

Appendix D

Truck Freight Modeling Methodology

COLORADO HIGHWAY 71 *(Limon north to Colorado/Nebraska state line)* TRUCK FREIGHT DIVERSION FEASIBILITY STUDY

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SH 71 Truck Freight Analysis

Truck Model Methodology

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List of Acronyms

AADT	Average Annual Daily Traffic
AON	All or Nothing
CDOT	Colorado Department of Transportation
DRCOG	Denver Regional Council of Governments
FHWA	Federal Highway Administration
NFRMPO	North Front Range Metropolitan Planning Organization
GIS	Geographic Information Systems
HCV	Heavy Commercial Vehicle
MP	Milepost
MPO	Metropolitan Planning Organization
MUT	Multi-Unit Truck
NHPN	National Highway Planning Network
OTIS	Online Traffic Information System (Colorado)
PPACG	Pikes Peak Area Council of Governments
SH	State Highway
SUT	Single Unit Truck
TAZ	Traffic Analysis Zone

1. Introduction

1.1 Purpose

The purpose of the SH 71 project is to analyze the freight movement and the achievability of diverting, or capturing growth of, truck freight onto the SH 71 / US 24 corridor. Diversion could occur from I-25 at Colorado Springs via US 24 or other locations. The goal of this analysis is to review the types and cost of improvements to SH 71 that will draw additional truck traffic, to determine the potential economic benefit to the trucking industry and local economies, and to develop funding options and implantation scenarios.

The analysis will collate the information into a report to be distributed to CDOT Region 4, CDOT Region 2, Ports-to-Plains Alliance, and the local stakeholders. This report addresses the SH 71 Multi-Unit Truck Model used to support the project.

1.2 Organization

WSP is providing this methodology to provide an understanding of how truck traffic is estimated on SH 71 for a base and future year. This methodology will include a review of:

1. SH 71 model philosophy
2. SH 71 Study Area
3. Observed Data (Truck Counts) Collection
4. Model Components
 - a. Assumptions
 - b. Traffic Analysis Zones
 - c. Highway Network
 - d. Travel Times and Model Approach
 - e. Reporting Segments
 - f. MUT Demand
 - g. Assignment Approach
5. Model Validation
6. Summary

1.3 Model Philosophy

The SH 71 model components and approach were assembled with a straightforward philosophy:

- The components such as zones and highway network are selected to focus on the SH 71 corridor. It is important, however, to include the I-25 corridor in the Front-Range region since congestion in this corridor can cause diversion of long-distance truck trips to SH 71.
- Integrating Front-Range area congestion into the SH 71 work will be done while maintaining the appropriate scale to the project. The intent is not to build a Colorado statewide model.
- The model approach will leverage available datasets from CDOT, FHWA, study datasets such as special counts and other.
- SH 71 will retain a “sketch” level approach while drawing on the WSP adaptation of the National Highway Planning Network (NHPN)¹ for network attributes such as travel speeds.

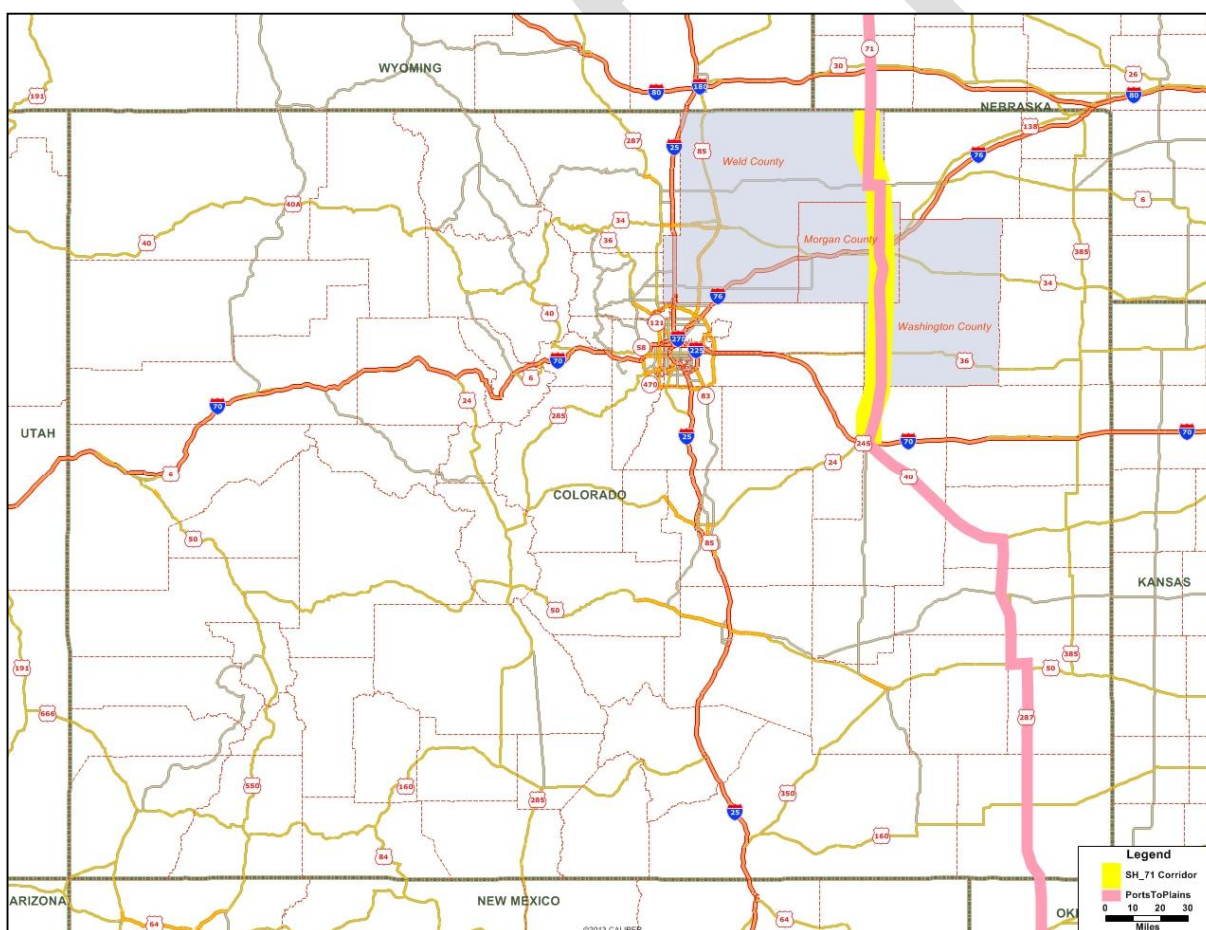
¹ National Highway Planning Network (NHPN) FHWA, <https://www.fhwa.dot.gov/planning/processes/tools/nhpn/>

- Multi-Unit Truck demand will be obtained from the FHWA's Freight Analysis Framework (FAF4.4) Commodity Flow Data² for trucks.
- A future year will be established and applied.

