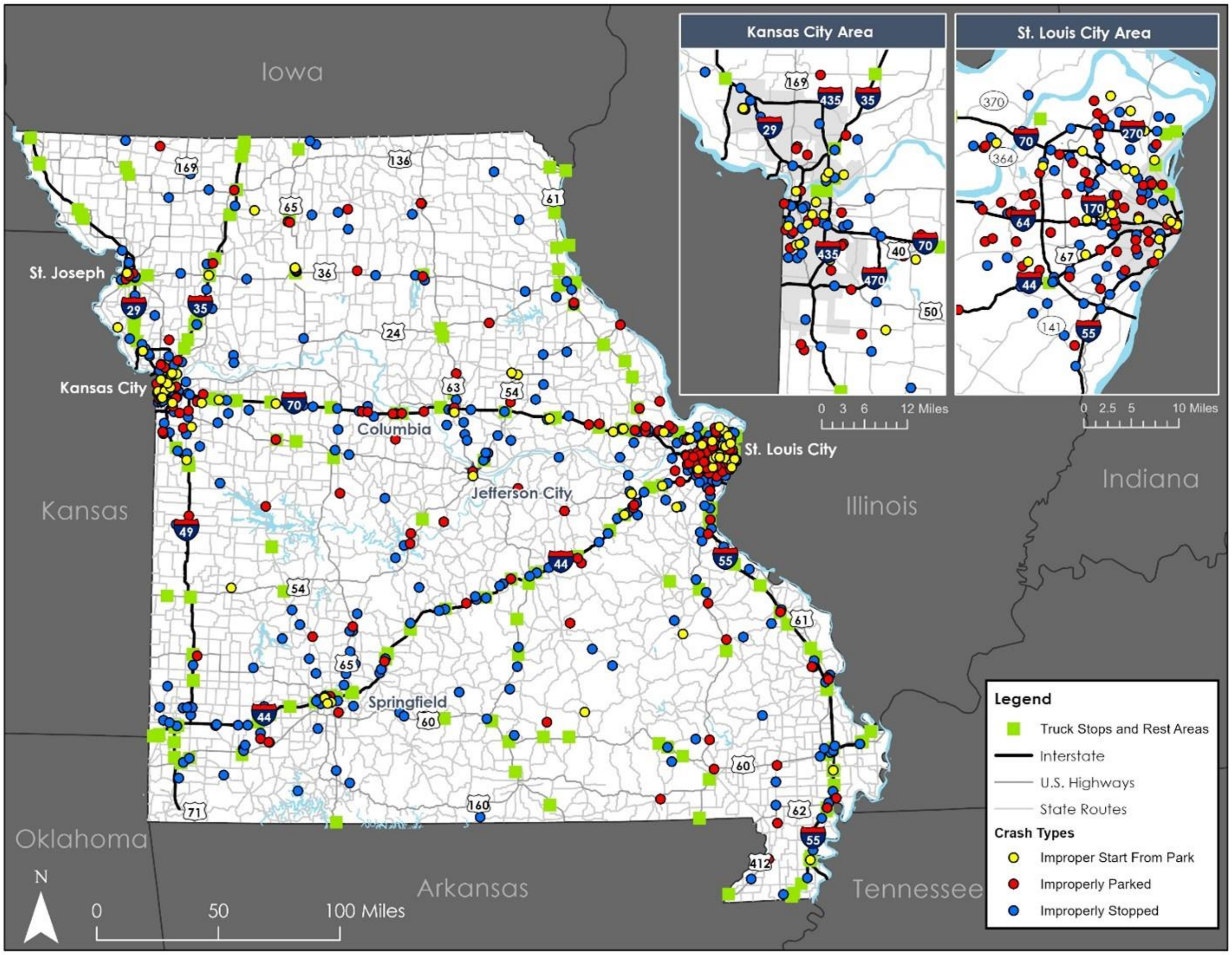
Even though these types of crashes represent only 0.74% of all the trucks involved in crashes over the five-year period, they typically occur when at least one vehicle is traveling at very low, or no speed. This indicates that as commercial vehicles are parked at inappropriate locations along roadways, ramps, or within designated truck parking location (but outside of designated parking spots), they increase the potential for safety incidents.

TABLE 5.10 STATEWIDE TRUCK INVOLVED CRASHES FOR IMPROPERLY PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK

Contributing Circumstance	MoDOT Definition	Total 5-Year Crashes
Improperly Parked	A vehicle improperly parked in a place normally designated for parking or improperly parked along the roadway traffic lanes, such as blocking a driveway, beside a fire hydrant or in a loading zone.	185
Improperly Stopped on Roadway	A vehicle in-transport that is stopped on a roadway inappropriately or when not directed to do so by a traffic control device or law enforcement officer	358
Improper Start from Park	A vehicle was parked and the improper start from the parked position contributed to the crash.	71
Total		**614**

Source: MoDOT through the MSHP STARS Database (2015 – 2019)

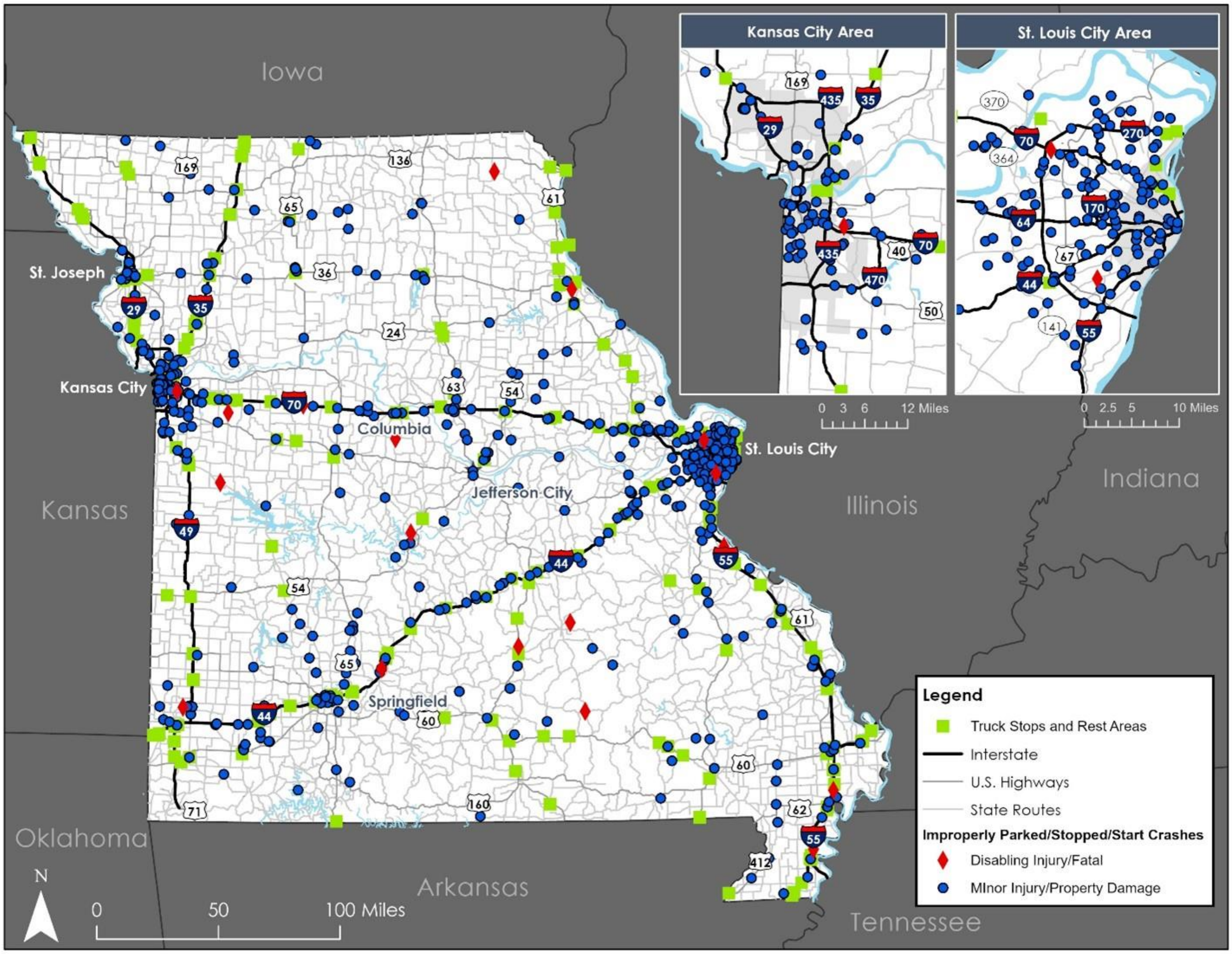
FIGURE 5.7 STATEWIDE CRASHES RELATED TO TRUCKS IMPROPERLY PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

Three scenarios were analyzed related to these types of crashes and their proximity to interstates and truck stops. Detailed maps for each of these three scenarios is included in Appendix C. The first scenario was for these types of crashes within 200 feet on either side of an interstate. Over the five-year analysis period, 119 trucks were involved in crashes with at least one of the three contributing circumstances related to parked trucks. The second scenario investigated these types of crashes within one mile of a designated truck parking site (both publicly and privately owned). Only 51 trucks were involved in these types of incidents. The final scenario investigated these types of crashes within five miles of a designated truck parking site. Almost 40% of these types of crashes (242) occurred within five miles of these designated sites.

FIGURE 5.8 STATEWIDE CRASH SEVERITY RELATED TO TRUCKS IMPROPERLY PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

The number and geographic spread of parked truck related crashes across Missouri as shown in Figure 5.7, Figure 5.8 and Appendix C, and the relatively low number of these crashes within one mile of a designated truck parking site**,** indicate that parked truck related crashes may not necessarily be more prevalent near designated truck parking sites but instead occur statewide at undesignated areas such as on shoulders and ramps. The implications of this are considered in more detail in the Truck Parking Technical Memorandum as part of the 2021 Missouri State Freight and Rail Plan.

6.0 Key Performance Trends

6

Measuring performance over time is critical to understanding the impacts of transportation policies, programs and investments in Missouri. The 2017 Missouri State Freight Plan focused on measuring trends and prioritizing projects under four goal areas: maintenance, safety, economy and connectivity and mobility. The plan identified multimodal performance metrics within each goal area both for the purpose of screening projects and to track plan implementation (Table 6.1). These metrics were chosen based on both MoDOT's rich history of using performance measurement, exemplified by the MoDOT Tracker[27] and in consultation with stakeholder groups.

TABLE 6.1 GOALS AND PERFORMANCE MEASURES FROM THE 2017 MISSOURI STATE FREIGHT PLAN

Freight Plan Goal	Performance Measure
Maintenance Maintain the freight system in good condition	• **Percent of the major highways in good condition** • **Percent of structurally deficient deck area on National Highway System bridges**
Safety Improve safety on the freight system	• **Number of commercial vehicle crashes resulting in fatalities or serious injuries** • *Rail crossing crashes or fatalities*
Economy Support economic growth and competitiveness	• **Goods movement competitiveness** • *Job and economic growth by key sector, including:* – *Agriculture* – *Manufacturing* – *Transportation/Logistics*
Connectivity and Mobility Improve the connectivity and mobility of the freight system	• **Freight tonnage by mode** • **Annual hours of truck delay** • **Truck reliability index**

Note: Bold indicates that the performance measures are applicable to highways

Source: MoDOT

The trends for each of these performance measures as they apply to highway freight is discussed in more detail below.

Highway Maintenance

The first performance measure used to track progress of the maintenance goal is the percentage of major highways in good condition. The 2017 Missouri State Freight Plan set a target of maintaining 85% of major highways in good condition. As of 2018, the state maintained 94% of interstates and 89% of U.S. routes good condition. Data for the past five years shows that the condition of state highways has been stable, and the percent of major highways in good condition is consistently above 90%, the condition of minor highways in good condition is above 80%, and the percent of low volume highways in good condition is above 70%.[28]

[27] https://www.modot.org/tracker-measures-departmental-performance

[28] https://www.modot.org/condition-state-highways-5c-jan-2020

The second performance metric used to track progress of the maintenance goal is the percent of structurally deficient deck area on NHS bridges. The 2017 Missouri State Freight Plan set a target of having less than 10% of structurally deficient deck area on NHS bridges. As of 2019, 7.5% of deck area on NHS bridges is structurally deficient, meeting MoDOT's goal.[29] This corresponds with 3.9% of bridges on the NHS that have any structurally deficient deck area.

Highway Safety

The first performance metric used to track safety on Missouri's highways is the number of fatalities and serious injuries in crashes involving trucks. MoDOT has set a target of fewer than 128 fatalities in truck-involved crashes per year with the ultimate goal of zero fatalities. As of 2019, there were 123 fatal truck-involved crashes that resulted in 157 fatalities.

Highway Economy

The 2017 Missouri State Freight Plan tracked the annual trends in the cost of transporting three key commodities in Missouri as compared to other midwestern states. Those three commodities are: the cost of shipping one ton of soybeans to New Orleans (largely by barge), the cost of shipping one ton of crop protection to Mexico (largely by rail), and the cost of shipping one motor vehicle to Toronto (by truck) or Los Angeles (by rail). Among these, the metric that applies to ports is the cost of shipping one ton of soybeans by barge. This data was tracked by the MoDOT Tracker through 2017, at which time it cost $408 per finished motor vehicle across all modes, representing an increase in cost as compared with the 2017 plan (which included data on costs in 2014). However, this metric is no longer tracked by MoDOT.

Highway Connectivity and Mobility

The first performance metric for connectivity and mobility is the freight tonnage by mode. This was tracked by the MoDOT Tracker up through October 2019. As discussed in Section 3.2, in 2018, 32.5 million trucks transported more than 400 million tons of freight worth more than $495 billion on Missouri's highways. This represents a decrease in tonnage as compared with past years tracked in the MoDOT Tracker.[30]

The second performance metric for highways is the annual hours of truck delay, which was identified as a metric under the Moving Ahead for Progress in the 21st Century (MAP-21) legislation. However, the Fixing America's Surface Transportation Act, passed after MAP-21, focused instead on the third performance metric for highways, the TTTR index. The TTTR index is a weighted average of truck congestion in the state. The 2017 baseline TTTR value was 1.25, and a lower number means that congestion is decreasing. The TTTR for 2019 is slightly higher than in 2017, with a value of 1.27 across the state. Further details about reliability on Missouri's highways are found in Section 4.2.

[29] https://www.modot.org/percent-structurally-deficient-deck-area-national-highway-system-5b-jan-2020

[30] https://www.modot.org/sites/default/files/documents/October2019Tracker.pdf

Appendix

Truck Volumes on Non-Interstates

A

This appendix supplements the analysis of truck volumes in Section 3.1, as well as the overview of infrastructure presented in Sections 2.2, 2.3 and 2.4, by providing additional details about truck volumes on non-interstates. In particular, it first presents the median truck volumes on different functional classes. Then, it examines the truck volumes on the different classification systems that affect non-interstates, in particular the National Highway System and Designated Highway Network. Finally, it presents the ten highest measurements of AADTT to show where the highest truck volumes on non-interstates are measured in Missouri.

Section 2.2 describes the different functional classifications under the Highway Performance Monitoring System. Table A.1 includes statistics about truck traffic on different roads as classified by functional classification. This table shows the extent to which both raw truck traffic measurements and truck traffic as a percentage of overall traffic decreases on roads of a higher functional class.

TABLE A.1 TRUCK VOLUME STATISTICS FOR HPMS FUNCTIONAL CLASSIFICATIONS

HPMS Functional Classification	(a) **Median AADTT**	(b) **Median AADT**	(c) **Percent Truck Traffic** = (a)/(b)
1 – Interstate	8,404	28,994	29%
2 – Principal Arterial–Freeways & Expressways	2,304	12,824	18%
3 – Principal Arterial–Other	718	5,638	13%
4 – Minor Arterial	252	3,487	7%
5 – Major Collector	62	945	7%
All	**2,703**	**9,064**	**16%**

Note: Roads with no truck traffic data have been excluded from these calculations.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Sections 2.3 and 2.4 discusses the different classification systems that apply to highways, in particular the NHS, National Highway Freight Network and the DHN. Because the NHFN is comprised mostly of interstates, truck volumes on this classification system are covered in Section 3.1. This appendix provides additional context for the NHS and DHN. Table A.2 shows the traffic statistics for these two road classification systems. This includes the highway miles, median AADTT and percentage of overall traffic for roads that are part of the NHS and DHN. Note that rows three and five add up to row one, and rows four and five add up to row two.

TABLE A.2 TRUCK VOLUME STATISTICS FOR MISSOURI'S NATIONAL HIGHWAY SYSTEM AND DESIGNATED HIGHWAY NETWORK

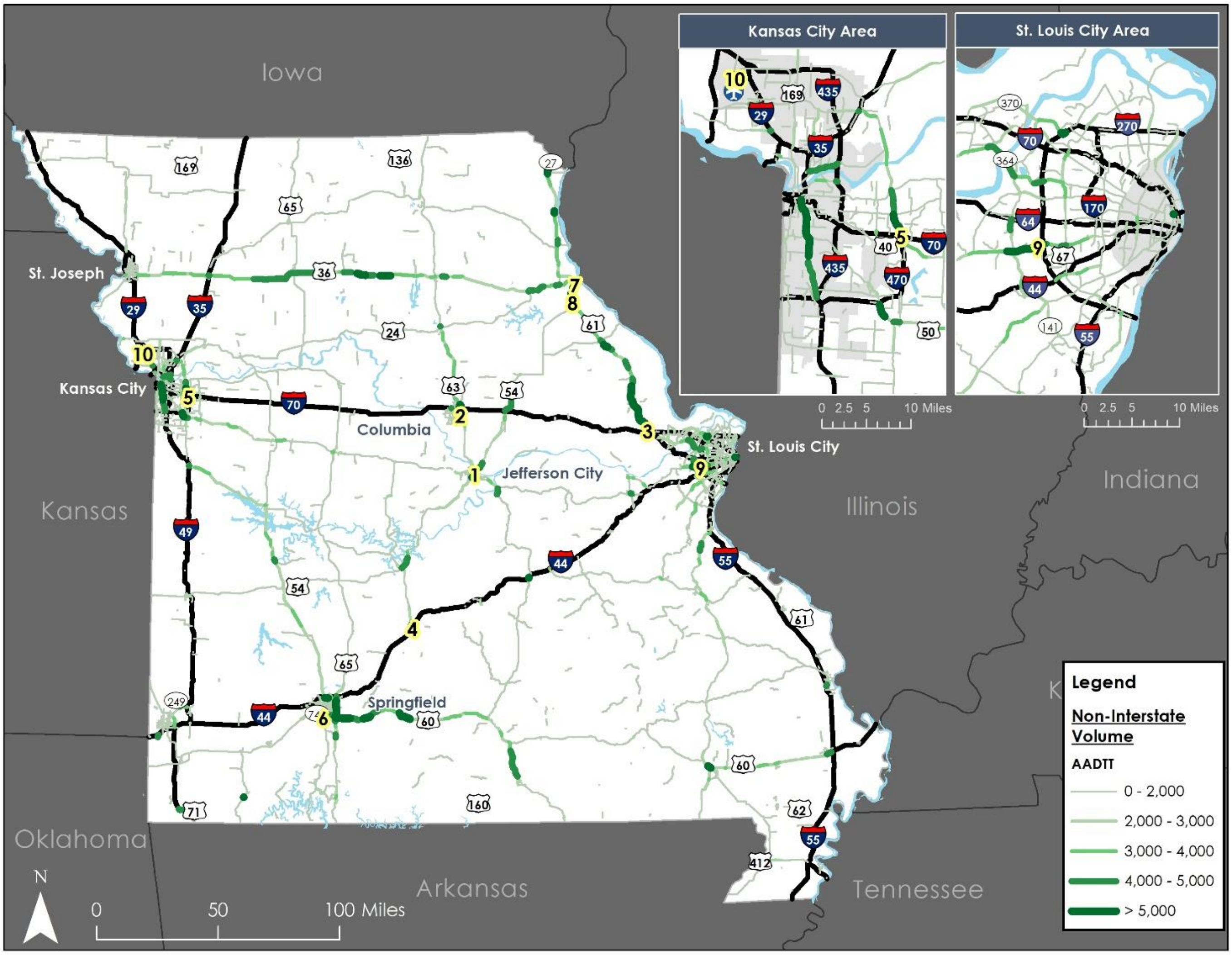
Missouri Road Classification	(a) **Highway Miles**	(b) **Median AADTT**	(c) **Median AADT**	(d) **Percent Truck Traffic** = (b)/(c)
All National Highway System (NHS) Roads	5,714	1,602	12,148	13%
All Designated Highway Network (DHN) Roads	4,930	2,288	11,323	20%
NHS-Only Roads	1,461	886	13,790	6%
DHN-Only Roads	677	352	1,998	18%
DHS and NHS Roads	4,253	2,366	11,735	20%

Note: Roads with no truck traffic data have been excluded from these calculations.

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Finally, Section 3.1 shows the truck traffic on all non-interstate roads. However, truck volumes on non-interstates are more likely to vary across different sections of a route, with some parts that have high traffic volumes and other parts that have low traffic volumes. Therefore, the method of using the length-weighted AADTT across entire routes misses some of the nuance of the variations in truck volumes along different routes. To provide this additional context, the 10 highest measurements of non-interstate AADTT have been labeled on Figure A.1 and further information about those locations is listed in Table A.3.

FIGURE A.1 MISSOURI NON-INTERSTATE AVERAGE ANNUAL DAILY TRUCK VOLUMES WITH 10 HIGHEST MEASUREMENTS OF AADTT



Note: *Roads with no truck traffic data have been excluded from this map.*

Source: *Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020*

TABLE A.3 TEN HIGHEST MEASUREMENTS OF AVERAGE ANNUAL DAILY TRUCK TRAFFIC ON NON-INTERSTATE ROADS

Rank	AADTT	Highway Name	Location
1	9,656	US-54	Jefferson City, crossing the Jefferson City Bridge
2	9,310	US-63	Columbia, near I-70 and the interchange with Vandiver Drive
3	9,160	US-61	Northwest Wentzville where it merges with I-70 and I-64
4	8,592	MO-5	Lebanon, near the Exit 129 interchange on I-44
5	8,422	MO-291	Eastern Kansas City, near Exit 15 interchange on I-70
6	8,202	MO-13	Springfield, at the interchange with U.S. 60.
7	8,130	US-61	Hannibal, near the end of I-72
8	7,728	US-61	South of Hannibal, north of the Salt River
9	6,948	MO-100	Des Peres, a commercial area southwest of St. Louis, near the I-270 interchange between interstates 64 and 44.
10	6,584	International Circle	Circulator route located at Kansas City International Airport adjacent to I-29 and I-495

Source: Highway Performance Monitoring System, 2018; analysis by Cambridge Systematics, 2020

Appendix
Highway Performance Maps

B

This Appendix will present complete performance data for Missouri roads based off an analysis of data from the National Performance Management Research Data Set spanning from January 1, 2019 – December 31, 2019. This analysis is limited to truck data and examines data split across five travel time periods:

- Morning Peak – From 6:00 a.m. – 10:00 a.m. on Weekdays
- Midday Peak – From 10:00 a.m. to 4:00 p.m. on Weekdays
- Evening Peak – From 4:00 p.m. to 8:00 p.m. on Weekdays
- Weekends – From 6:00 a.m. to 8:00 p.m. on Weekends
- Nights – From 8:00 p.m. to 6:00 a.m. on both Weekdays and Weekends.

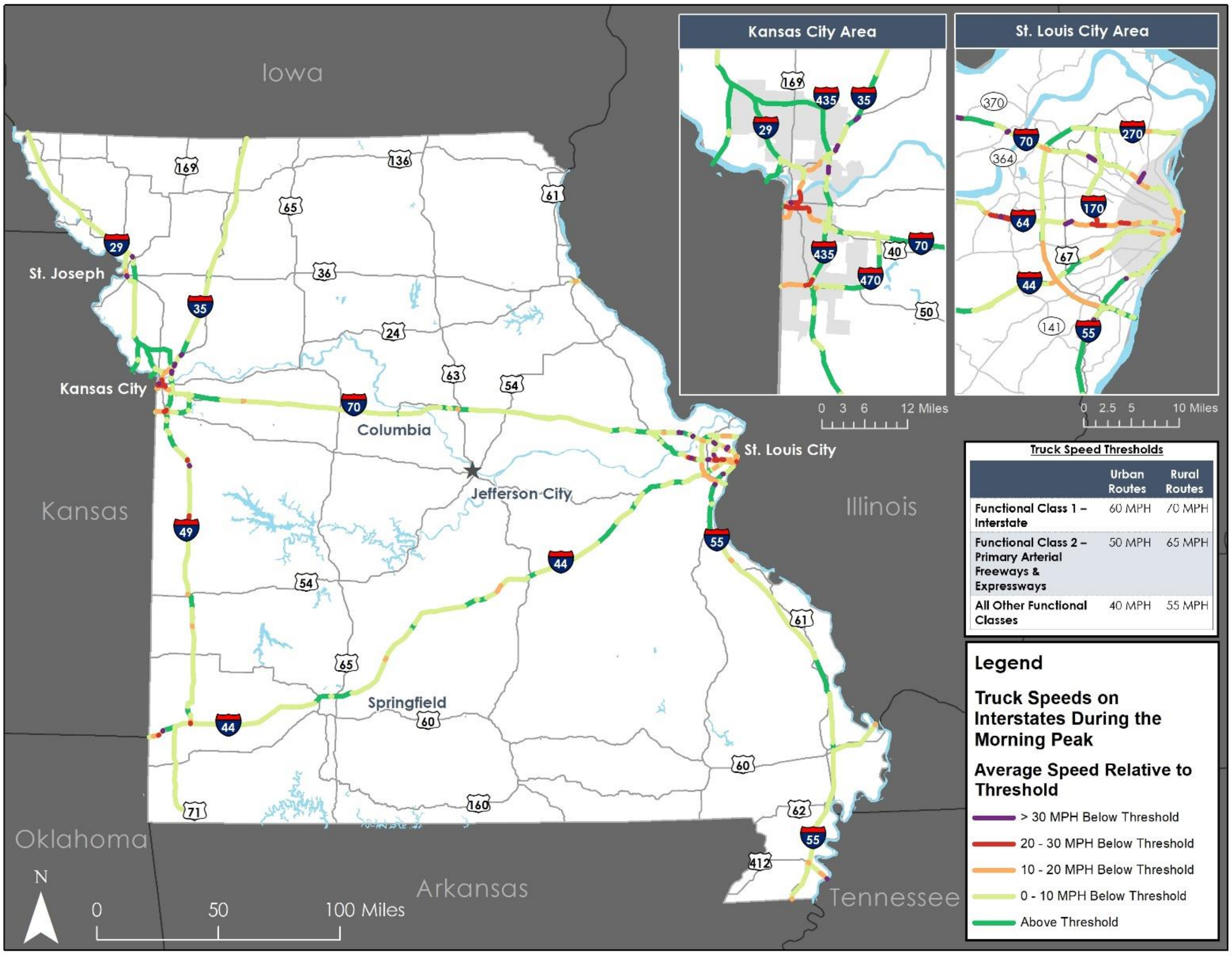
This Appendix presents statewide maps for two different performance metrics:

- **Average Truck Speed –** the average speed that trucks were measured as traveling during the given time period. This is considered a measure for congestion on a road, where higher speeds indicate less congestion. Thresholds for uncongested roads were chosen based on the functional class of the route and whether the area was in a rural or urban area. Those thresholds are listed in the figures below.
- **Truck Travel Time Reliability –** the ratio of truck travel times at the 95th percentile to the 50th percentile over an individual segment of road. This is considered a measure of reliability on a road. The greater the difference between the 95th percentile and the 50th percentile of travel times, the higher the TTTR, and the less reliable that stretch of road is during that time period. For this analysis, a TTTR of 1.45 or greater was considered unreliable on both interstates and non-interstates.

B.1 Truck Speed

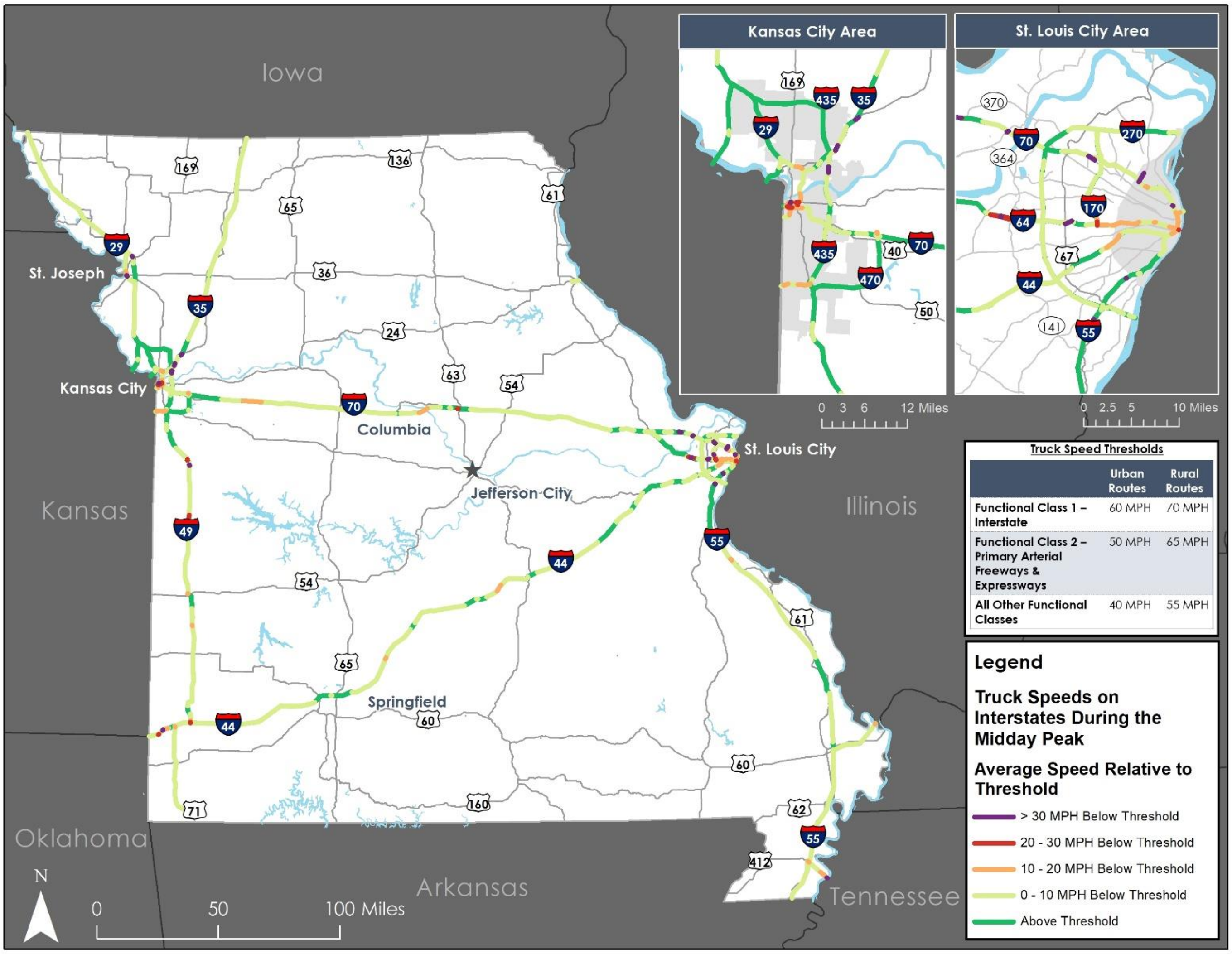
Interstates

FIGURE B.1 MORNING PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



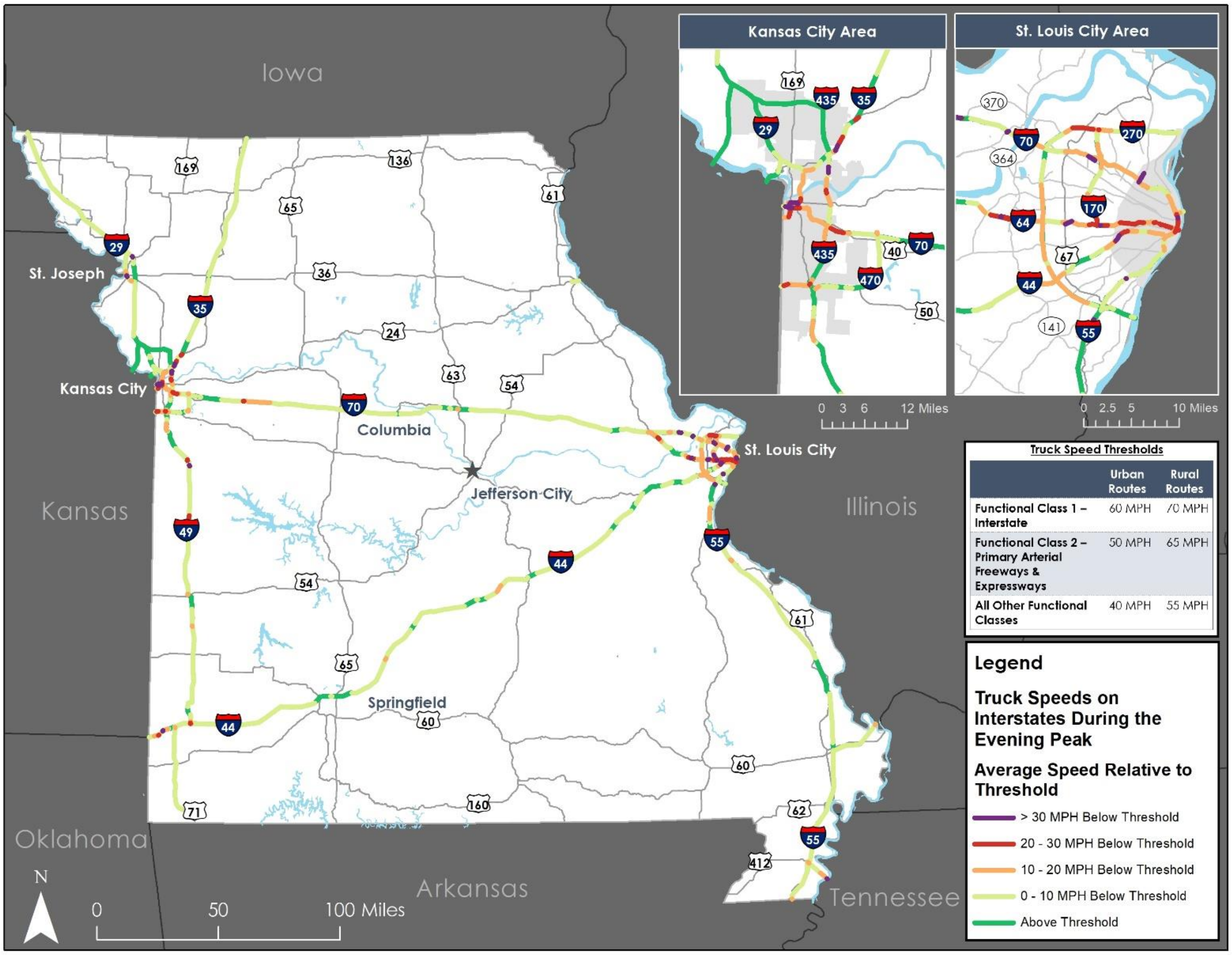
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.2 MIDDAY PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



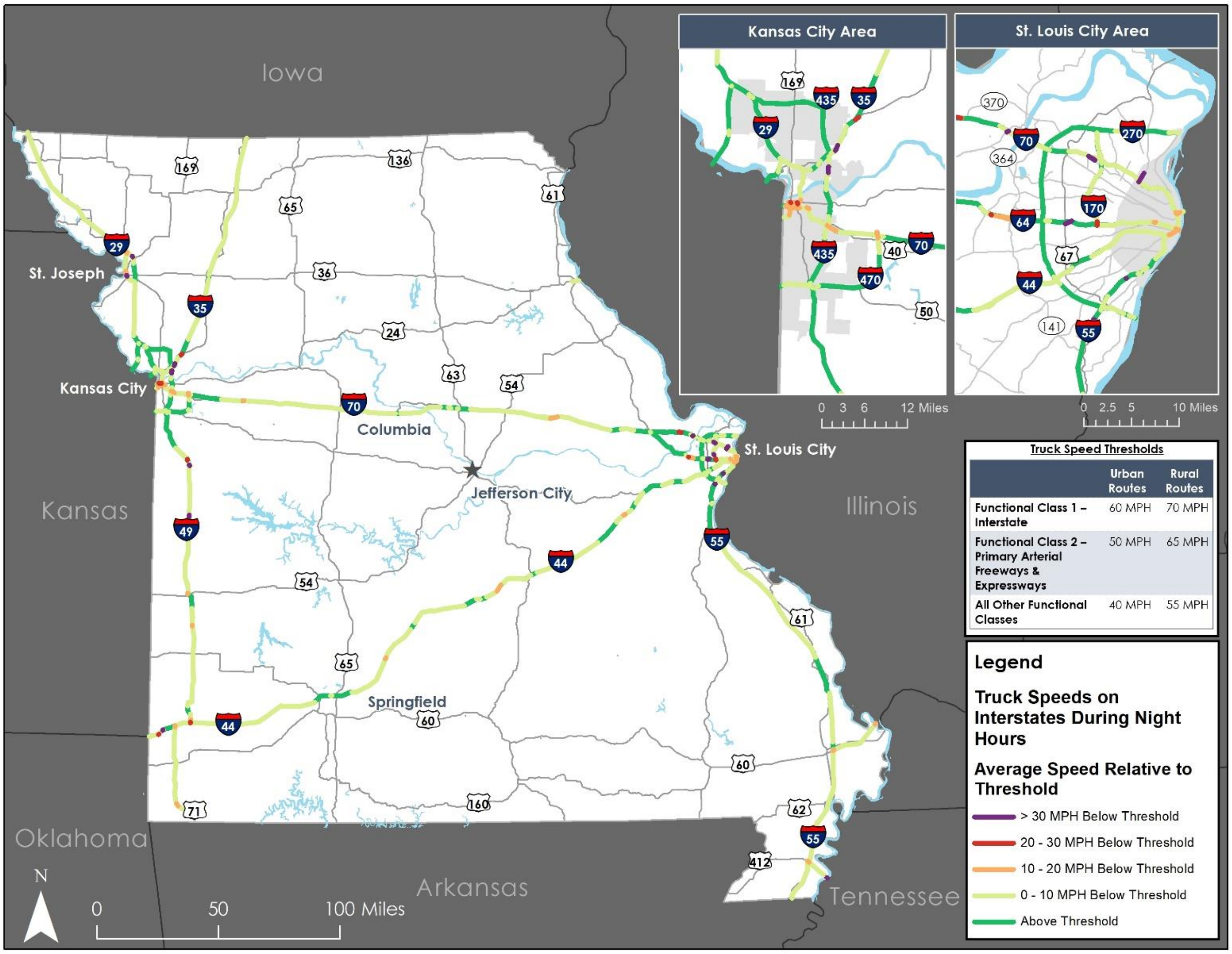
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.3 EVENING PEAK AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