2. SH 71 Study Corridor

The limits of the study corridor are from SH 71 at MP 102 in Limon, CO to the Colorado/Nebraska state line at MP 232. The limits of analysis include US 24 from MP 304 in Colorado Springs to MP 377 in Limon and its connection to SH 71 via US 40. Modeling impact limits are much broader, and include the entire continental U.S. with an emphasis on Dumas, New Mexico to Scottsbluff, Nebraska and Douglas, Wyoming. The SH 71 study corridor is a component of the Ports-to-Plains³ Alliance highway corridor which extends from Mazatlán, Mexico to Alberta, Canada. Figure 2-1 shows the SH 71 corridor in yellow, the Ports-to-Plains alignment in pink and the interstate and state highways in the state. Four counties are important to the SH 71 project: Lincoln, Morgan, Washington and Weld.

Figure 2-1: Colorado Truck Diversion Influence Area



Source: SH 71 Study

² Freight Analysis Framework (FAF), http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/, accessed 2017.

³ Ports to Plains Alliance: A Corridor of National Significance, <http://portstoplains.com/index.php>, accessed October, 2017.

3. Observed Data Collection

One key task of the SH 71 effort was to gather sufficient observed truck data to populate the Multi-Unit Truck model. This work involved two distinct efforts: MUT truck observed counts and research into Super 2 highway speed and capacity assumptions. The observed truck information was used as targets to validate the model. The SH 71 extent was reviewed to establish a base speed for the approximately 130-mile extent. The SH 71 alternatives to be tested could then be adjusted to reflect the associated improved speeds. Multi-unit trucks conform to the category “combination” in the CDOT OTIS database.

3.1 Truck Traffic Counts

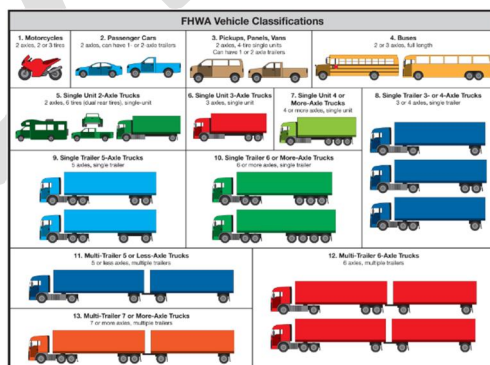
3.1.1 Truck Vehicle Definitions

Truck vehicle definition used for count collection generally follows the FHWA category definitions shown in Table 3-1 and Figure 3-1. Multi-unit trucks are the focus of the SH 71 work.

Table 3-1: FHWA Vehicle Classifications

CDOT Category	FHWA ID	Description
Passenger Vehicles	Class 1	Motorcycles
	Class 2	Passenger Cars
	Class 3	Other Two Axle, Four Tire Single Unit Vehicles
Single-Unit Trucks	Class 4	Buses
	Class 5	Two Axle, Six Tire, Single Unit Trucks
	Class 6	Three Axle Single Unit Trucks
	Class 7	Four or More Axle Single Unit Trucks
Multi-Unit Trucks	Class 8	Four or Fewer Axle Single Trailer Trucks
	Class 9	Five Axle Single Trailer Trucks
	Class 10	Six or More Axle Single Trailer Trucks
	Class 11	Five or fewer Axle Multi Trailer Trucks
	Class 12	Six Axle Multi Trailer Trucks
	Class 13	Seven or More Axle Multi Trailer Trucks

Source: FHWA: Office of Highway Policy Information, Travel Monitoring and Surveys Division
Figure 3-1: FHWA Vehicle Classifications



Source: FHWA: Office of Highway Policy Information
Travel Monitoring and Surveys Division

3.1.2 Count Sources

Truck traffic counts were collected from several sources and concentrated on 2018 average weekday Multi-Unit Trucks; AADT was collected as well to understand the percentage heavy truck on key roadways. The key type of source was online traffic count databases or plots. 270 MUT traffic counts were assembled from the DOT websites of four states: Colorado, Wyoming, Kansas, and Nebraska.

- Colorado Traffic Counts – Colorado traffic counts were obtained from the Colorado DOT OTIS <http://dtdapps.coloradodot.info/Otis/TrafficData> for year 2018. 160 locations were identified in the study area which includes the I-25, I-76, I-70, SH 71, US 385 and US 40 corridors in the state. These represent highways that feed into or compete with SH 71. OTIS reports on three vehicle categories, Average Annual Daily Traffic (AADT), Single Unit Trucks (SUT) and MUT Trucks, all of which were collected. Both short duration and continuous count locations were used for this study.
- Wyoming Traffic Counts – Wyoming traffic counts were obtained from the Wyoming DOT Interactive Transportation System Map found at <https://apps.wyoroad.info/itsm/map.html>. Four locations on I-80 and I-25 in Wyoming were identified and traffic data collected. I-80 is an interstate that draws traffic from I-25, I-76 and SH 71 in Colorado and must be included to understand Colorado truck movements. The Wyoming database reports on two vehicle categories, total AADT and truck AADT. For the purposes of this study, truck AADT is assumed to be combination or MUT truck as defined by the Colorado DOT. The truck counts were collected in exurban locations on I-80 and I-25 in Wyoming to maximize the likelihood that the trucks were MUT “over-the-road” vehicles.
- Nebraska Traffic Counts – Nebraska traffic counts were obtained from the Nebraska DOT website found at <http://dot.nebraska.gov/travel/map-library/> for the year 2018. A total of 26 locations in Nebraska were identified and traffic data collected. I-80 is an interstate that draws traffic from I-25, I-76, US-385 and SH 71 in Colorado and must be included to understand Colorado truck movements. The Nebraska database reports on two vehicle categories, Total Vehicles and Heavy Commercial Vehicles (HCV). For the purposes of this study, HCV is assumed to be combination or MUT truck as defined by the Colorado DOT. The truck counts were collected in exurban locations on I-80 in Nebraska to maximize the likelihood that the trucks were MUT “over-the-road” vehicles.