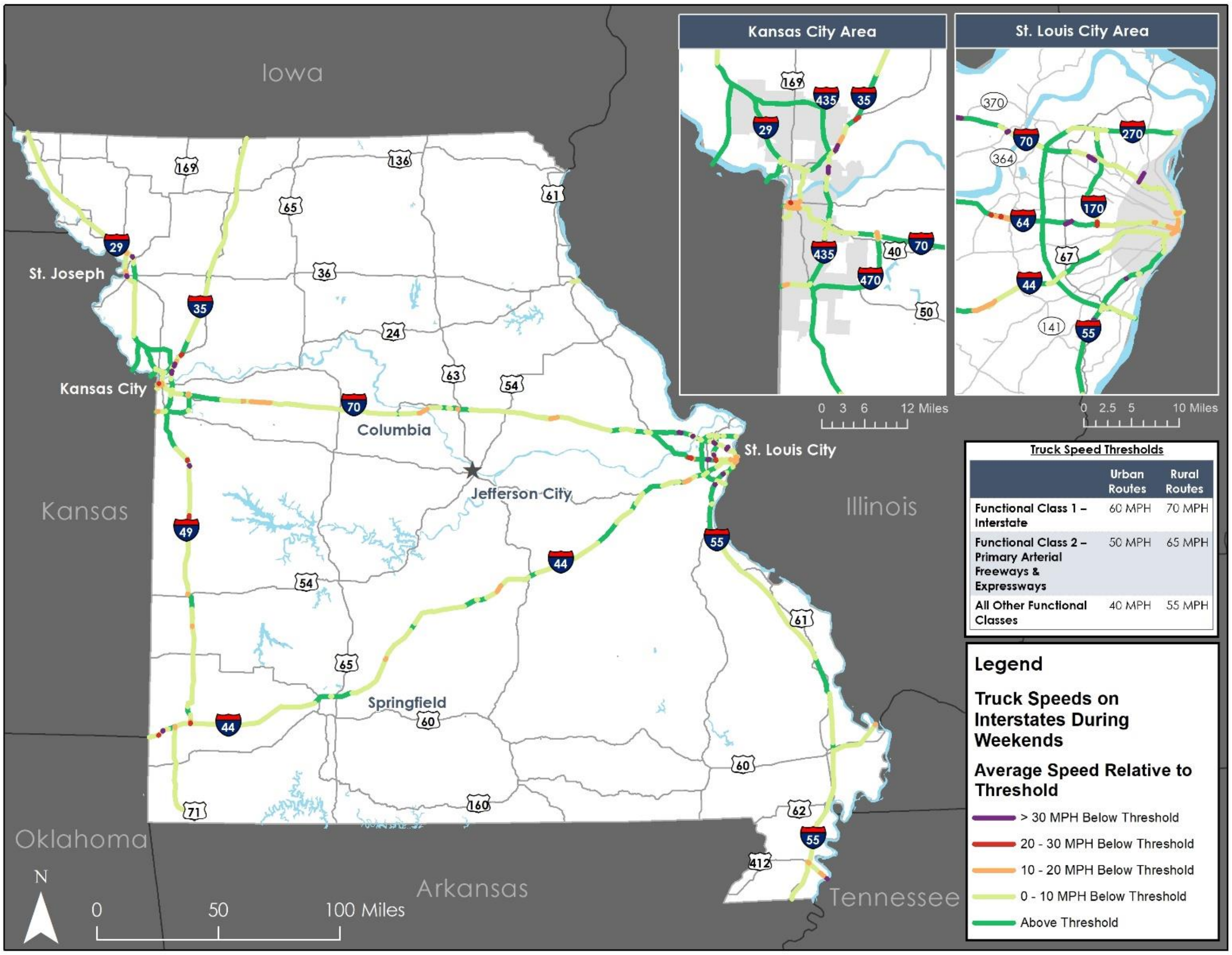
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.4 NIGHT AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

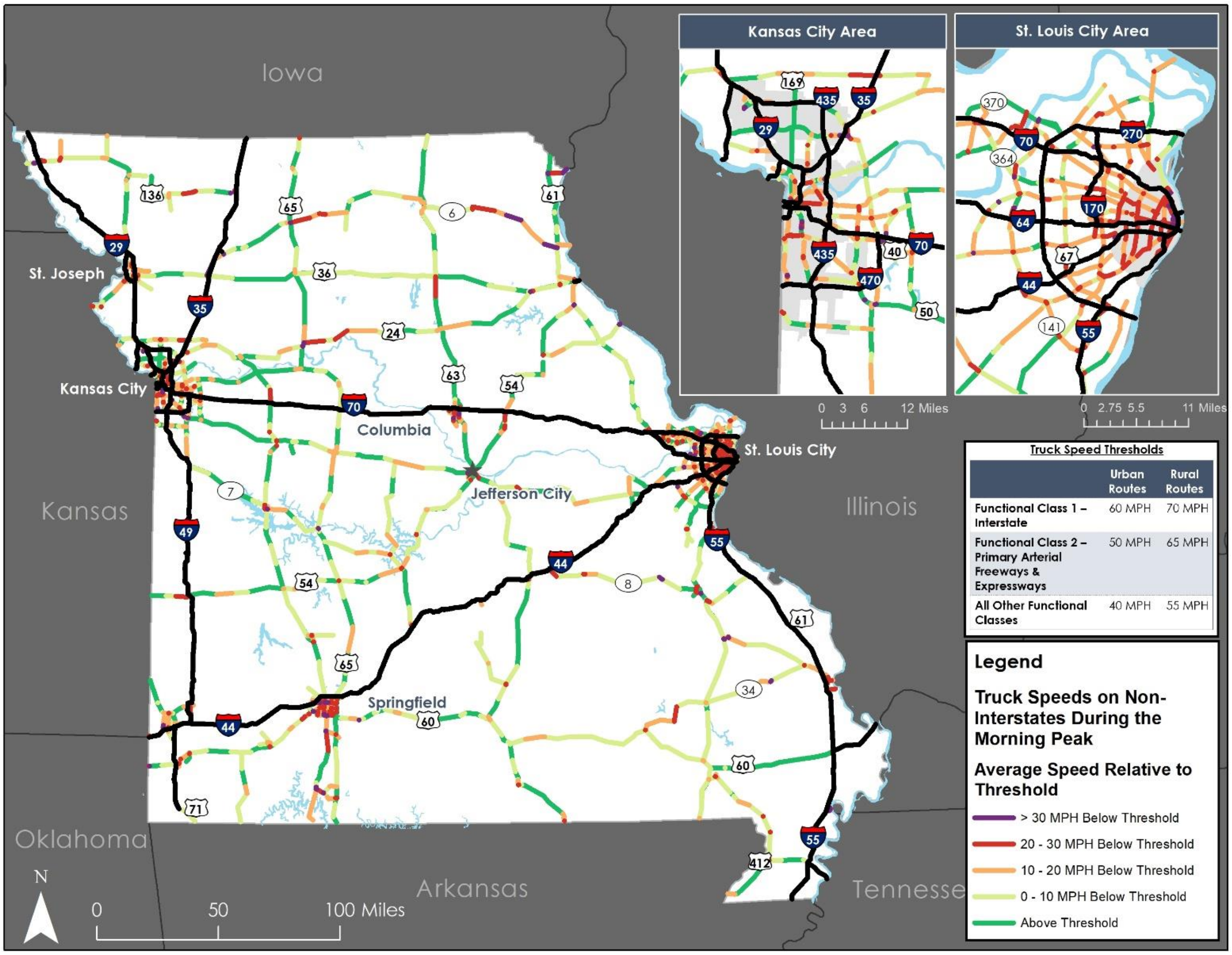
FIGURE B.5 WEEKEND AVERAGE TRUCK SPEEDS ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

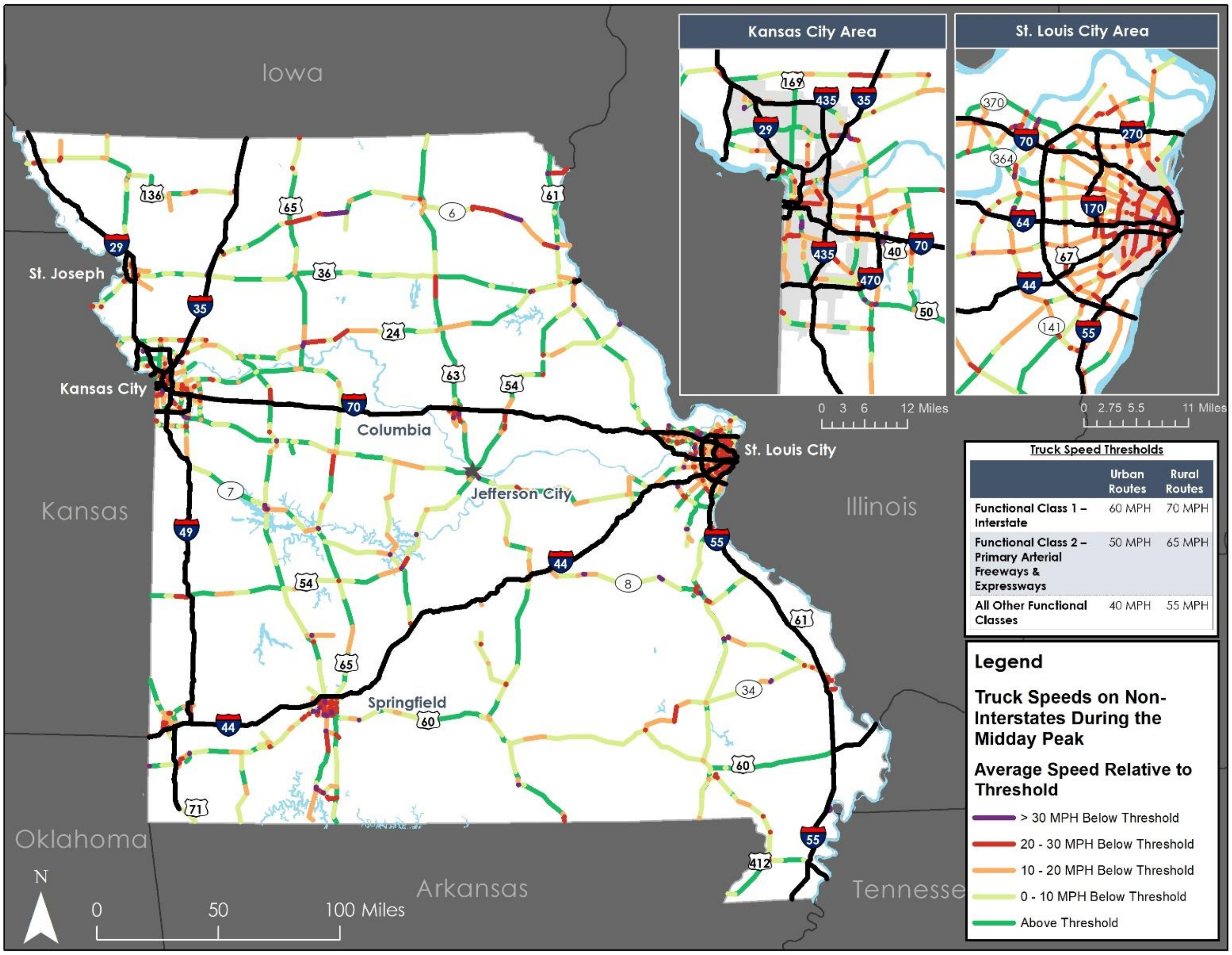
Non-Interstates

FIGURE B.6 MORNING PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



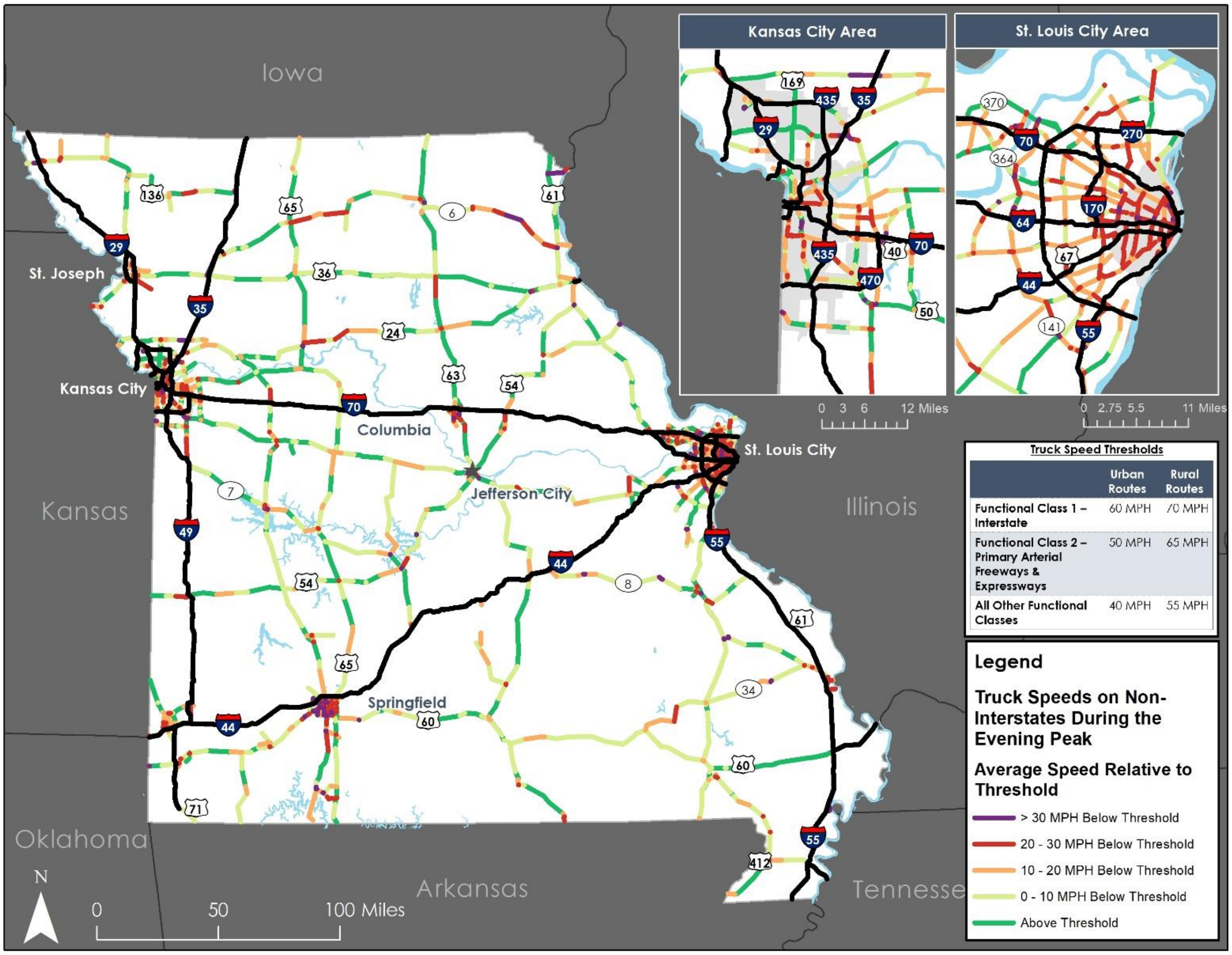
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.7 MIDDAY PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



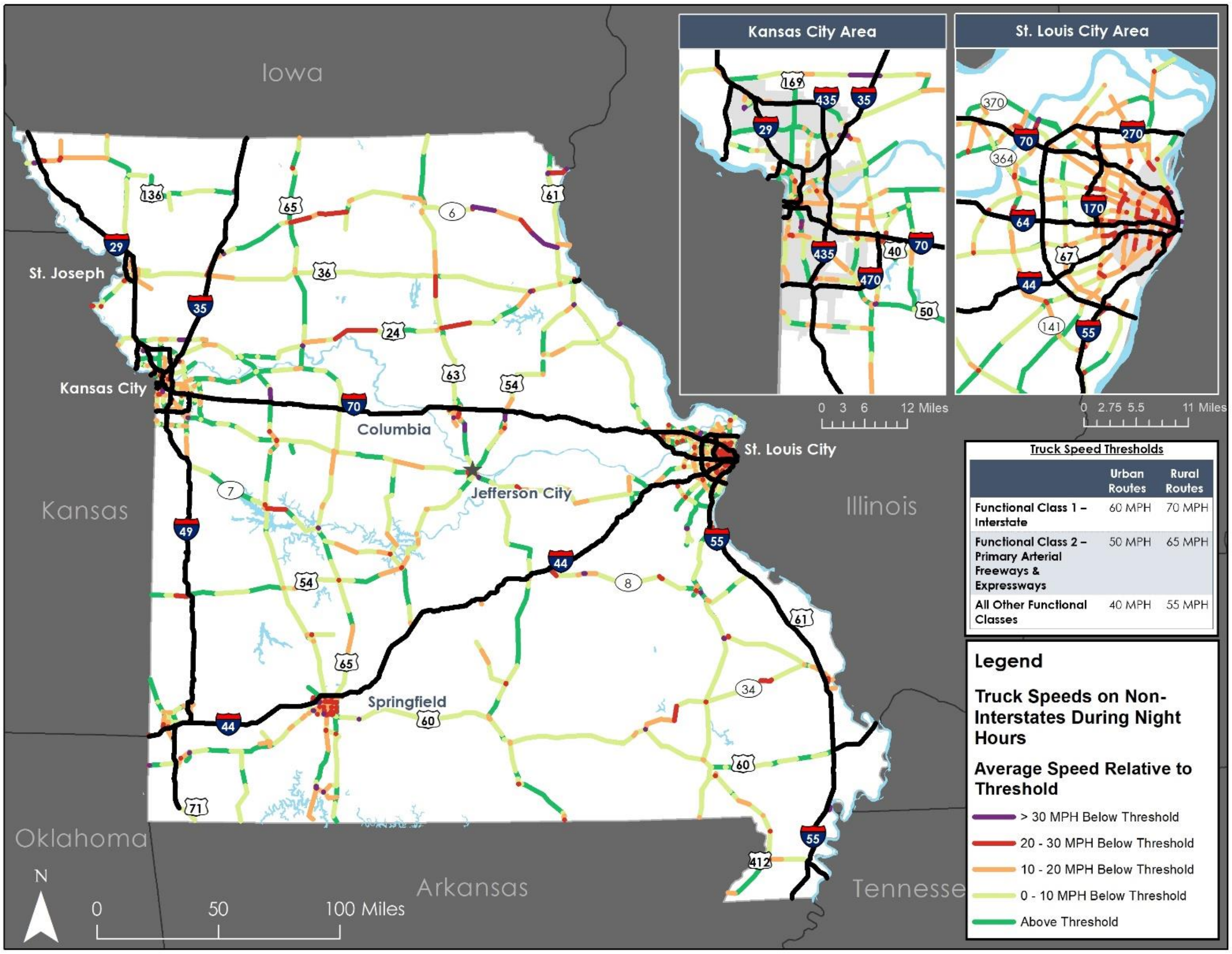
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.8 EVENING PEAK AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