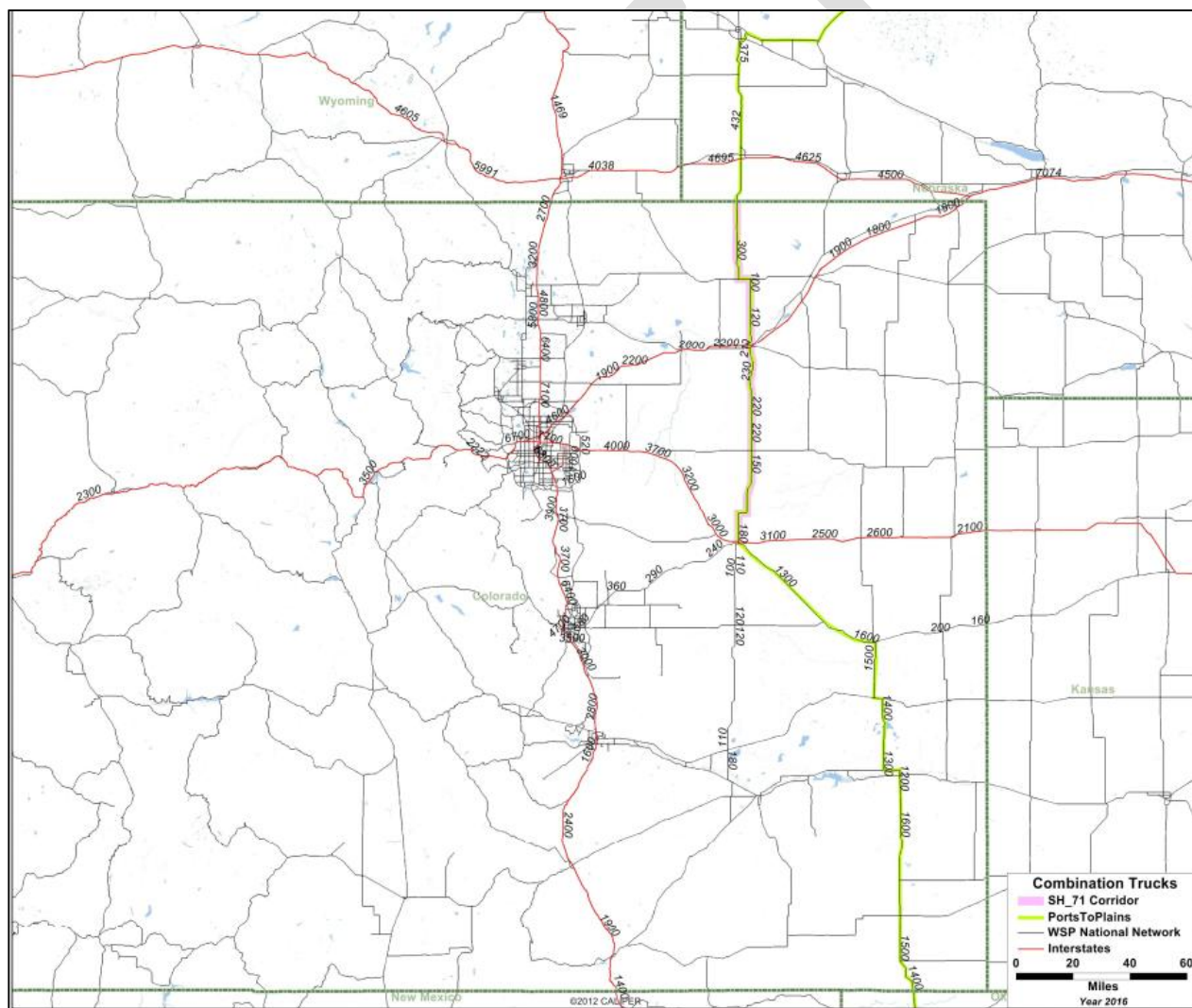
The traffic count values from all states were entered into a GIS shape file for viewing and analysis. This shape file is consistent with the WSP national highway network which means that the MUT truck counts can be used for analysis and validation of the SH 71 corridor. The mapping and model preparation approach was simple: take all the MUT truck counts relevant to SH 71 in three adjoining states and map them to allow a quick overview of truck flows. The following rules were followed:

1. All MUT truck flows are totals, i.e. the sum of the trucks in both directions, summed. Only Wyoming provides the truck flows by direction for review; their data was summed to one direction to be consistent with the other states.
2. The intent of the MUT data collection was to capture MUT trucks in exurban areas in keeping with the long-haul movement focus of the SH 71 study.

3. Toll facilities in the Colorado system, such as E-470, an eastern loop around Denver, are included in the OTIS database and thus truck data on them was collected as part of this effort.
4. The collection protocol was focused on roads that compete with or feed SH 71. As an example, I-25 through Denver carries many north-south through trucks. A small number of these trucks could divert to SH 71 if their trip were of a long duration and if SH 71 were made more attractive with speed or capacity improvements.
5. MUT truck counts were collected on the following roads had, either along the entire length of the road in Colorado, or of sufficient length to provide value to the SH 71 study: I-25, I-70, I-76, I-80, US 287, US 24, SH 71, and E-470.

The MUT count collection effort focused on the area from I-80 on the north to the New Mexico state line on the south and from I-70 just east of Grand Junction on the west to the Kansas state line on the east.

Figure 3-2: Colorado Multi-Unit Truck Counts 2018



Source: OTIS (Online Traffic Information), accessed 2018

3.1.3 Count Findings

The following are the findings from the MUT truck observed data collection.

Combination (or MUT) Truck Statistics

- Minimum: 100-150 MUT trucks is the minimum observed in this focused data collection. These counts generally occurred on SH 71 on segments carrying 500-800 AADT.
- Maximum: 12,000 MUT trucks is the maximum observed in this focused data collection. These counts occurred in Denver near the junctions of I-70 and I-25 on segments carrying 230,000 to 250,000 AADT.
- Highest Percentage Truck: The areas with highest percentage truck, calculated by dividing MUT truck counts by AADT are on I-80 in Nebraska where 60% observed truck percentage occurs. These instances are in the exurban segments of the interstate where 4,500 truck and 7,000 AADT segments can be found.
- Highest Percentage Truck in Colorado: The area with highest percentage truck, calculated by dividing MUT truck counts by AADT is on US 287 in southeast Colorado (Ports-to-Plains route) where 45%-50% observed truck percentage occurs. These instances are in the exurban segments of the highway where 1,400 truck and 3,000 AADT segments can be found.

SH 71

- Extent: The SH 71 study corridor is about 120 miles long, extending from the Colorado/Wyoming state line in Weld County south to the municipality of Limon, CO.
- MUT Truck Traffic: Observed MUT truck value ranges from 100-300 in 2018. At Limon on the south, I-70, US 287/40, US 24 and SH 71 converge. In Limon, it looks like heavy truck traffic to and from points southeast and northwest use US 287/40 (Ports-to-Plains) and I-70, both of which are diagonals, to connect Denver with points to the southeast. On the north end of SH 71 near the state line with Wyoming, truck traffic is moving to and from I-80, hitting SH 71's highest observed truck flow of about 300 MUT trucks.

Statewide Patterns

- I-25 Extent and Traffic: I-25 traverses Colorado north-south extending about 300 miles. Its maximum MUT truck observed value (12,000) is in Denver. Its lowest value is at the New Mexico state line on the south where the value is 1,400.
- I-25 Truck Traffic to/from I-80: I-80 is a big draw with over 4,000 daily MUT trucks on this facility. From Denver, I-25 is the best way to access I-80 if you are headed west. However, if you are headed east, I-76 which cuts diagonally from Denver to intersect I-80 in Nebraska, is the shortest route. Using SH 71 to access I-80 makes sense only if SH you are not delivering or picking up on the Front-Range.
- Ports-to-Plains: The Ports-to-Plains (US 287/40 US) route is very strong (1,300-1,600 MUT trucks) south of Limon. But north and west of Limon, I-70 seems to take over carrying the bulk of the trucks. North of Limon and well into Nebraska, SH 71 does not exceed 430 observed MUT trucks daily.

3.1.4 SH 71 Specific Truck and MUT Counts

The SH 71 also allowed for the collection of current year MUT counts, which included a multi-unit truck breakout. The team discussed collecting on the county roads that feed SH 71 but we determined that the low truck traffic level on these roads combined with the need for additional truck counts on SH 71 in areas not captured by CDOT counts pointed to a need to focus on and verify SH 71. Accordingly, counts were collected at:

- SH 71 MP 220 – between Stoneham and Nebraska state line.
- SH 71 MP 190 – between Stoneham and Brush.
- SH 71 MP 155 - Near Woodrow.
- SH 71 MP 125 – between Last Chance and Limon.
- SH 71 – just south of Limon.
- US 24 – southwest of Limon.

These counts were integrated with the CDOT OTIS counts for multi-unit truck. While there was small variation, the two count sources were consistent with each other.

This data collection and brief analysis has provided a first look at MUT truck flows in the SH 71 study area and beyond. The WSP national network was used to conduct several simple tests of modeled truck flows. Select link analysis is one means of identifying the counties where trucks begin and end their trips; a set of road segments on SH 71 and I-25 receive select link analysis in Section 5.

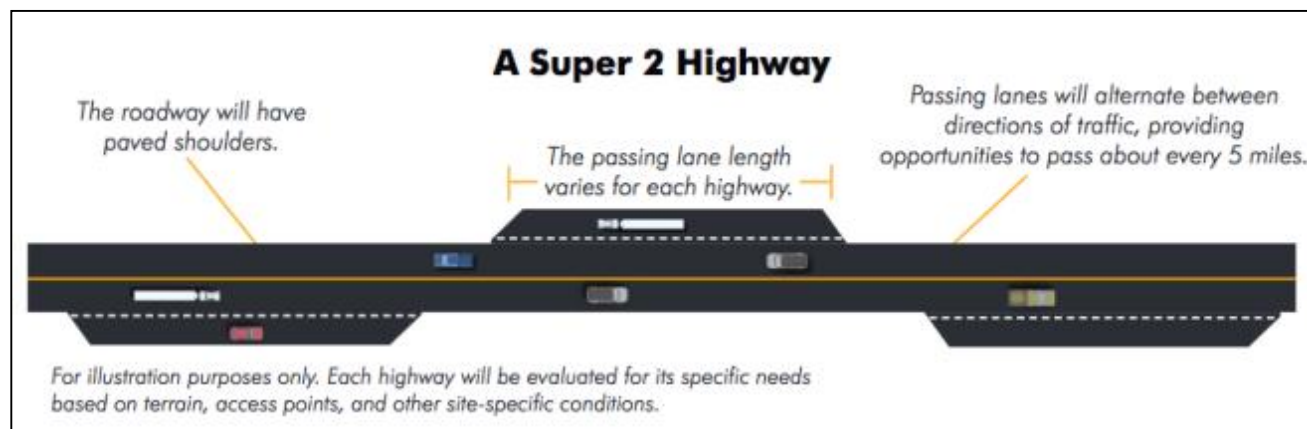
3.2 Speed Capacity Research for Super 2 Highways

The SH 71 work also involved research into Super 2 highway speed and capacity assumptions. There is no universal definition of a highway known as a Super 2. A super two, super two-lane highway or wide two-lane in the United States is a two-lane surface road built to highway standards, typically including partial control of access, occasional passing lanes and hard shoulders. A diagram is shown in Figure 3-3. It is often built for eventual conversion to freeway or divided highway status once traffic volumes rise. It has also been used in cases where environmental concerns are prevalent, such as where Interstate 93 becomes a Super 2 in Franconia Notch, New Hampshire. The Texas DOT, TxDOT, has a provision for Super 2 design that uses occasional passing lanes in each direction and allows at-grade intersections. Other interstates, such as I-95 in Maine near the Canadian border, I-70 through eastern Utah, and I-15 through northern Idaho and southern Montana, were once two-lane expressways but have since been converted to 4-lane.

The Ports-to-Plains project as well as the Nebraska Department of Transportation, NDOT, define Super 2 as a two-lane roadway with wider paved shoulders and additional passing lanes every five miles or so⁴. Super 2 roadways improve safety where truck traffic exists and is growing. The NDOT is considering “Super 2” highways to stretch Nebraska’s highway dollars; their engineers have said the design could increase traffic flow at less than half the price of a new four-lane highway: about \$1.5 million per mile instead of \$4 million per mile.

⁴ “Super 2 Highways Considered for Stretching Road Budgets, Omaha World Herald, September 2016, <https://heartlandexpressway.com/2016/05/30/super-2-highways-considered-for-stretching-road-budgets/>.

Figure 3-3: Diagram of a Super 2



Source: Rapid City Journal, accessed 2018

Super 2 highways can be assumed to operate at a higher average speed over a segment longer than 10-15 miles, given the 5-mile frequency of the standard Super 2 passing lane inserts. Sensitivity tests were run on the SH 71 extent to test the truck diversion given increased speed limits.

4. Model Components

4.1 Model Assumptions

The SH 71 study was launched with a specific goal in mind: to estimate truck use in 2040 from growth as well as diversion to SH 71. Thus, the following assumptions and decisions are made:

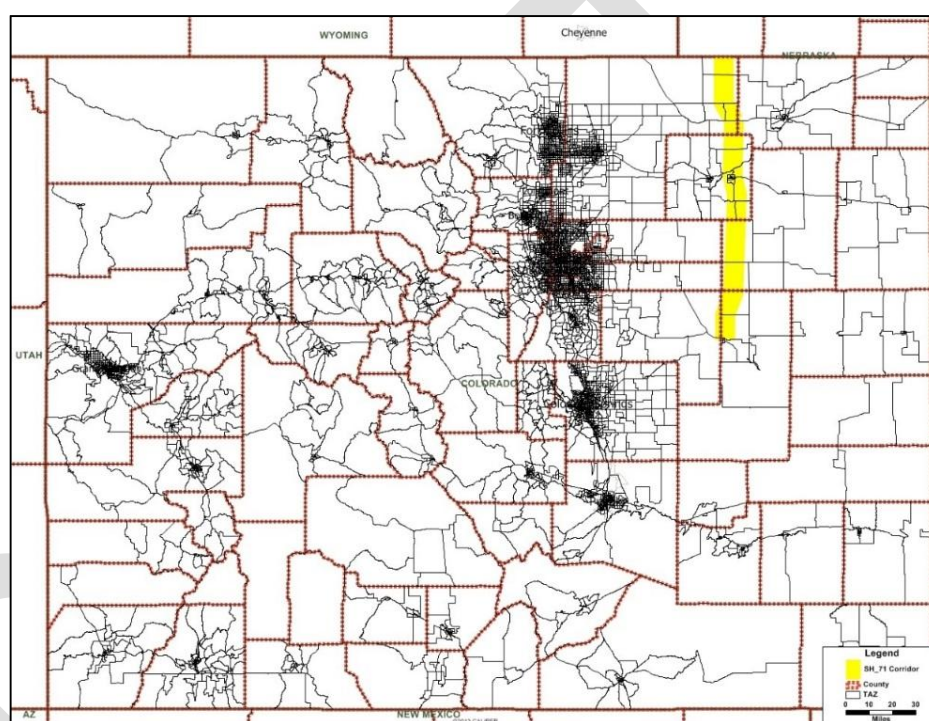
- Multi-Unit Trucks (MUTs) alone are modeled.
- 2018 was selected for the base year truck model and validated to recent MUT counts:
 - Over 130 CDOT counts
 - 10-15 Wyoming and Nebraska I-80 counts
 - Custom counts in the SH 71 study corridor
- CDOT's Colorado Statewide Model zone system and network was adapted. The base year CDOT statewide model network was used throughout.
- A daily (24-hour) model was built; no highway tolling is used.
- Segment geography was established for reporting purposes.
- SH 71 is the focus with I-25 also tabulated to capture diversion effects.
- Shortest path using time is used for the truck assignment. The starting point for time was the attribute for speed from the National Highway Planning Network (NHPN), expanded into Colorado.
- Demand tables extracted from the most recent Freight Analysis Framework (V4.3) truck commodity flow data converted into national truck flows.