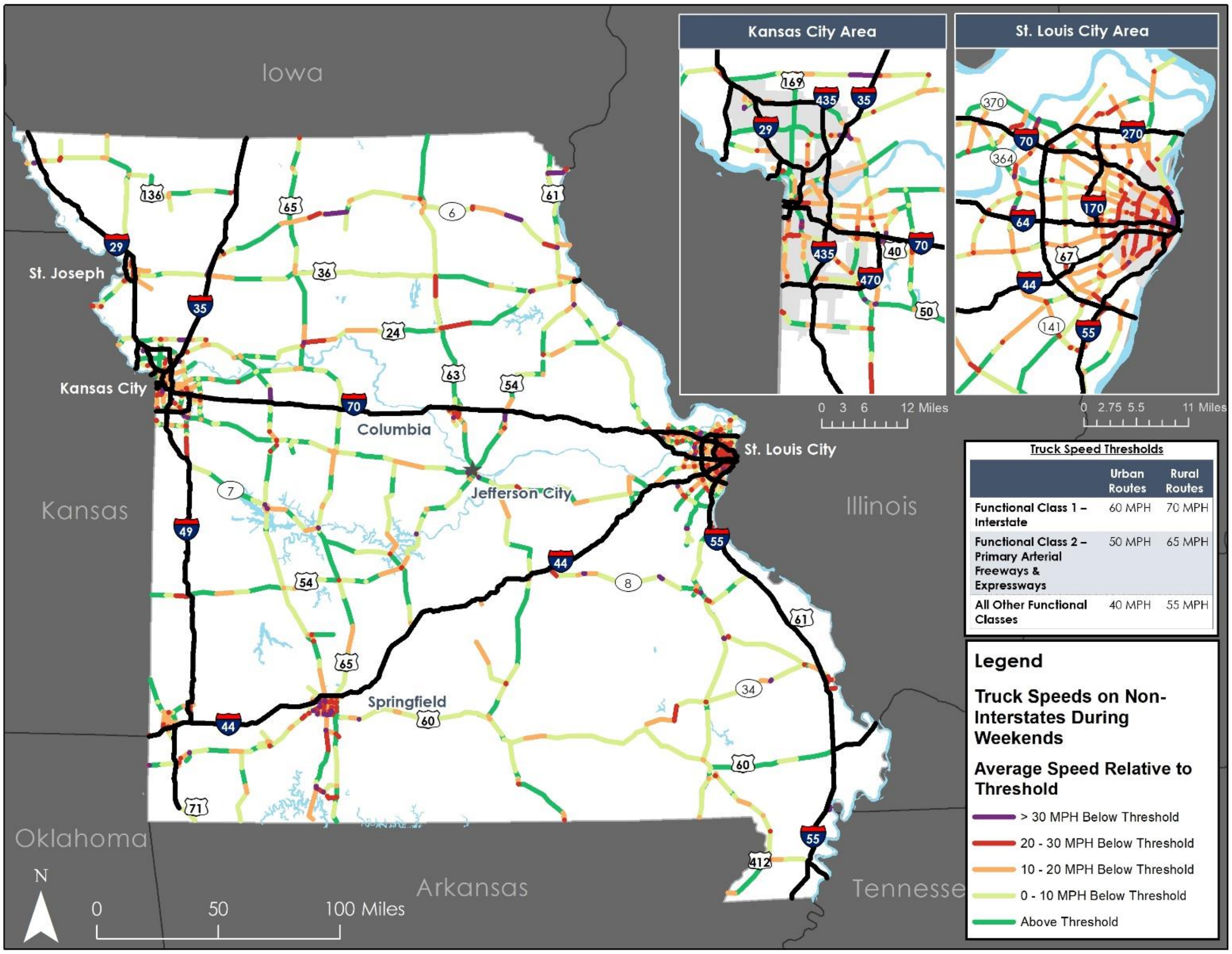
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.9 NIGHT AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.10 WEEKEND AVERAGE TRUCK SPEEDS ON NON-INTERSTATE HIGHWAYS

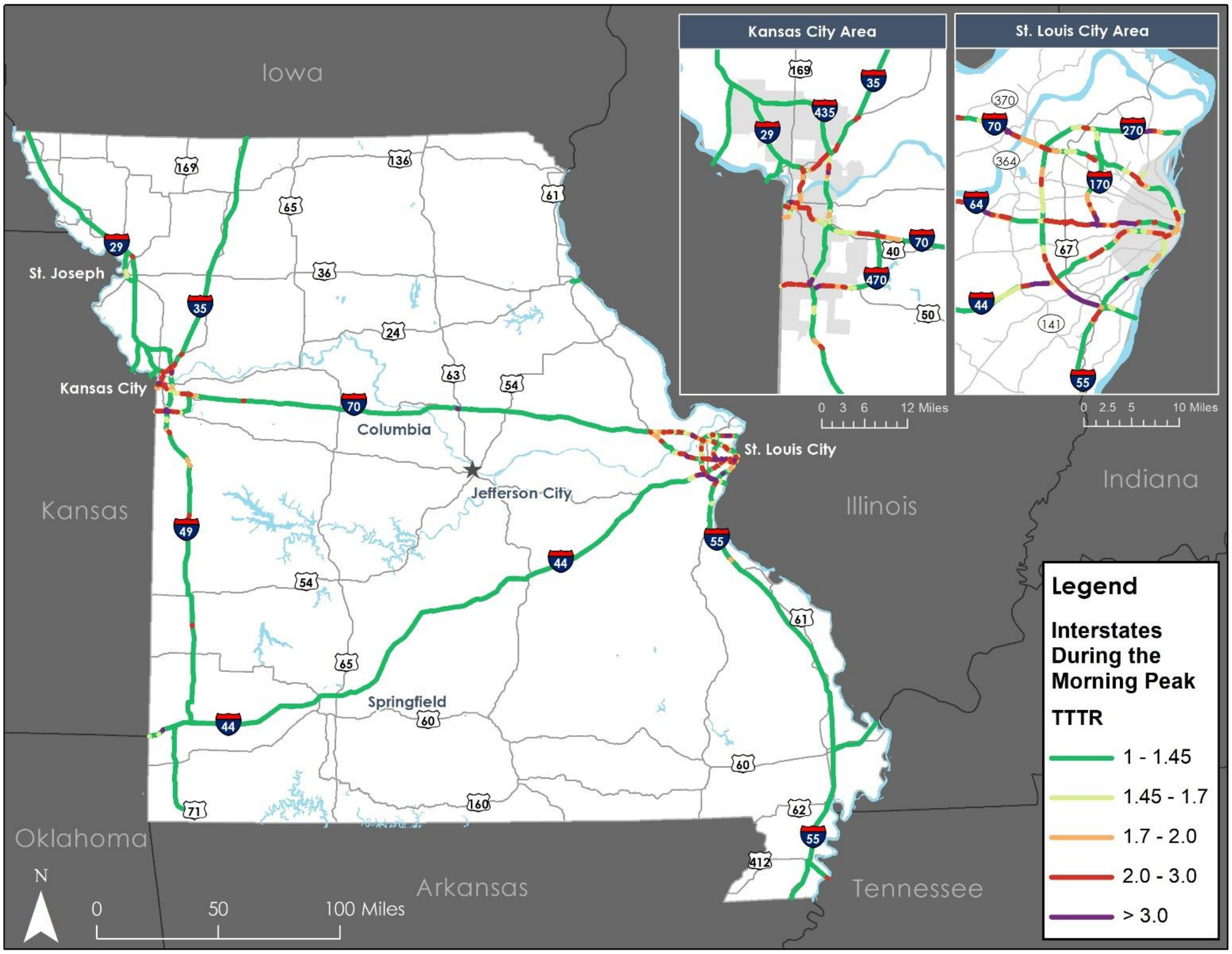


Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

B.2 Truck Travel Time Reliability

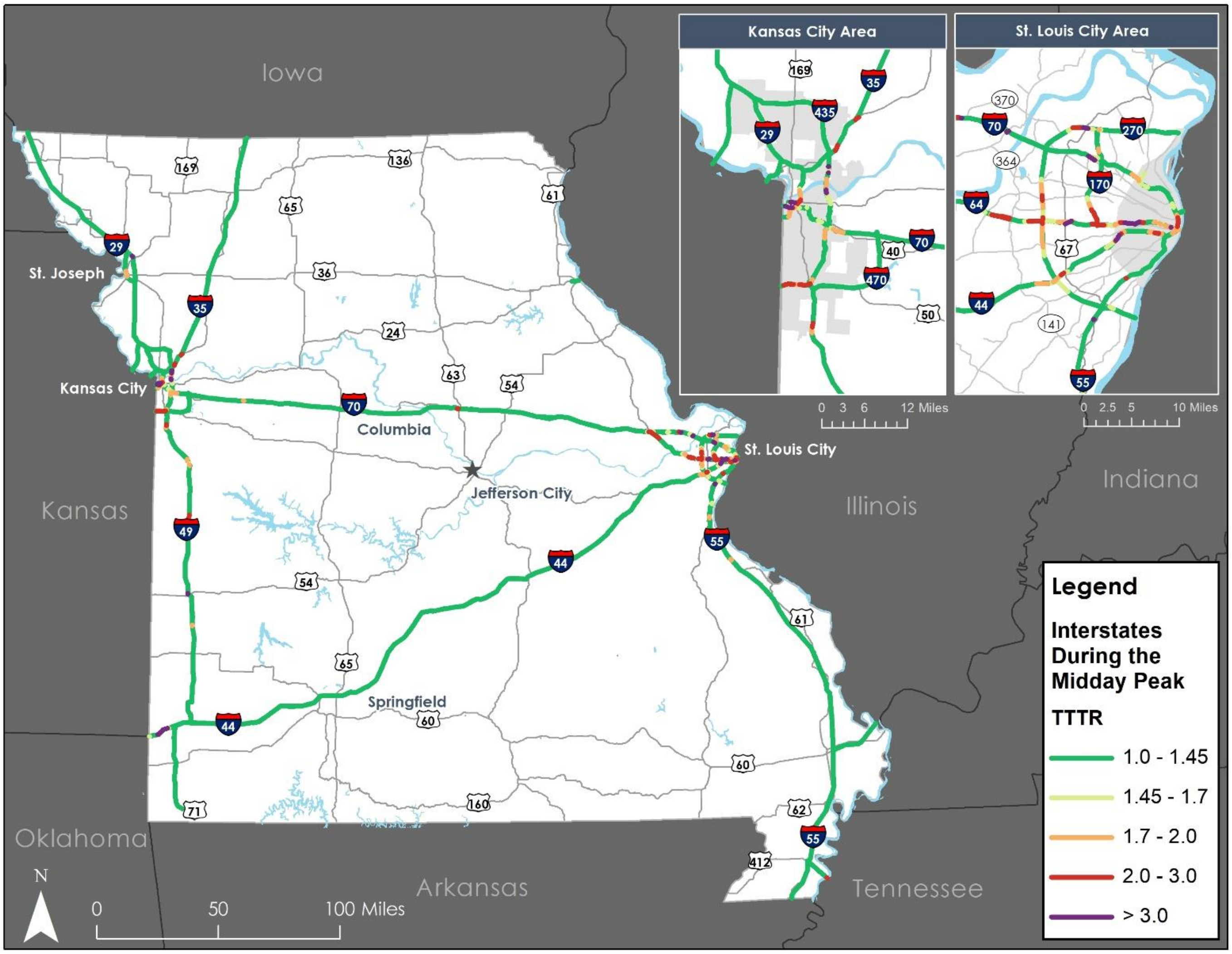
Interstates

FIGURE B.11 MORNING PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



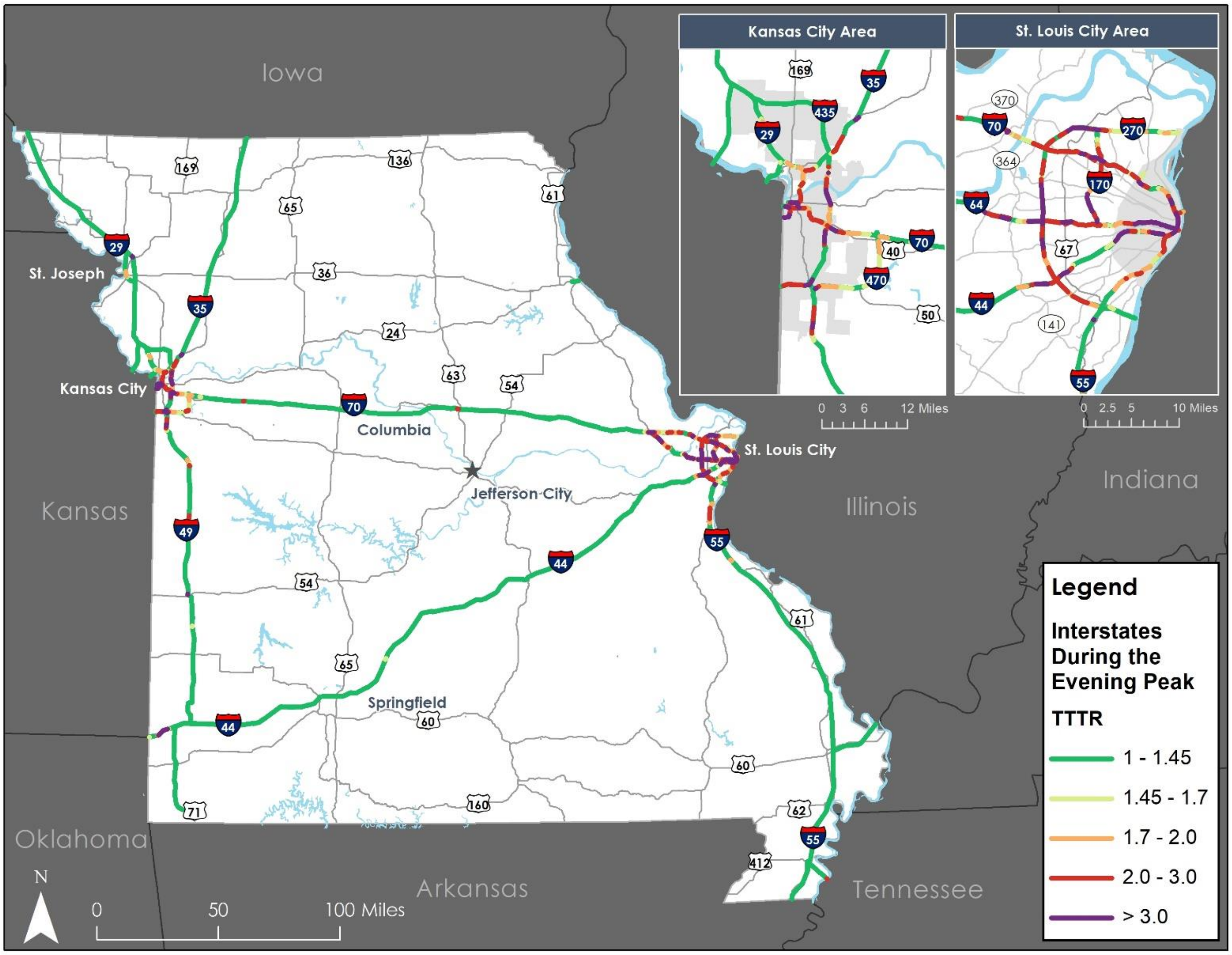
Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020*

FIGURE B.12 MIDDAY PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



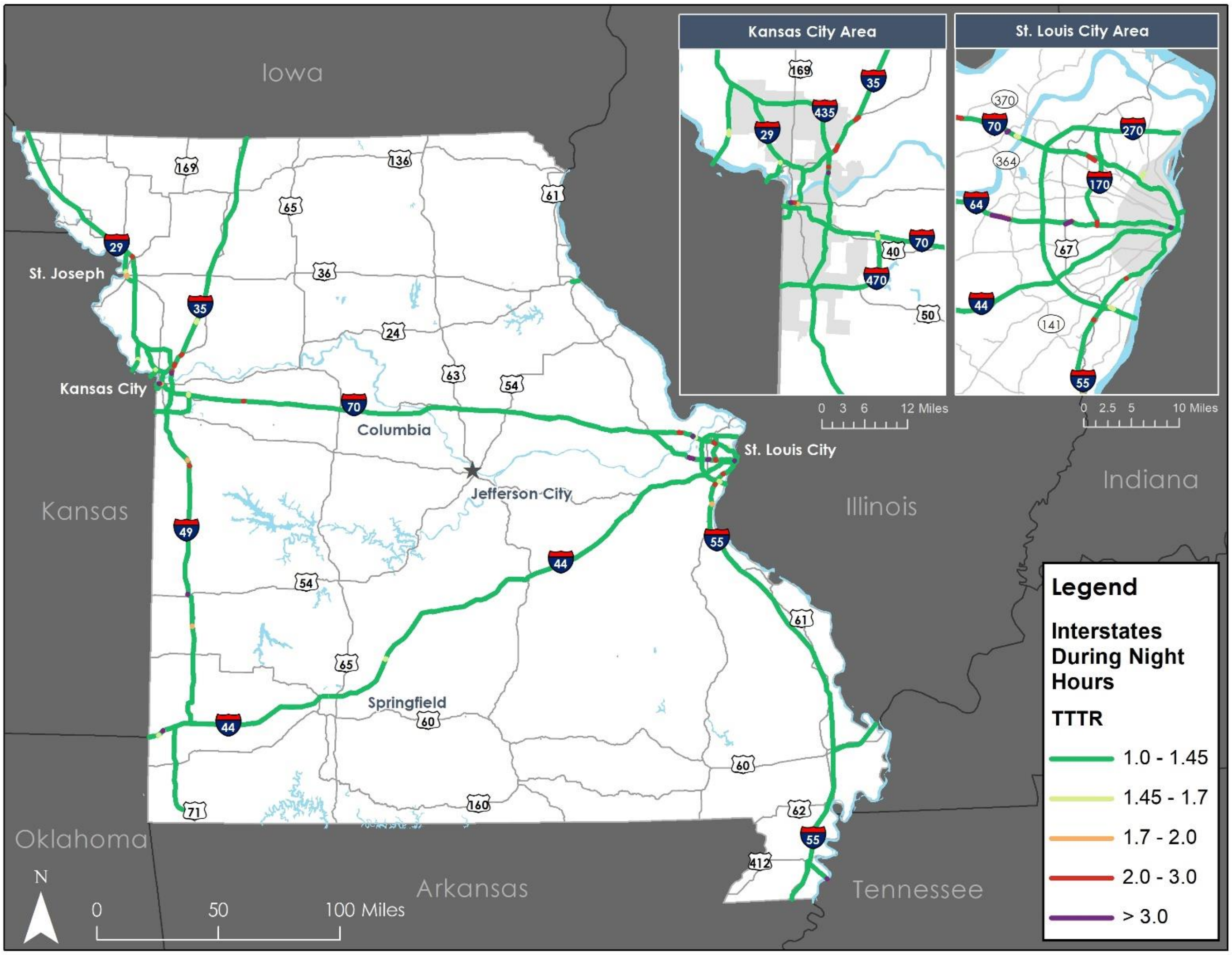
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.13 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