4.2 Zone System

4.2.1 In Colorado

The SH 71 project has the benefit of a statewide traffic analysis zone (TAZ) system provided by the Colorado DOT as part of the Colorado statewide travel model⁵. The original CDOT zone system consisted of 6,440 zones with very fine detail in the MPO areas of the state as well as sufficient detail in the non-MPO, small municipality and rural parts of the state to serve the SH 71 work. Note the SH 71 corridor with sub-county detail zones addressing Brush, Fort Morgan and Limon. Twenty-one zones were added in the SH 71 corridor area to enhance connectivity yielding a final Colorado zone total of 6,461. CDOT also provided zone level attributes on population and employment in the Colorado zones.

Figure 4-1: SH 71 Zone System (Colorado View)



Source: Colorado DOT Statewide Model file, 2017

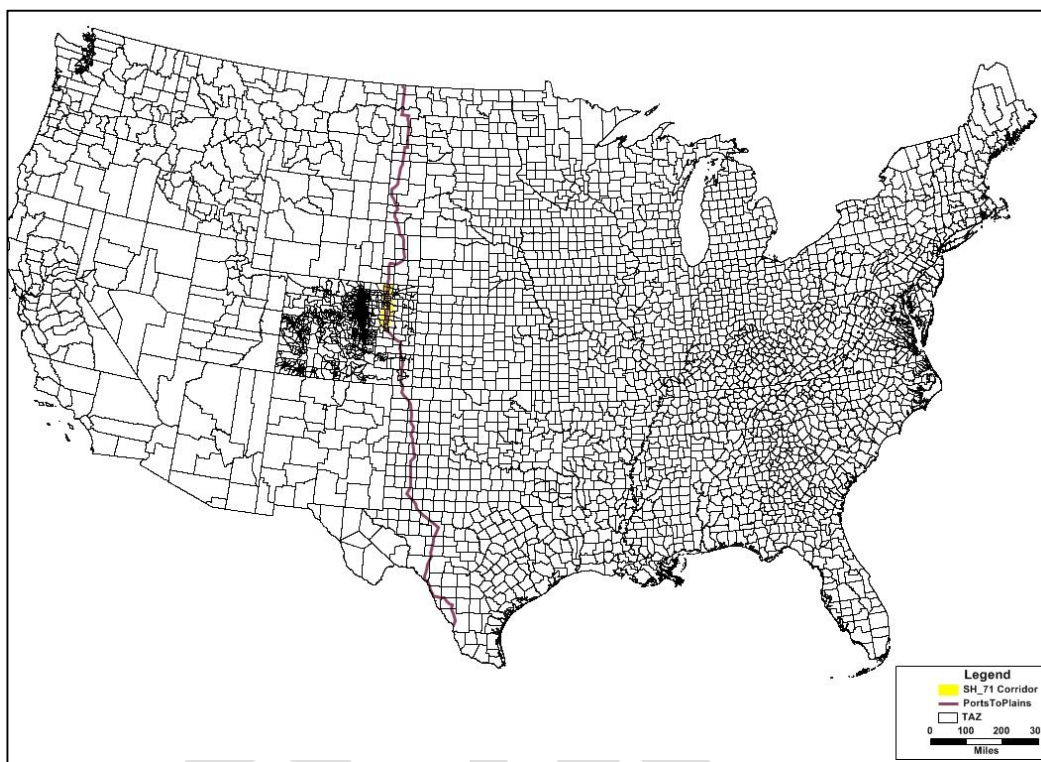
4.2.2 National Zones

WSP maintains a national zone system in the form of standard county level GIS polygons. These are used for high level commodity and truck flow analysis. They can also be combined with a detailed zone system such as the one held by CDOT and applied to corridor studies such as the SH 71 work. Figure 4-2 shows the entire national and Colorado specific zone system assembled for SH 71. Note the presence of the Ports-to-Plains alignment of which SH 71 forms a segment. Table 4-1 provides a summary of the zone system coverage, geography, total zones and centroid identification number. The two zone sets were joined to

⁵ PowerPoint Presentation, Colorado DOT, "Statewide Travel Model: What can it do to Enhance Planning", <https://www.codot.gov/programs/planning/documents/stac-archives/2016-stac/may2016stac/statewide-travel-model-stac-may2016>

form a customized SH 71 national zone system capable of estimating truck traffic to, from and through the SH 71 corridor.

Figure 4-2: SH 71 Zone System (National View)



Source: SH 71 Study: (FAF national zones + CDOT Statewide Model Colorado zones)

Table 4-1: Summary of SH 71 Zone System

State	Geography	# of Zones	Centroid ID
Colorado	CDOT Statewide Model	6461	60001 - 66461
All Other States	County	3055	1001 - 56045
All		9516	