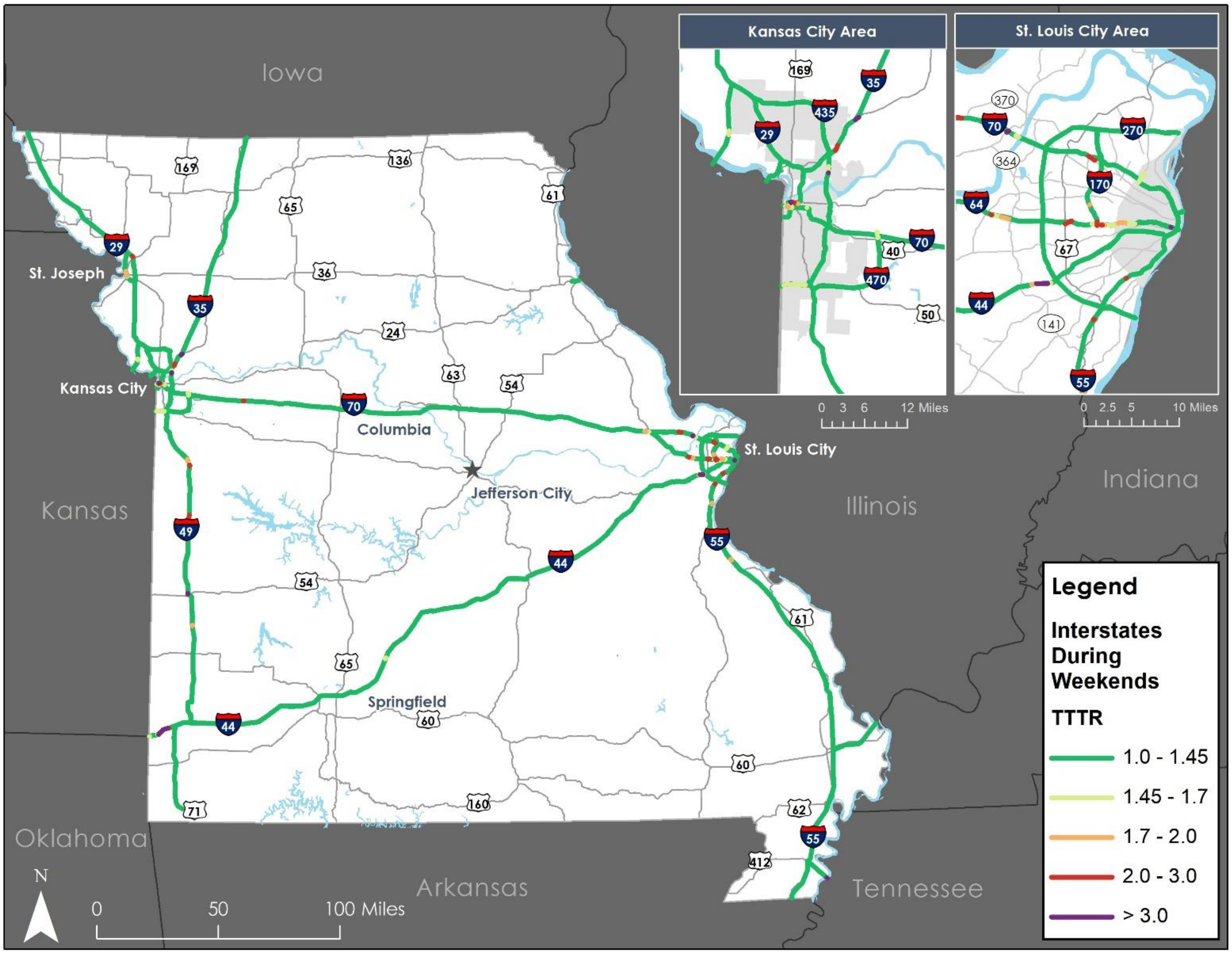
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.14 NIGHT TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

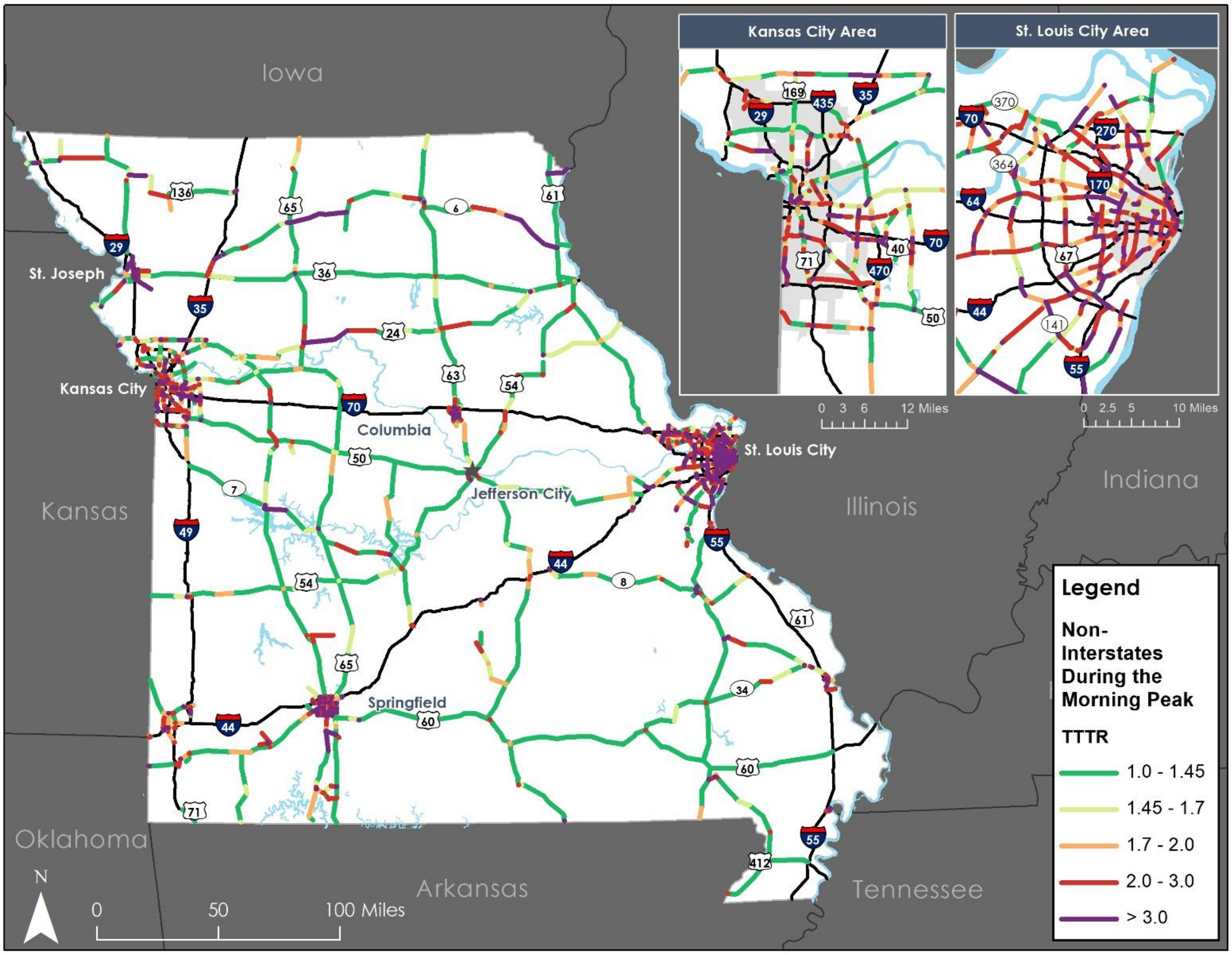
FIGURE B.15 WEEKEND TRUCK TRAVEL TIME RELIABILITY ON INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

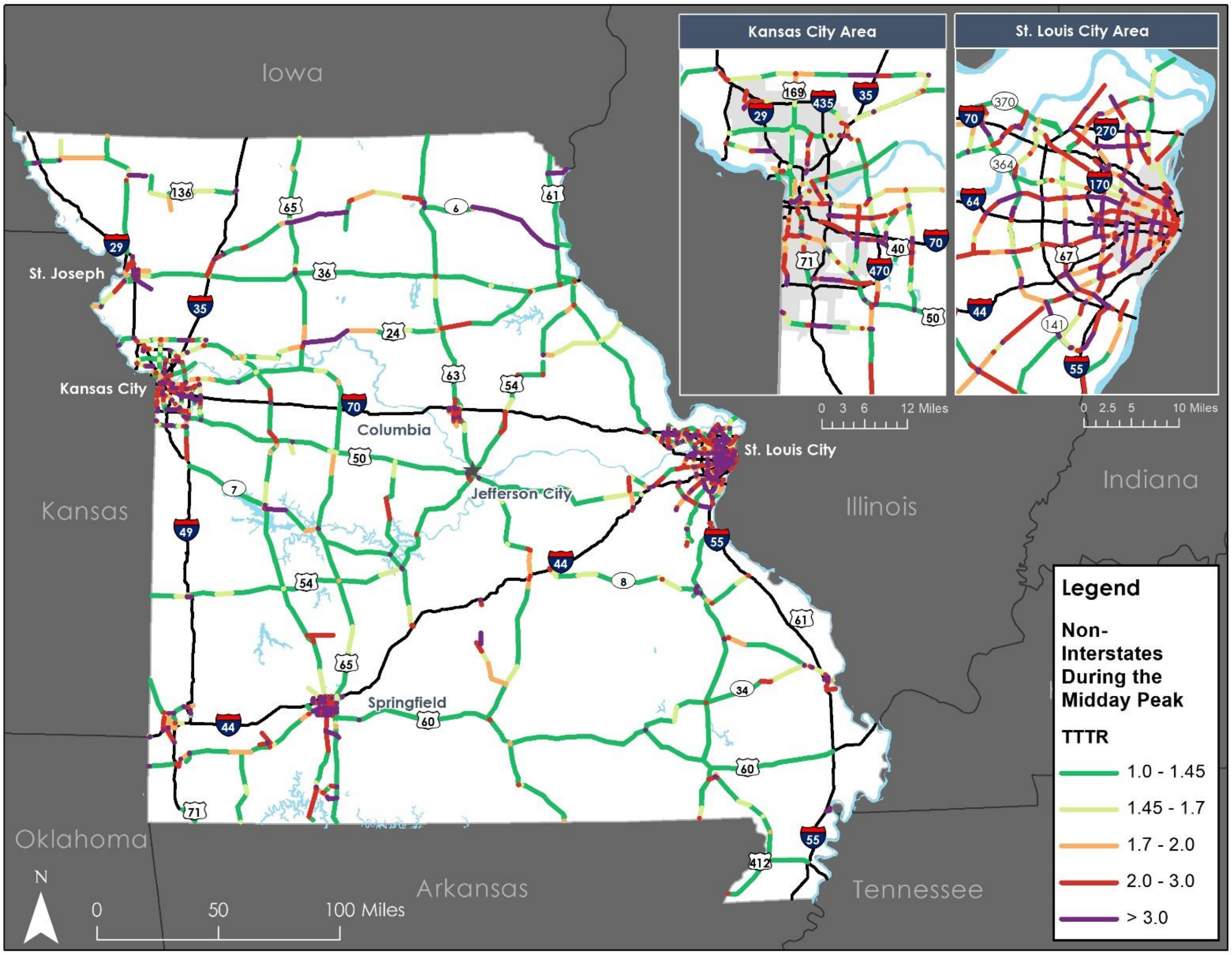
Non-Interstates

FIGURE B.16 MORNING PEAK TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATE HIGHWAYS



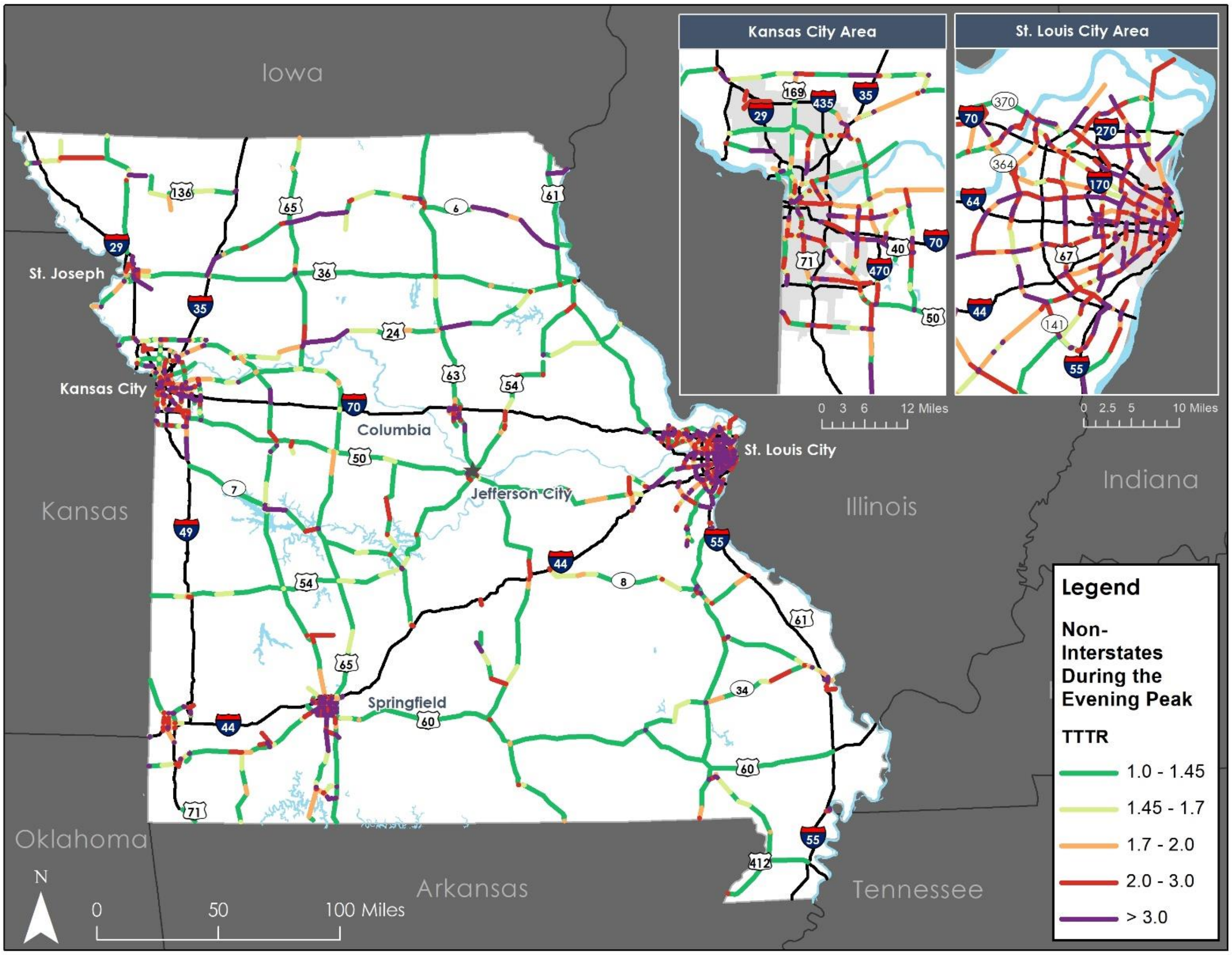
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.17 MIDDAY PEAK TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATE HIGHWAYS



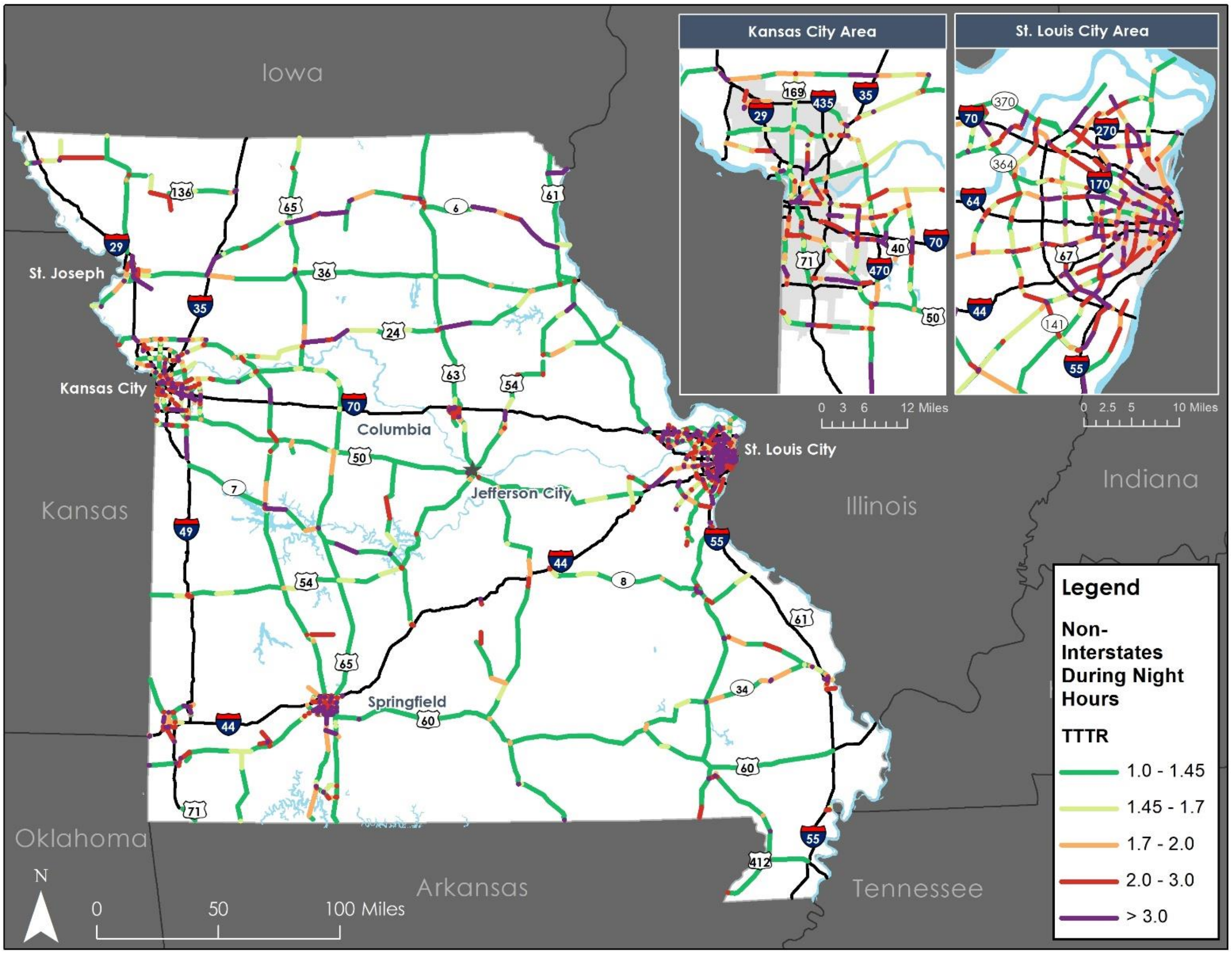
Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.18 EVENING PEAK TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATE HIGHWAYS



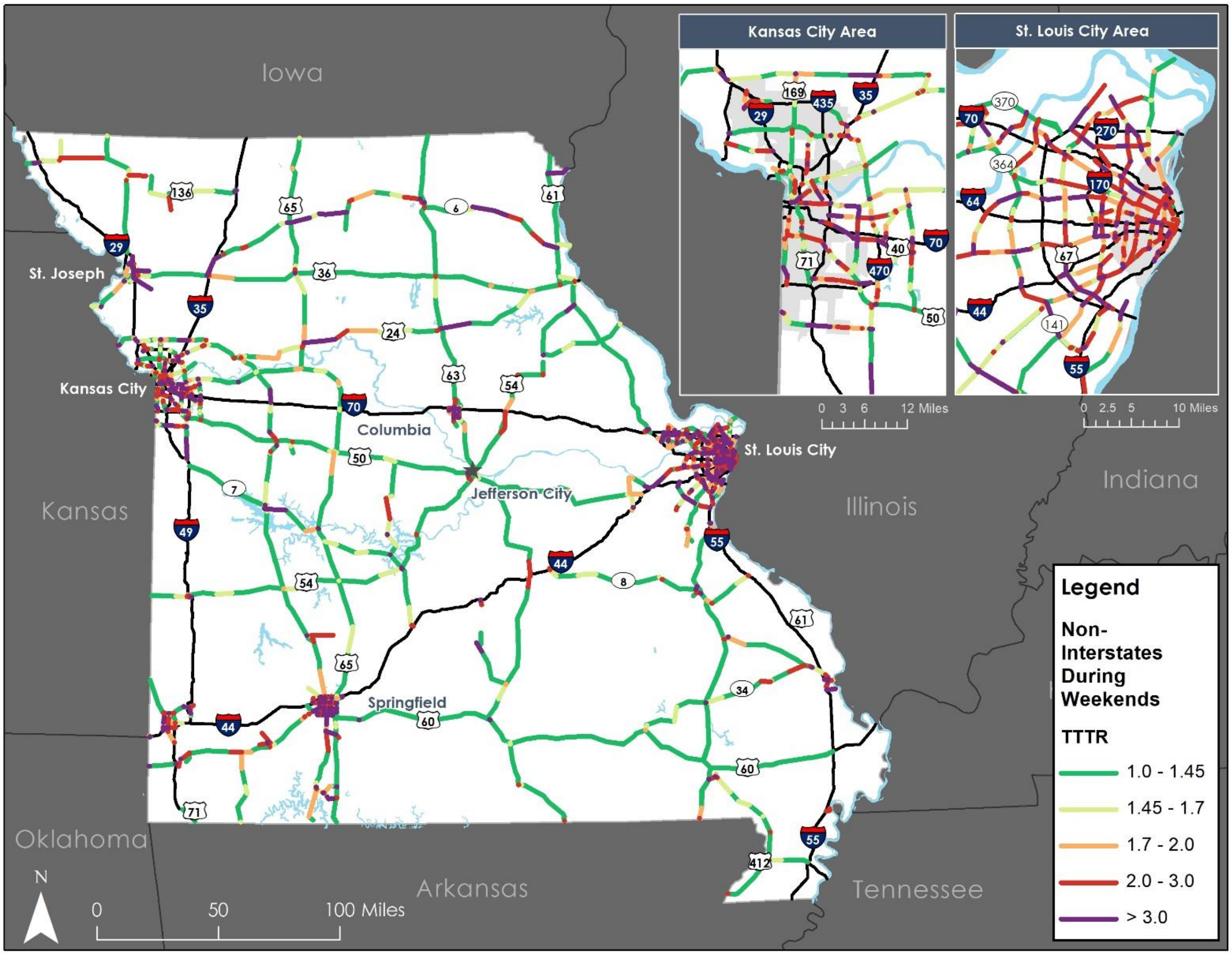
Source: *National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020*

FIGURE B.19 NIGHT TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

FIGURE B.20 WEEKEND TRUCK TRAVEL TIME RELIABILITY ON NON-INTERSTATE HIGHWAYS



Source: National Performance Management Research Data Set, 2019; analysis by Cambridge Systematics, 2020

Appendix
Safety Crash Rate Calculations

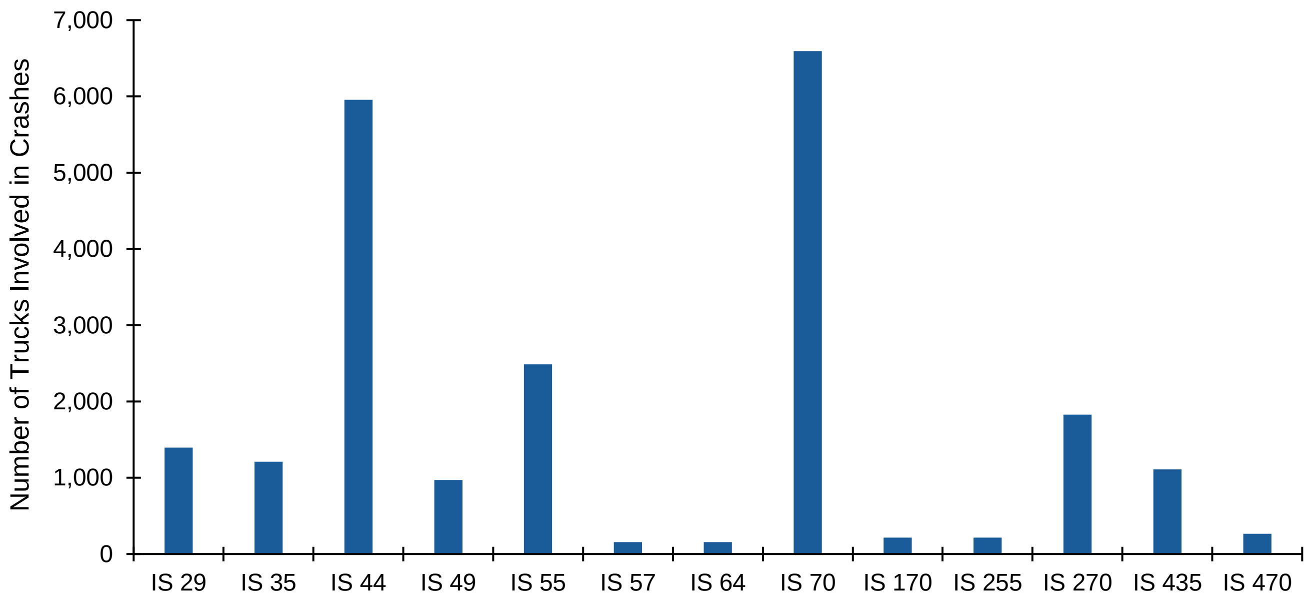
C

C.1 Interstate Crash Rates

A detailed analysis was conducted for trucks involved in crashes on the interstate and U.S. route systems that carried high volumes of truck traffic (at least 225,000 of truck miles travelled) between 2015 – 2019. Data was compiled along interstates for the following categories:

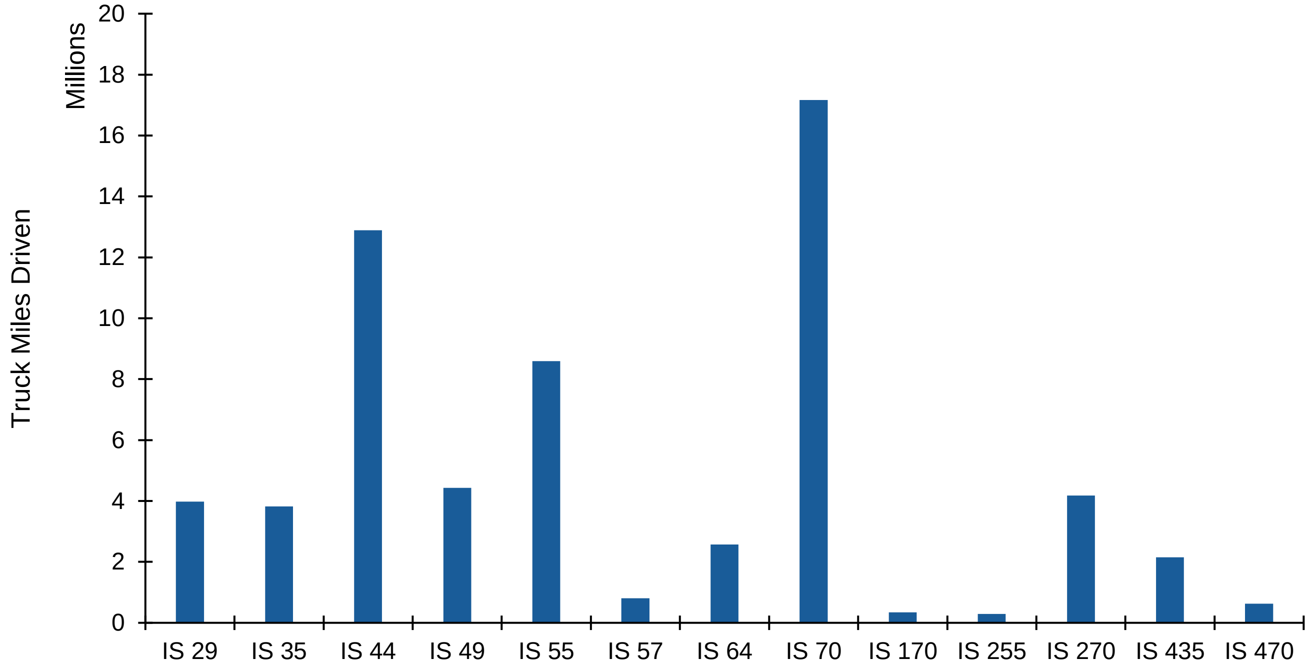
- Total truck miles driven
- Total trucks involved in crashes
- Trucks involved in crashes per mile
- Trucks involved in crashes rate per million truck miles traveled

Figure C.1 shows truck miles driven on Missouri's interstates between 2015 – 2019. Figure C.2



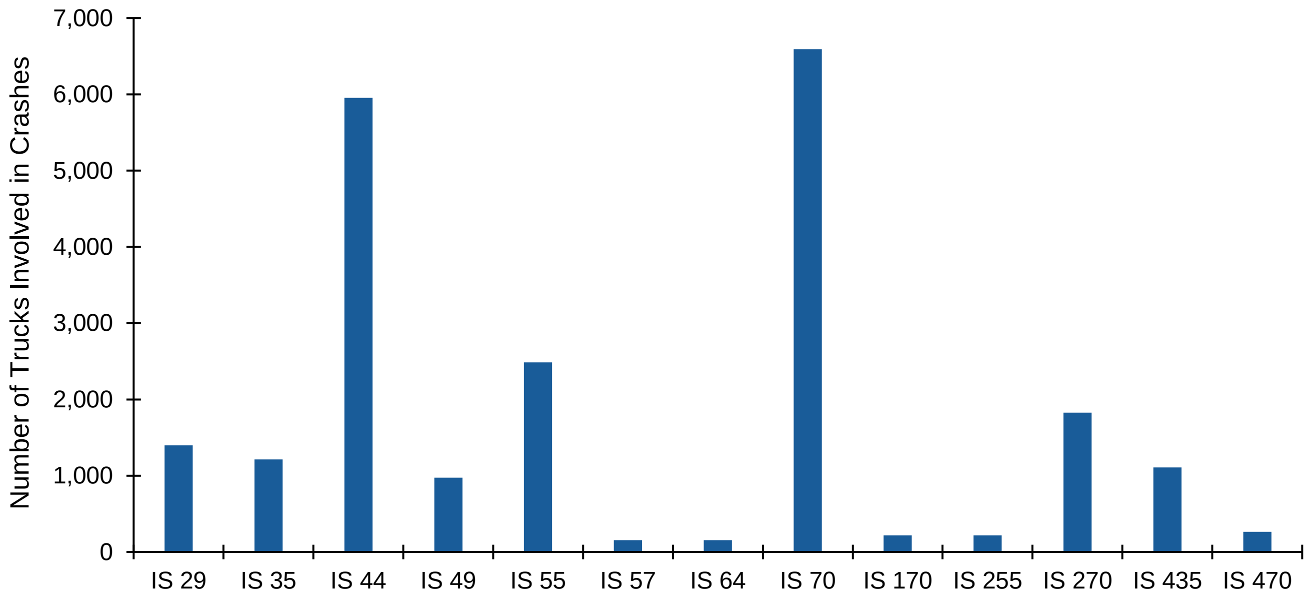
shows the total number of trucks involved in crashes on each of Missouri's interstates between 2015 – 2019 (23,678).

FIGURE C.1 INTERSTATE TRUCK MILES DRIVEN (2015 – 2019)



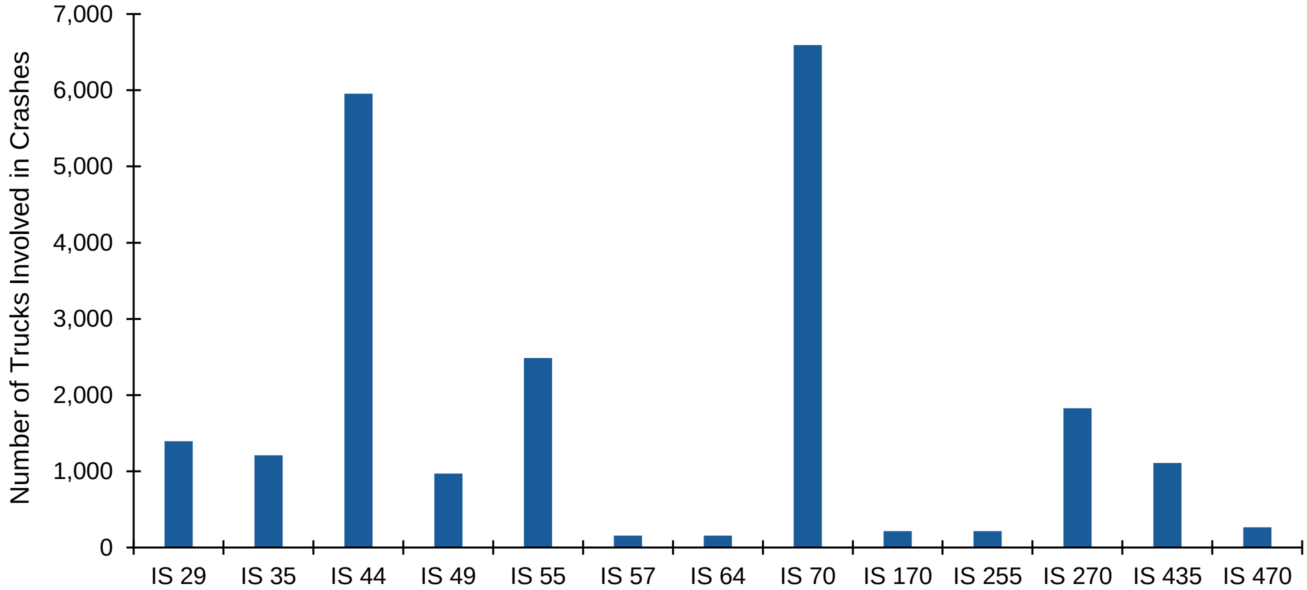
Source: MoDOT through the MSHP STARS Database (2015 – 2019)

FIGURE C.2 INTERSTATE TRUCKS INVOLVED IN CRASHES (2015 – 2019)



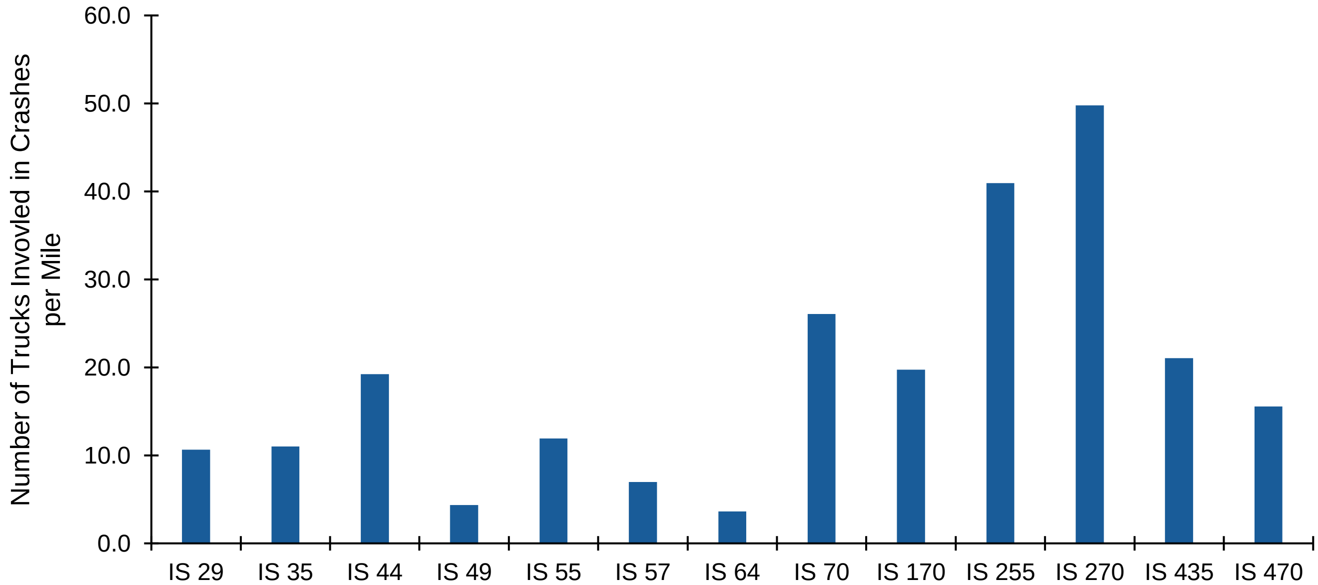
Source: MoDOT through the MSHP STARS Database (2015 – 2019)

As seen in Figure C.1, I-70 and I-44 carried the highest volumes of interstate truck traffic in Missouri over the five-year period analyzed with 17.1 million and 12.9 million truck miles, respectively. Figure C.2



shows a similar trend with I-70 and I-44 having the highest number of trucks involved in a crash over the five-year period with 6,592 and 5,955, respectively. This can be attributed in part to the lengths of these interstates at 252.8 miles and 309.4 miles, respectively.

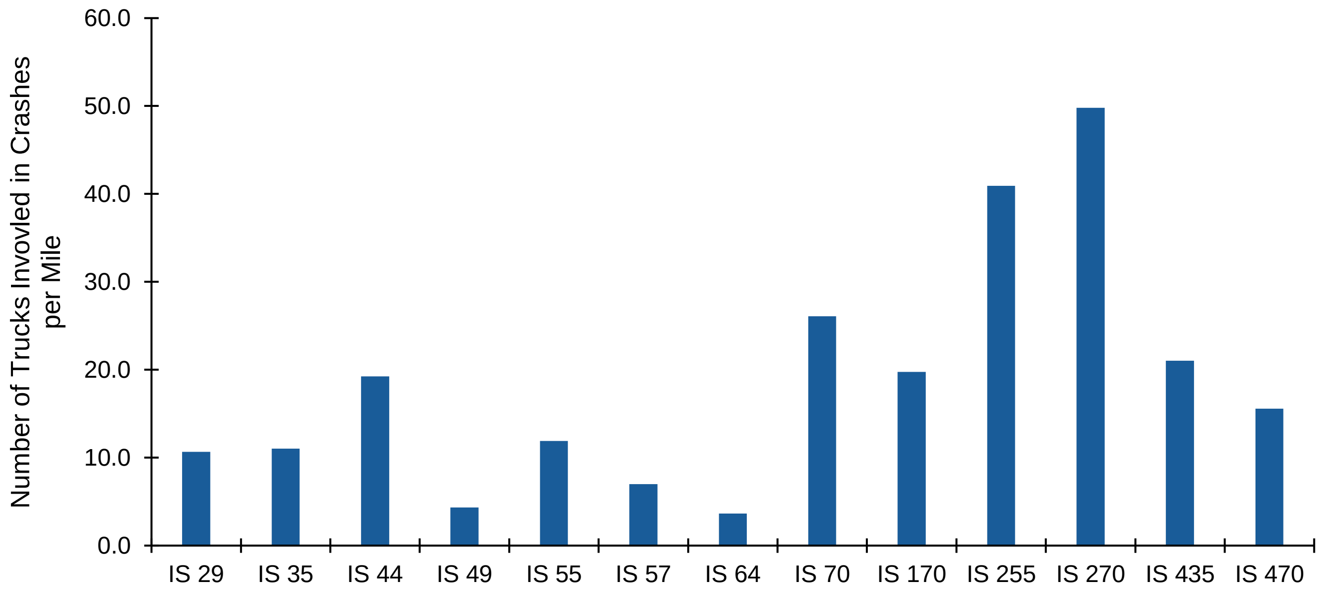
While the absolute number of trucks involved in crashes along an interstate route is important, to better understand the magnitude of crash rates along interstates, the number of trucks involved in crashes per mile of interstate roadways were computed (see Figure C.3



).