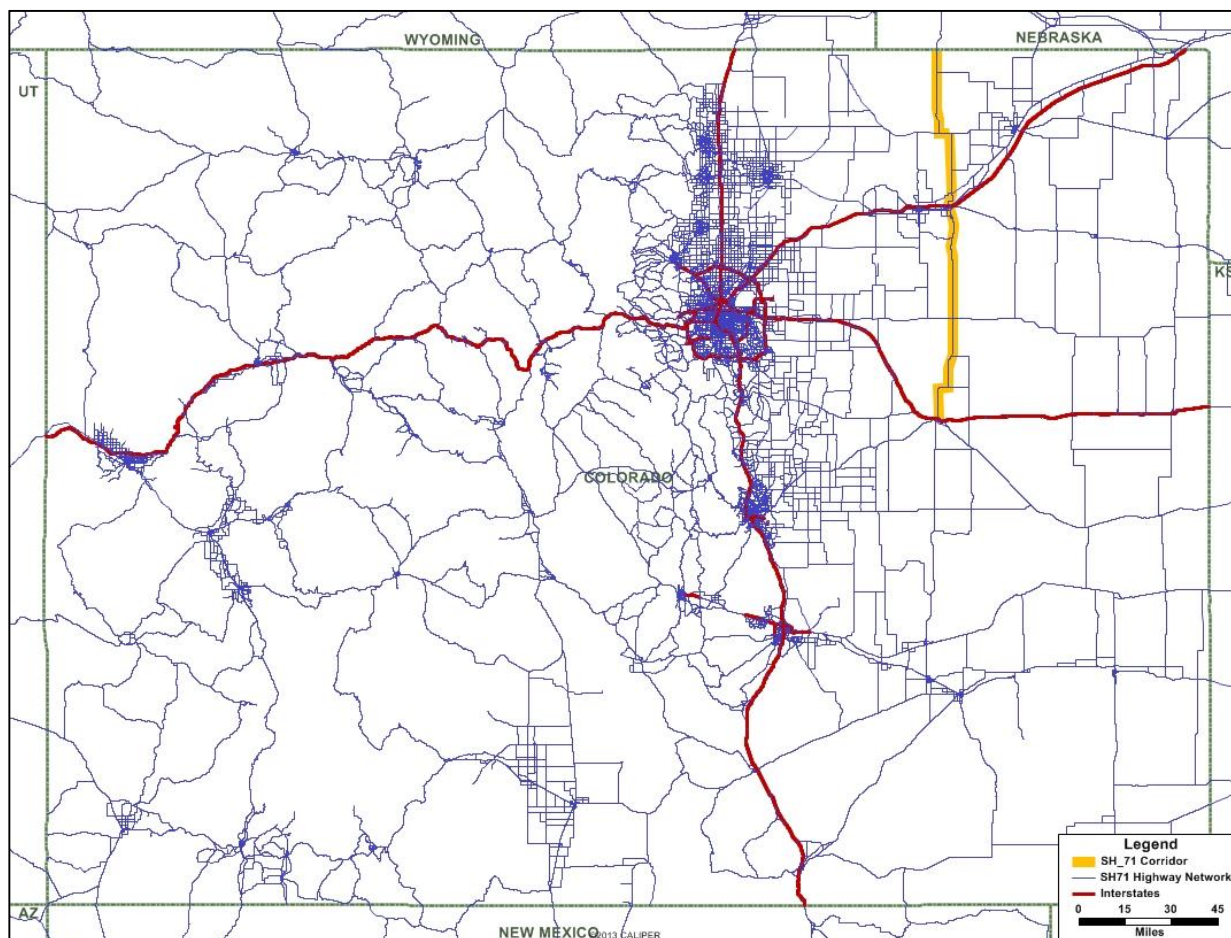
Source: SH 71 Study

4.3 Highway Network

4.3.1 Colorado Highway Network

In a similar fashion to the hybrid TAZ layer, the SH 71 project has the benefit of a statewide highway network provided by the Colorado DOT as part of the in-progress Colorado statewide travel model. The Colorado DOT network contains over 6,000 road segments covering the state and includes the functional classes of interstate, expressway, principal arterial, minor arterial, major collector and ramp. Centroid connector links are also included to make the network assignable. The Colorado network is shown in Figure 4-3.

Figure 4-3: SH 71 Highway Network (Colorado View)

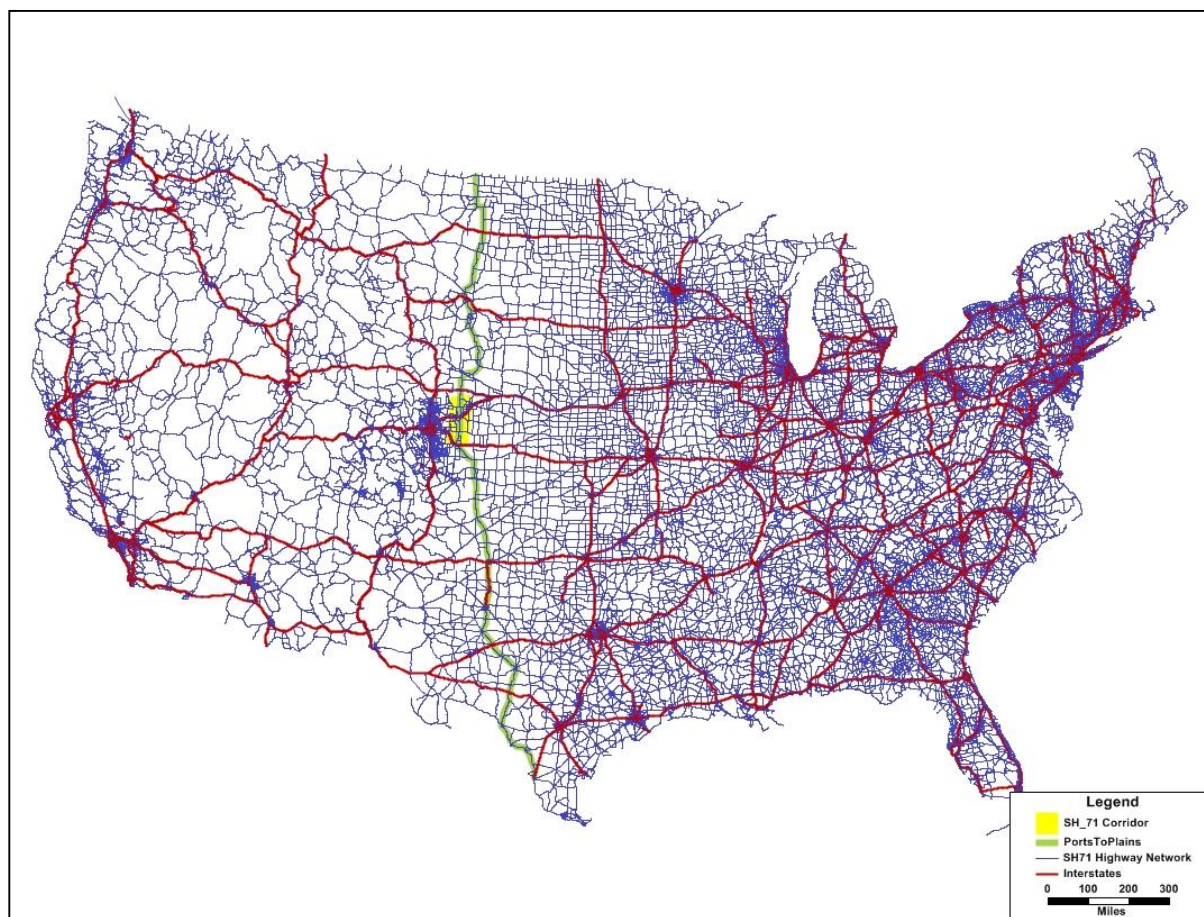


Source: Colorado DOT Statewide Model file, 2017

4.3.2 National Highway Network

WSP maintains a national highway network developed from the National Highway System Version 2016.09 and contains state primary and secondary roads, National Highway System (NHS), National Network (NN) and several intermodal connectors as appropriate for the freight network modeling. The network consists of over 440,000 miles of equivalent road mileage. The data set covers the 48 contiguous states plus the District of Columbia, Alaska, and Hawaii. Figure 4-4 shows this national network. Note the presence of the Ports-to-Plains alignment of which SH 71 forms a segment.

Figure 4-4: SH 71 Highway Network (National View)



Source: SH 71 Study: (NHPN national network + CDOT Statewide Model Colorado network)

Like the TAZ join process, the network process spliced the Colorado and national networks to form a highway network customized to the SH 71 work. Table 4-2 provides a summary of the highway network coverage, source, and total link records. The two networks were joined to form a customized SH 71 national highway network sufficient to capture trucks on SH 71 as well as any truck diversion from I-25 to SH 71. The national coverage allows long-distance truck movements to be captured as well.