As seen in Figure C.1 and Figure C.2, I-270 carried 4.2 million truck miles and had 1,800 trucks involved in crashes between 2015 – 2019 (fourth highest of all interstate routes for both elements). However, as seen in Figure C.3, I-270 had the highest number of trucks involved in crashes per mile of roadway, with 50 trucks involved in crashes per mile of interstate over the five-year period analyzed.

FIGURE C.3 INTERSTATE TRUCKS INVOLVED IN CRASHES PER MILE (2015 – 2019)

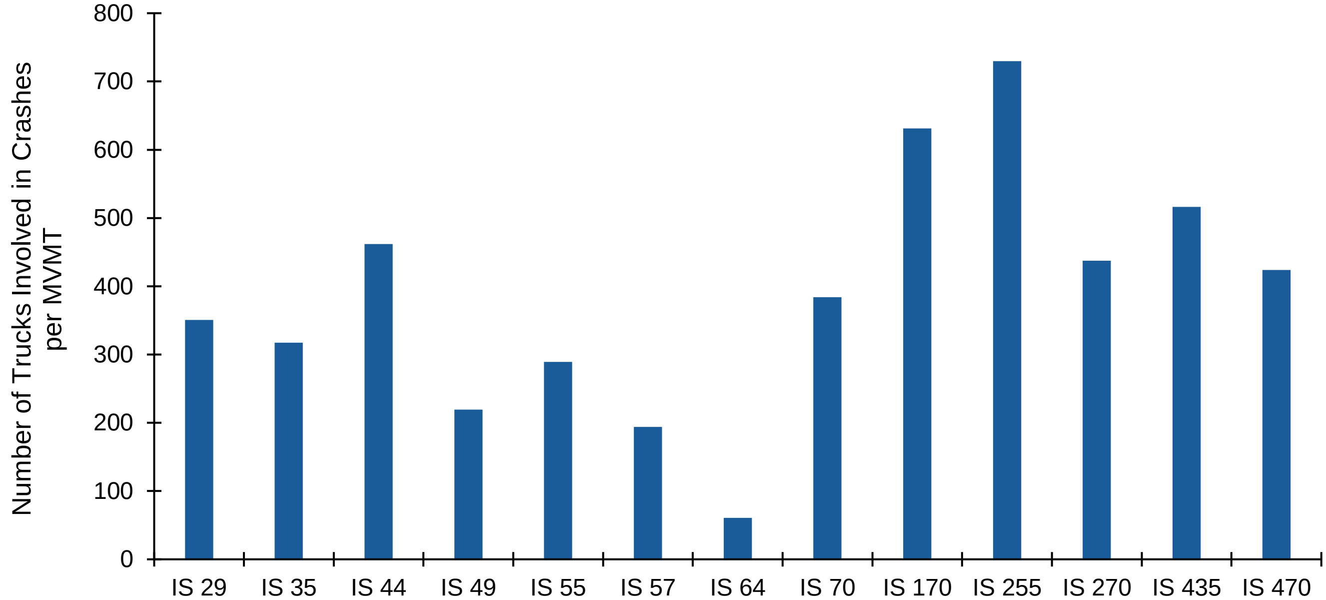


Source: MoDOT through the MSHP STARS Database (2015 – 2019)

Crash rates are traditionally presented as a five-year rate of crashes per million vehicle (truck) miles traveled. For this analysis, actual truck miles driven in 2018 were obtained from MoDOT. To determine five-year truck miles traveled, this number of truck miles was multiplied by five to obtain an estimate of truck miles traveled over the five-year analysis period. The number of trucks involved in incidents for the five year period was also obtained from MoDOT and was used, in conjunction with the estimated truck miles traveled, to develop crash rates for all interstates and U.S. routes that carried more than 225,000 truck miles between 2015 – 2019.

Figure C.4 shows interstate five-year trucks involved in crashes rates. As these rates are based on approximated five-year truck miles driven, they should be used for comparative purposes only. I-255 is the top interstate corridor by this metric, with a truck involved crash rate of more than 700 trucks involved in a crash per MVMT.

FIGURE C.4 INTERSTATE FIVE-YEAR TRUCKS INVOLVED IN CRASHES RATES (2015 – 2019)

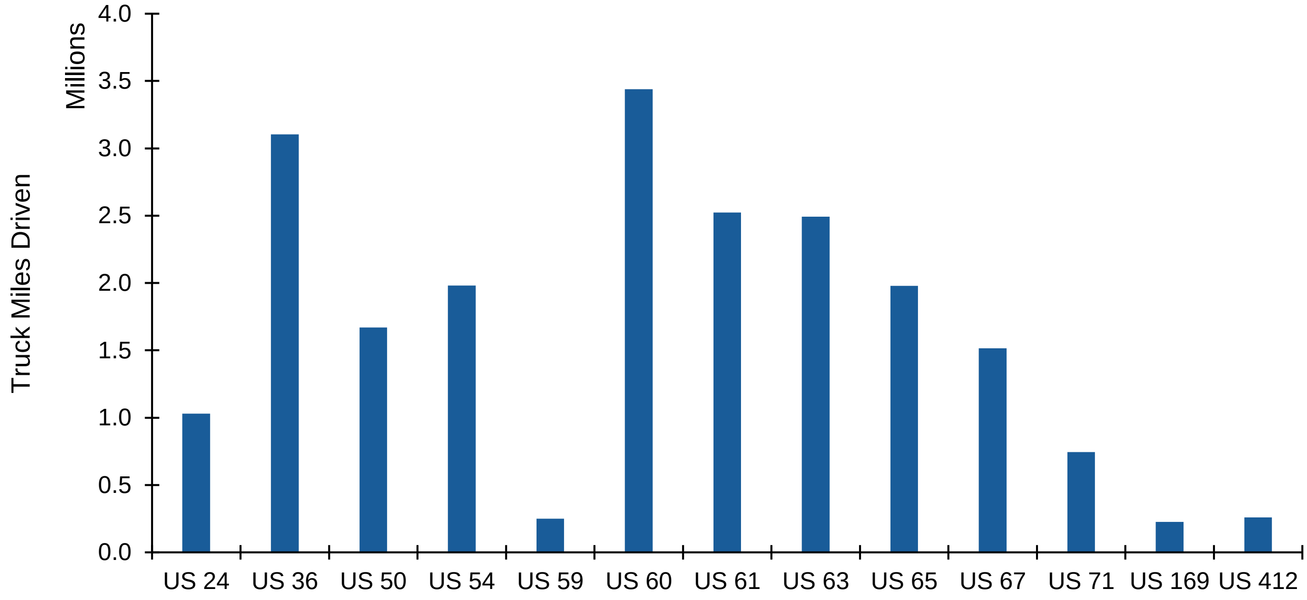


Source: MoDOT through the MSHP STARS Database (2015 – 2019)

C.2 Non-Interstate Crash Rates

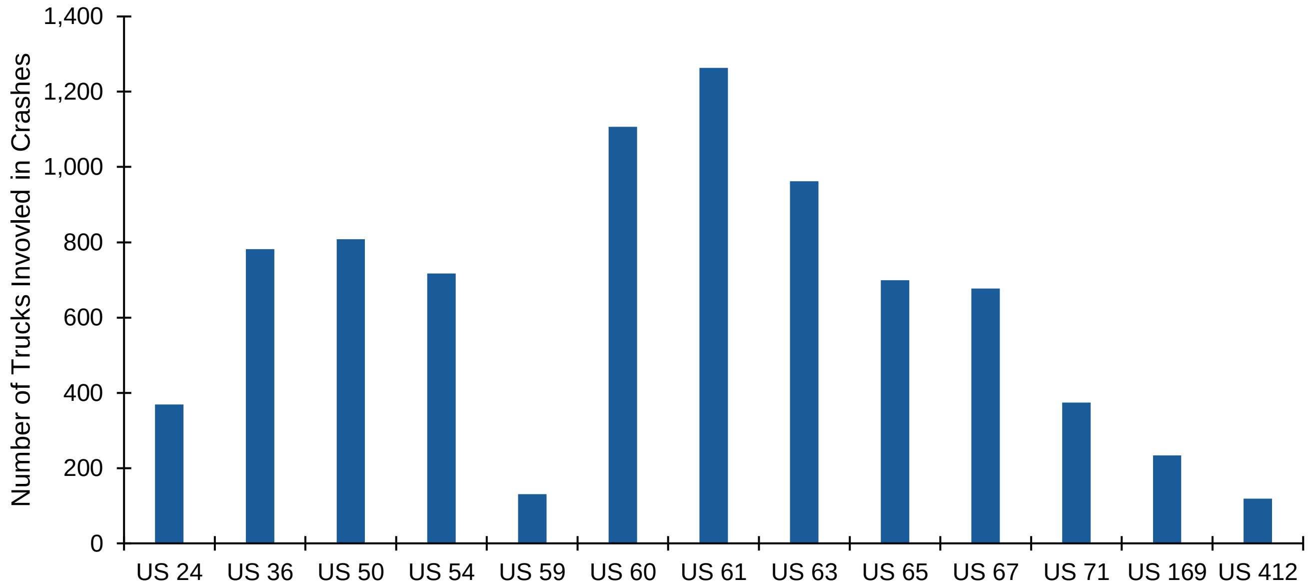
A similar analysis of the number of trucks involved in crashes was performed for all U.S. routes in Missouri. This information is presented in Figure C.5 through Figure C.8. The analysis for U.S. routes was performed in the same manner as the analysis for the interstate routes.

FIGURE C.5 U.S. ROUTE TRUCK MILES DRIVEN (2015 – 2019)



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

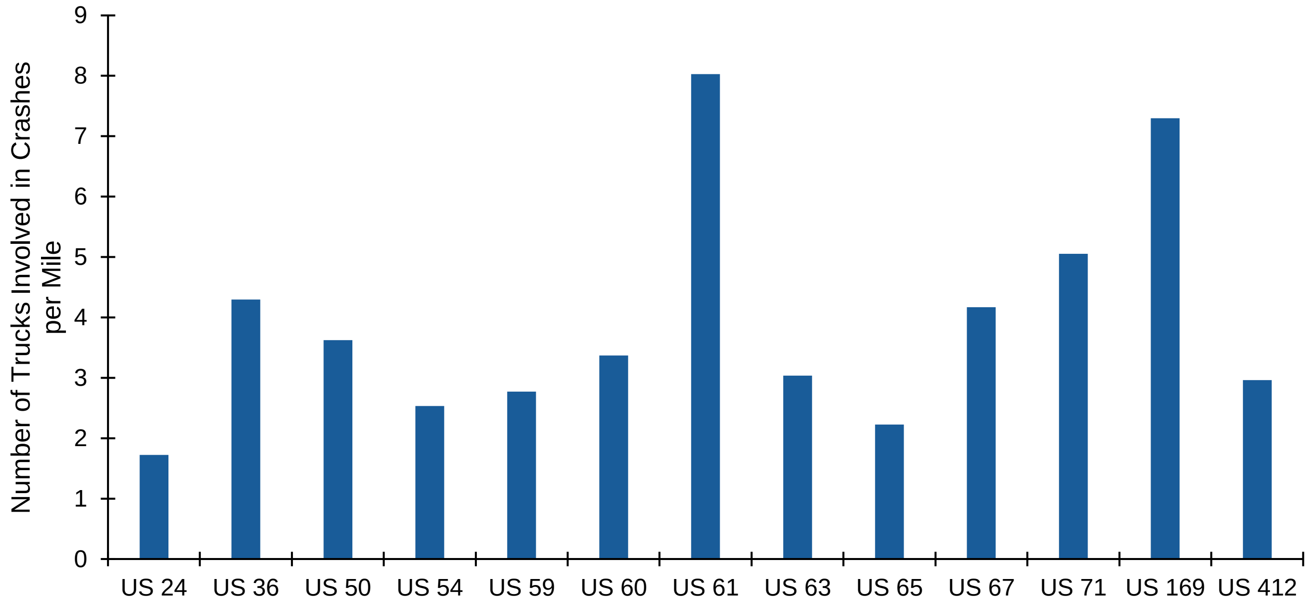
FIGURE C.6 U.S. ROUTE TRUCKS INVOLVED IN CRASHES (2015 – 2019)



Source: MoDOT through the MSHP STARS Database (2015 – 2019)

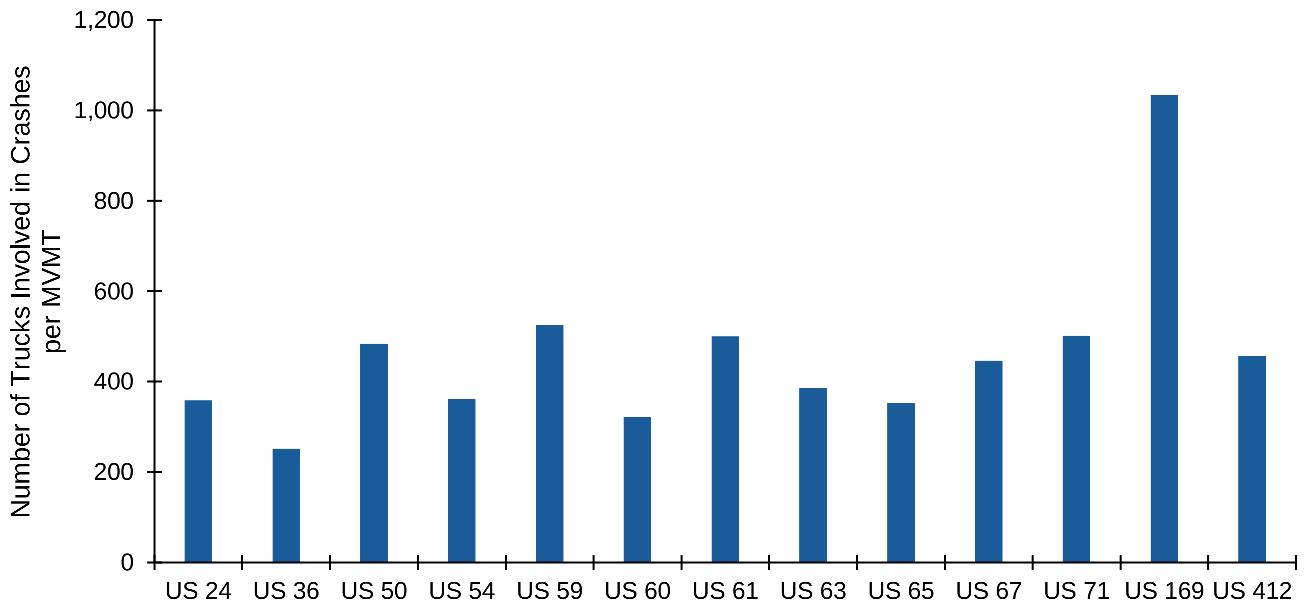
As shown in Figure C.5, U.S. 60 and U.S. 36 had the highest number of truck miles travelled with more than 3 million miles of truck travel over the 2015 – 2019 analysis period each. U.S. 60 also had the second highest number of trucks involved in crashes per mile (more than 1,100 per roadway mile), second only to U.S. 61 (more than 1,250 per roadway mile) as shown in Figure C.6. U.S. 36 had the fifth highest number of trucks involved in crashes with 782.

FIGURE C.7 U.S. ROUTE TRUCKS INVOLVED IN CRASHES/MILE (2015 – 2019)



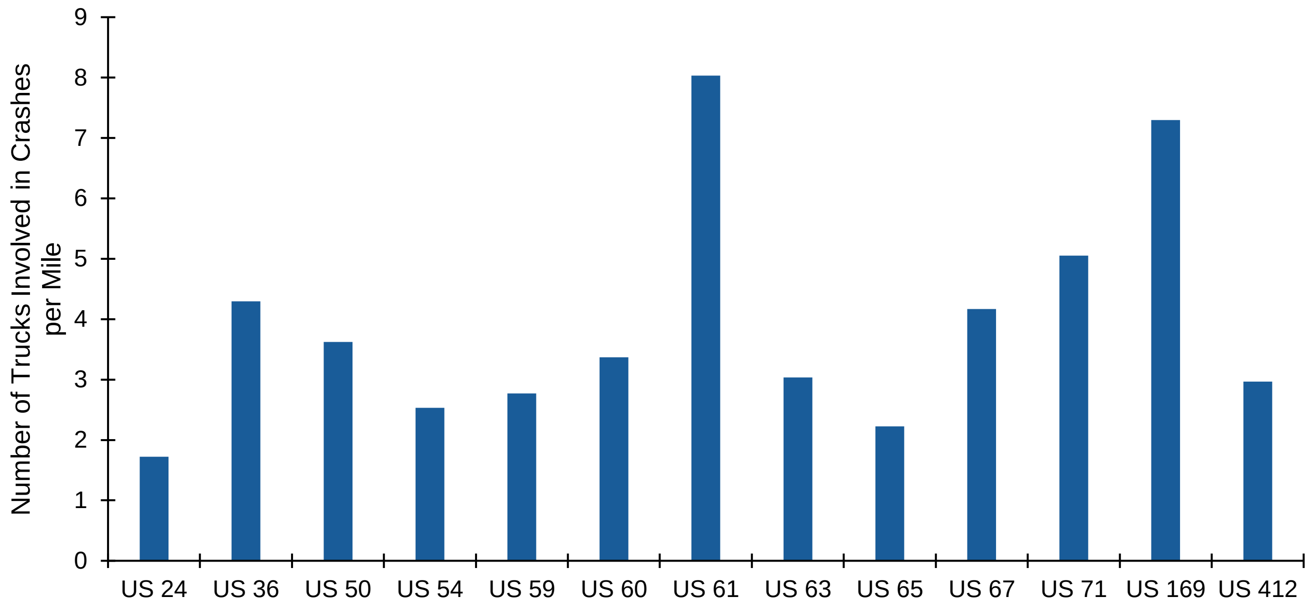
Source: MoDOT through the MSHP STARS Database (2015 – 2019)

FIGURE C.8 U.S. ROUTE TRUCKS INVOLVED IN CRASHES RATE (2015 – 2019)

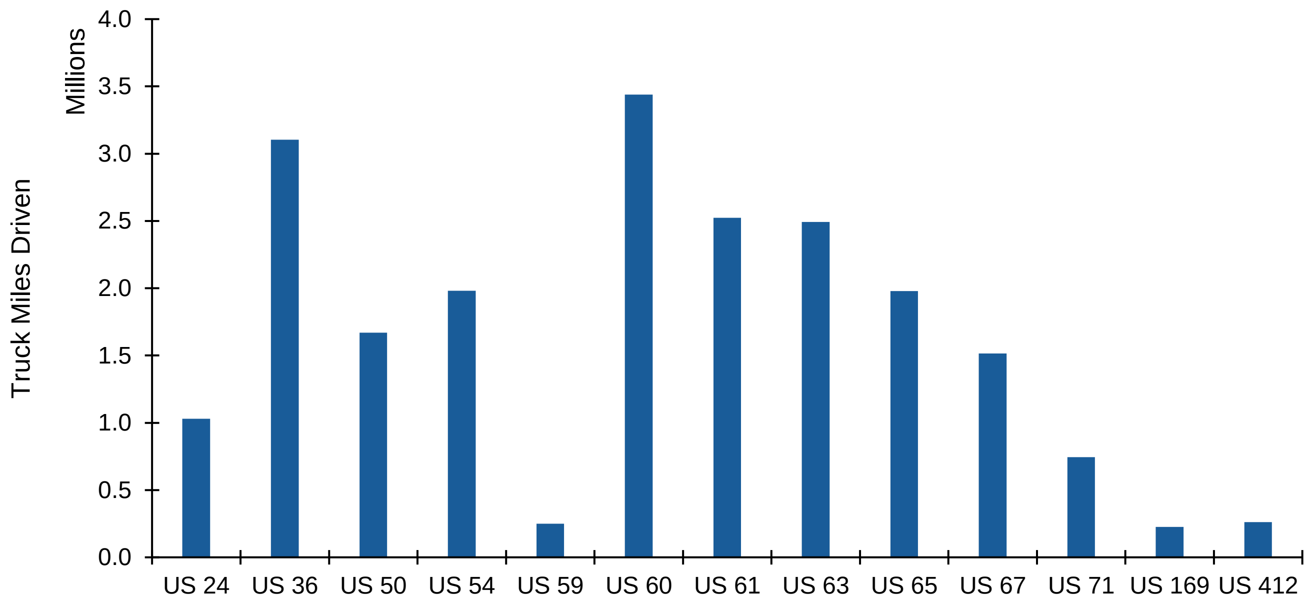


Source: MoDOT through the MSHP STARS Database (2015 – 2019)

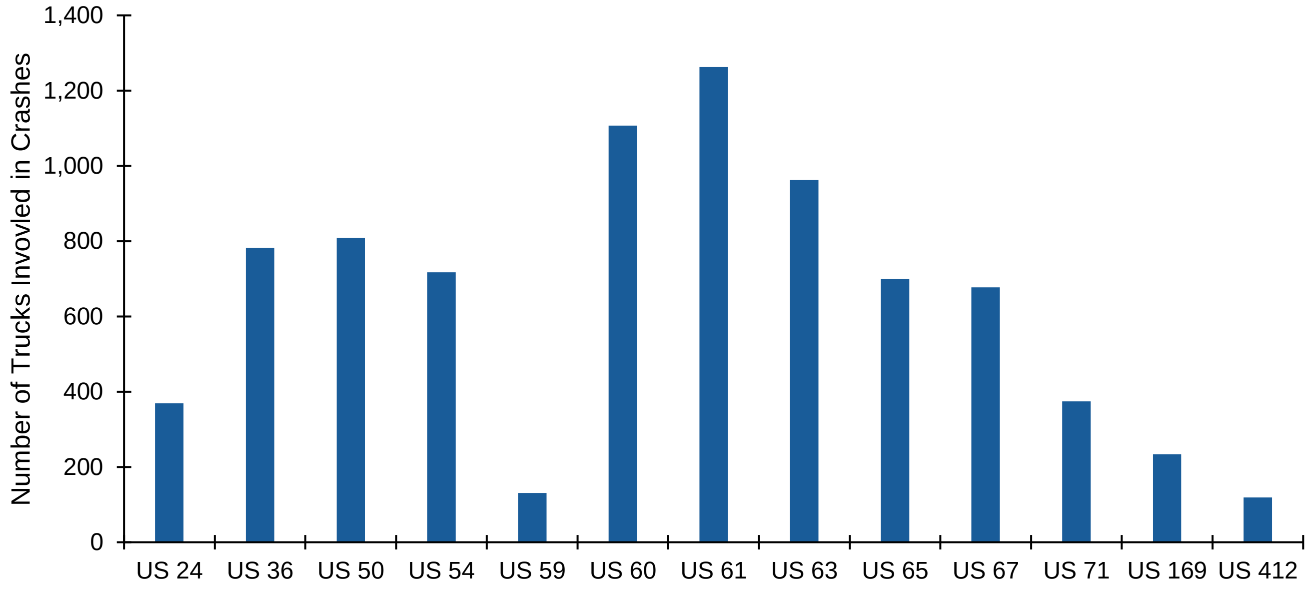
Analyzing the data presented in Figure C.7



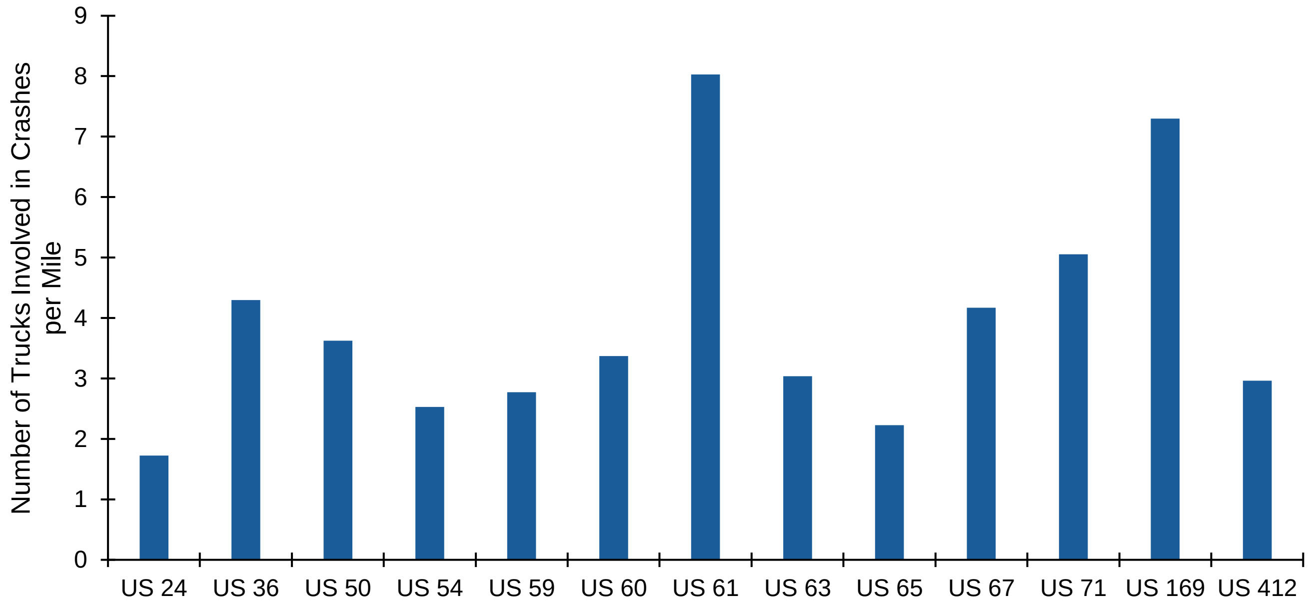
, U.S. 61 has the highest number of trucks involved in crashes per mile for the 2015 - 2019 analysis period with 8.0. U.S. 169, which had very low truck miles traveled of 226,000 miles (Figure C.5



), and total trucks involved in crashes of 234 (Figure C.6



), had the second highest number of trucks involved in crashes per mile of 7.3, second only to U.S. 61 with 8.0 crashes per mile (Figure C.7



).

As shown in Figure C.8, U.S. 169 also had the highest five-year rate of trucks involved in crashes per MVMT, with a rate of more than 1,000. U.S. 71, U.S. 59 and U.S. 61 each have more than 500 trucks involved in crashes per MVMT.

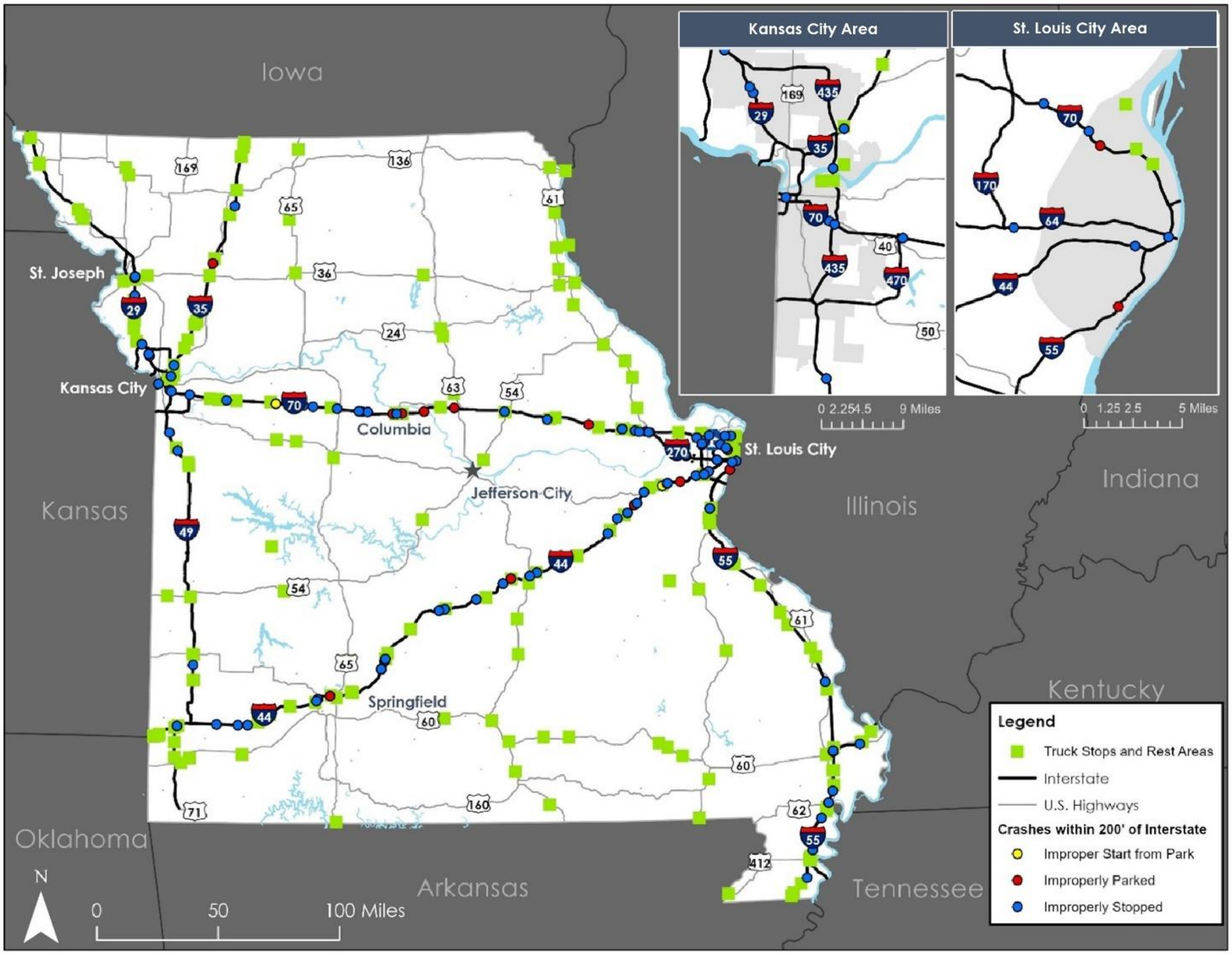
C.3 Truck Parking Detailed Analysis

Three scenarios were analyzed related to parked truck crashes and their proximity to interstates and truck stops. The first scenario was for these types of crashes within 200 feet on either side of an interstate. Over the five-year analysis period, 119 trucks were involved in crashes with at least one of the three contributing circumstances related to parked trucks. These locations are depicted in Figure C.9.

The second scenario investigated these types of crashes within one mile of a truck stop and/or designated truck parking (both publicly and privately owned). These locations are depicted in Figure C.10. Only 51 trucks were involved in these types of incidents.

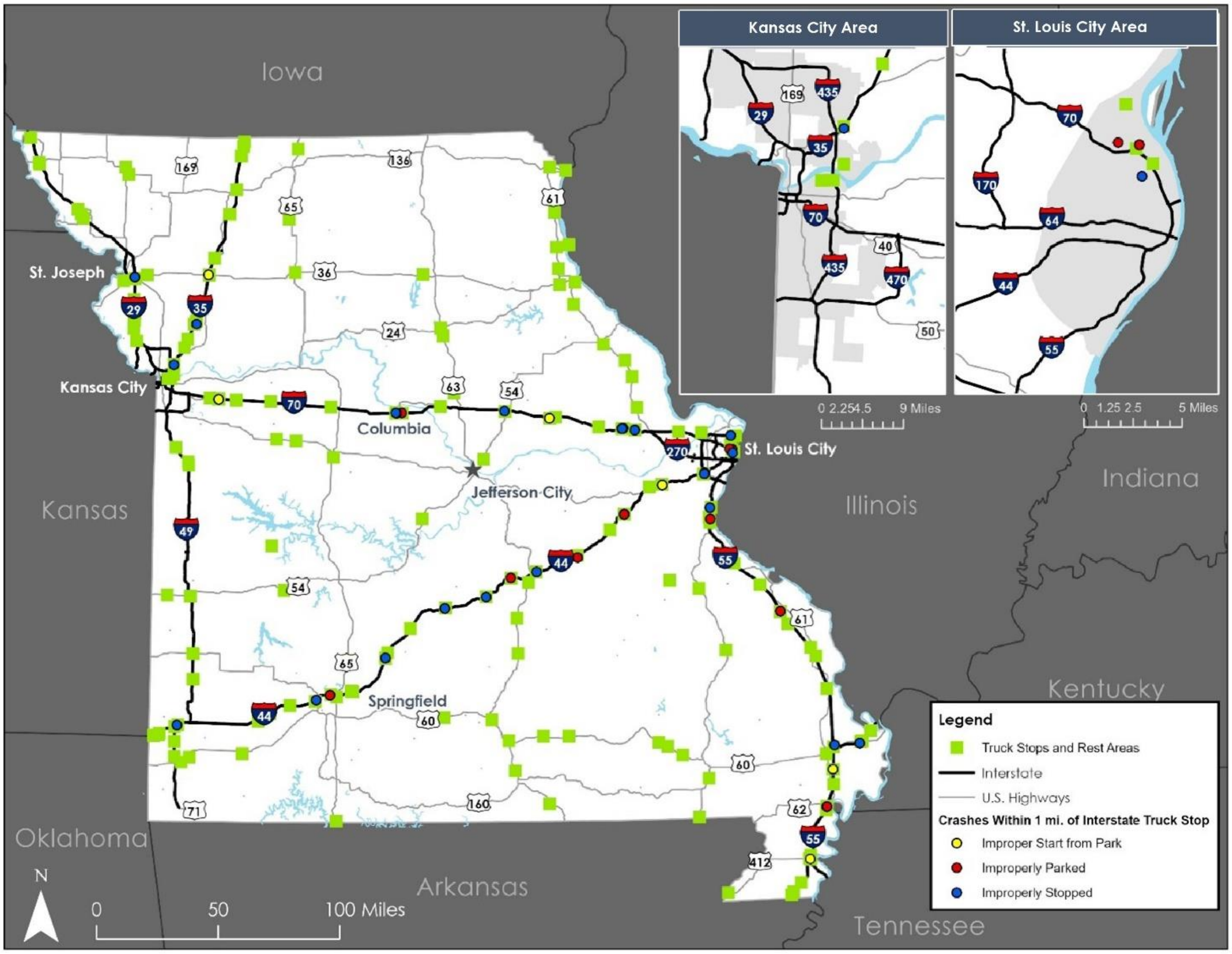
The final scenario, investigating these types of crashes within five miles of a designated truck parking location, is presented in Figure C.11. Almost 40% of these types of crashes (242) occurred within five miles of a truck stop/truck parking.

FIGURE C.9 STATEWIDE CRASHES RELATED TO TRUCKS IMPROPERLY PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK WITHIN 200' OF AN INTERSTATE



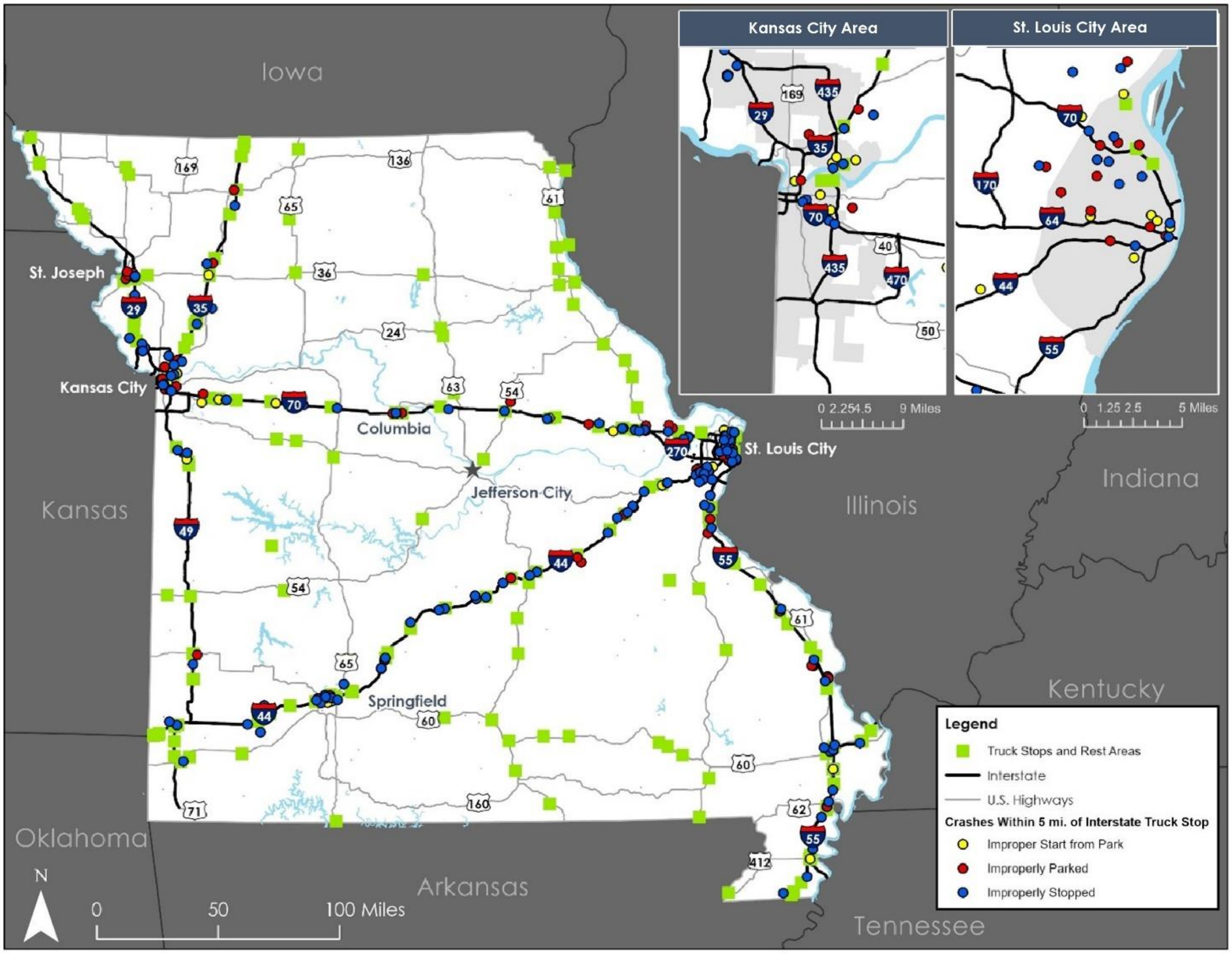
Source: MoDOT

FIGURE C.10 STATEWIDE CRASHES RELATED TO TRUCKS IMPROPERLY PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK WITHIN ONE MILE OF A TRUCK STOP OR TRUCK PARKING



Source: MoDOT

FIGURE C.11 STATEWIDE CRASHES RELATED TO IMPROPERLY TRUCKS PARKED, IMPROPERLY STOPPED ON ROADWAY AND IMPROPER START FROM PARK WITHIN FIVE MILES OF A TRUCK STOP OR TRUCK PARKING



Source: MoDOT