Table 4-2: Summary of SH 71 Zone System

State	Source	# of Network Link Segments
Colorado	CDOT STM	51,433
All Other States	WSP Library (NPHN)	664,020
All		715,453

Source: SH 71 Study

4.4 Travel Times and Model Approach

The SH 71 model requires that over-the-road truck travel of both short and long distances can be captured using a zone system and network with the scale and geographic coverage to get the job done. A facility such as SH 71 can serve 500+ mile hauls if it offers a shorter path to operators. The desired truck model must feature sufficient sensitivity to reflect SH 71 as well as I-25 congestion and stay within the project resources. To this end, several tests were run to establish a level playing field for establishing a reliable national truck model capturing flows north-south through Colorado. The goal was to capture an average “time to traverse” the I-25 and the SH 71 corridors including both short truck trips within Colorado as well as long distance trips that start well away from the SH 71 corridor and may travel through Colorado to complete their trips.

- **Time of Day Speeds:** Use of CDOT’s statewide model highway network was explored. This highway network is statewide and is composed of the various MPO model networks in the state plus non-urban areas. It contains time by time period. In the Denver area, the statewide network carries the link level attributes from the DRCOG model. Among these time periods, a.m. and p.m. peak hour speeds are available. These speeds, used regionally, reflect the longer times it takes to cross the Denver region on I-25 during a peak period such as the time between 7:00 am and 8:00 am. The North Front Range MPO and the Pikes Peak Area Council of Governments also contributed their travel model peak and off peak speeds. At the national level, however, no congested speeds are available to the SH 71 truck model. Sensitivity model runs demonstrated that showing congestion in the Front Range alone, and nowhere else in the U.S., perturbed the truck flows creating an altered truck assignment in Colorado.
- **Average Daily Speeds:** The establishment of a daily assignment and an average daily speed was explored. This approach took the posted speed assumptions from the National Highway Planning Network and applied them to the Colorado statewide network using a shared functional highway class. The speeds assumed in the NHPN were adapted across Colorado. This approach was consistent with a daily national truck assignment and the needs of the SH 71 study. Table 4-3 shows the link segment functional class and assumed speed. These speeds are also consistent with the Ports-to-Plains expected speeds⁶ as reviewed by that group at the start of the SH 71 study. This approach was chosen for the SH 71 truck model.

Table 4-3: SH 71 Link Segments Functional Class & Speed

MASTER_CLASS	DESCRIPTION	SPEED RANGE (MPH)	AVERAGE SPEED
1	Interstate	55-80	64.8
2	Expressway	55-65	59.2
3	Principal Arterial	35-65	47.1
4	Minor Arterial	30-55	45.2
5	Major Collector	25-55	42.5
6	Ramp	25	25.0
8	Centroid Connector	35	35.0

Source: SH 71 Study

⁶ Email and spreadsheet “Speeds_P2P_jkredits.XLS”, Joe Kiely, Ports-to-Plains Alliance, November 2017.

4.5 Reporting Segments

To facilitate reporting of truck model results, a reporting protocol was established. The highway segments that formed SH 71 were divided into three logical segments:

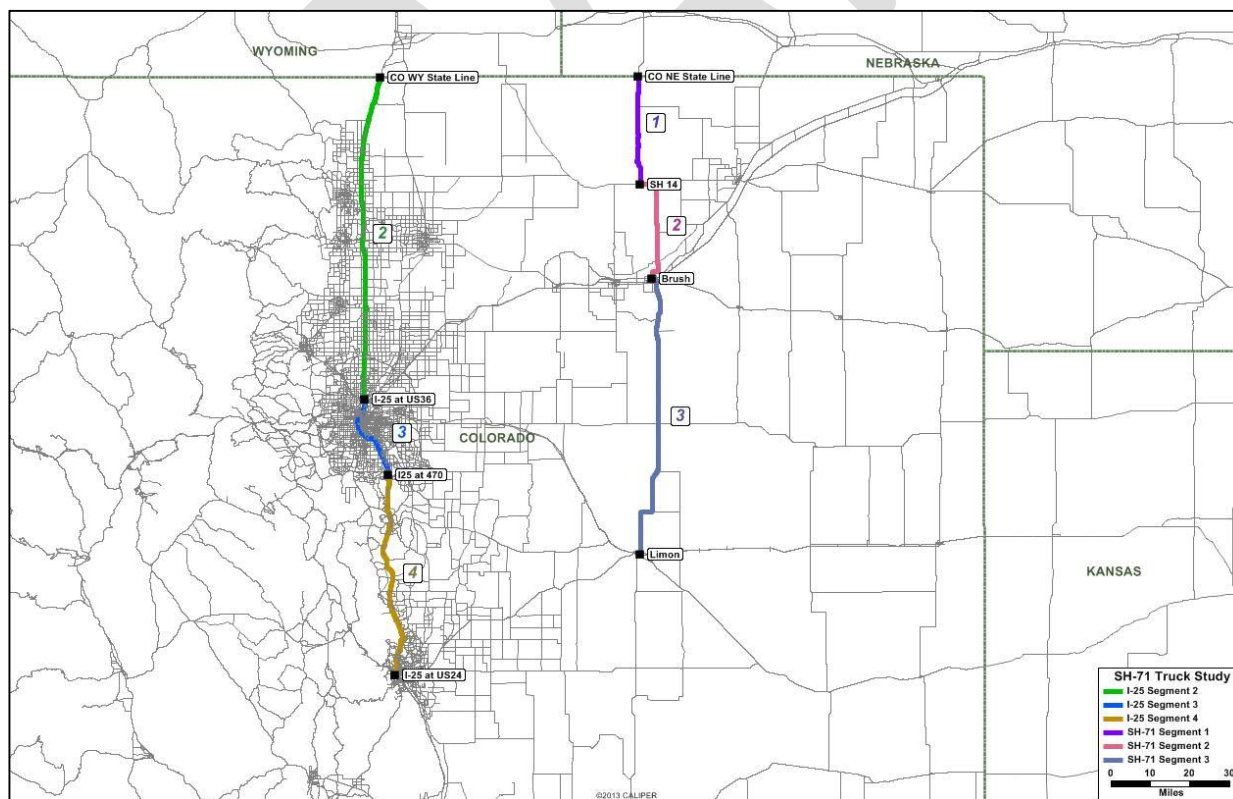
- SH 71: Segment 1 – Nebraska State Line to SH 14 in Colorado
- SH 71: Segment 2 – SH 14 to Brush, CO
- SH 71: Segment 3 – Brush to Limon, CO.

The highway segments that formed I-25 in the extended study area were divided into three logical segments:

- I-25: Segment 2 – Wyoming State Line to US 36
- I-25: Segment 3 – US 36 to E-470 (South)
- I-25: Segment 4 – E-470 (South) to US24 in Colorado Springs.

These segments are shown in Figure 4-5. The segment dividing points are consistent with intersection with major roadways, and street density. The establishment of the study segments allows the calculation of a centerline road length, drive time in minutes, and average speed to traverse. The speeds and the multi-unit truck results were weighted by the length of the highway segment. The segments also serve up the changes in the travel model in palatable format for the reviewer. Truck volumes and speeds/time tabulation allow calculation of truck VMT and VHT, facilitating comparison.

Figure 4-5: SH 71 Reporting Segments



Source: SH 71 Study

Table 4-4 shows a snapshot of the standard report for the SH 71 MUT model. Once the future base was assembled and run, the alternatives could readily be processed and compared to it using this standard report.

Table 4-4: Standard Report for SH 71 Multi-Unit Trucks (2018 Base)

SH-71 MULTI-UNIT TRUCK (MUT) REPORT									
HIGHWAY	SECTION ID	SECTION DESCRIPTION		CENTERLINE MILES	TOTAL SEGMENT DRIVE TIME (MINUTES)	AVERAGE DAILY MUT SPEED	AVERAGE DAILY MUT TRAFFIC 2018 (sum of two directions)*	MUT VMT	MUT VHT
SH-71		FROM	TO						
SH-71	1	CO-NE State Line	SH 14	27	25	65.0	239	6,539	101
SH-71	2	SH 14	Brush CO	29	27	64.8	188	5,490	85
SH-71	3	Brush CO	Limon CO	74	69	64.9	205	15,252	236
TOTAL SH-71				131	121	64.8	208	27,281	421
HIGHWAY	SECTION ID	SECTION DESCRIPTION		CENTERLINE MILES	TOTAL SEGMENT DRIVE TIME (MINUTES)	AVERAGE DAILY MUT SPEED	AVERAGE DAILY MUT TRAFFIC 2018 (sum of two directions)*	MUT VMT	MUT VHT
I-25		FROM	TO						
I-25	1	CO-WY State Line	I-25 at US 36	82	72	68.3	2,755	452,080	6,632
I-25	2	I-25 at US 36	I-25 at 470 (S)	23	21	65.0	3,778	170,630	2,625
I-25	3	I-25 at 470 (S)	I-25 at US 24	52	46	67.9	2,205	229,602	3,384
TOTAL I-25				157	139	67.6	2,720	852,312	12,640
*Weighted by Highway Segment Length Report									
	2018	ALT	Diff	% Diff	2018 BASE YEAR TRAFFIC FORECAST (MULTI-UNIT TRUCKS)				
SH-71									
Truck VMT	27,281	-	(27,281)	-100%					
Truck VHT	421	-	(421)	-100%					
I-25									
Truck VMT	852,312	-	(852,312)	-100%					
Truck VHT	12,640	-	(12,640)	-100%					

Source: SH 71 Study

Table 4-4 is designed to present MUT model results for the SH 71 study corridor. The SH 71 and I-25 segments presented in Figure 4-5 are used to organize the table. The three segments of SH 71 are presented (in grey color) at the top of the table with the section ID and section description provided for each. The three segments of I-25 are presented (in blue color) at the middle of the table with the section ID and section description provided for each. Centerline miles are included for each segment and facility. The model result columns are presented in the next five columns of the table.

- Total Segment Drive Time (Minutes) - the total segment drive time is the sum of all link segments times in both directions on an average day for the specific segment being tabulated.
- Average Daily MUT Speed - the average daily MUT speed is the weighted average of all link segments speed in both directions on an average day for the specific segment being tabulated.
- Average Daily MUT Traffic - the average daily MUT traffic is the weighted average of all link segments speed on an average day for the specific segment being tabulated.
 - For SH 71 the traffic is a two-way value.
 - For I-25, because the facility is coded as a dual carriageway, the MUT traffic is a one-way value. The OTIS MUT value was obtained, then divided in two and loaded on "matching" sides of a segment of I-25. Some typical daily values on I-25 lie in the 6,000-7,000 range for daily two-way MUTs in 2018. Thus, the 2,667 average on I-25 for 2018 represents a cut-point with 5,334 daily MUTs.

- MUT VMT - MUT Vehicle Miles Traveled are calculated by multiplying the MUTs times the length in miles of the segment.
- MUT VHT - MUT Vehicle Hours Traveled are calculated by multiplying the MUTs times the total time to traverse the segment in hours.

A summary report box at the bottom left of the standard report called “Report” shows a top summary of the model run and allows comparisons of the 2018 and 2040 results as well as the 2040 alternatives to the 2040 base.

4.6 Multi-Unit Truck Demand Tables

The demand tables for the SH 71 truck model were established using FHWA’s Freight Analysis Framework (FAF4.4) Commodity Flow Data⁷. The Freight Analysis Framework (FAF) was the only open source data available for analyzing truck freight flows at a national level for a base and future year. FAF Version 4.4 was used for this work. The steps in data processing to obtain the Multi-Unit Truck demand tables are as follows:

1. The FAF 4.4 data for 2018 was downloaded and prepared for processing. Truck commodity flows for FAF districts (132 across the U.S.) were disaggregated into 3,123 by 3,123 county-to-county matrix flows. Additional information on this disaggregation process can be found in WSP documentation⁸.
2. Each commodity was then converted into Multi-Unit Trucks using a payload factor keyed to the type of commodity being transported.
3. The trucks by commodity were then summed producing a county-to-county truck demand table.
4. The FAF 4.4 truck commodity flow was then processed for the year 2040 to obtain future year truck demand tables.
5. For both the 2018 and 2040 truck demand tables, a second disaggregation step was performed to take the county-to-county truck table to the more finely-grained Colorado statewide TAZ geography shown in Figure 4-1. This final step enhanced the fidelity of the results by including small TAZs and matching highway network in the SH 71 corridor. The disaggregation attribute used was total employment.
6. The truck trip table was then assigned using the SH 71 national network shown in Figure 4-4. The results were compared to the observed Colorado data for MUTs collected as part of the study. The focus area was the SH 71 and I-25 corridor from the state line north to US 24 on the south.
7. Adjustment in the form of an origin-destination matrix adjustment was made to the base year MUT table to fit it to observed conditions. The row and column totals were prepared for both 2018 and 2040 demand tables and their difference used to “grow” the 2040 in a fratar balancing step.

4.7 Assignment Approach

Section 4.4 presented the network development that was conducted knowing what type of truck traffic assignment approach would be consistent with project needs and resources. The selected assignment approach features:

⁷ Freight Analysis Framework (FAF), http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/, accessed 2017.

⁸ WSP FAF44 Disaggregation_Methodology_2016_final.DOC, WSP, 2016.

- All-or-Nothing (AON) daily truck assignment based on posted speeds converted to travel times throughout the entire continental U.S. This approach attempts to replicate decision making of over-the-road truck operators who choose a shortest path for their journey. Stopping places for driver meals and overnights are not captured in this model effort.
- Assumption that capacity of the roadway is not directly included as an input to assignment. When lanes are added to SH 71 for model testing, an asserted speed increase is used to reflect the altered ease of using this road. The assumption is that the extra driving or passing lane will allow faster speeds.

5. Validation & Select Link Analysis

5.1 Multi-Unit Truck Traffic

In the development stages of the SH 71, it was determined that the origin-destination matrix estimation would serve the SH 71 project most efficiently for demand table development. There are several reasons for this approach. The development of an entire national truck model is not within the scope or intent of the SH 71 truck estimation. A statewide model application would have been a valuable tool to apply if it were available. At the time of this study, the Colorado statewide model was under development; CDOT could provide a finely grained zone system and highway network as building blocks for the SH 71 project. These input elements saved valuable resources which benefitted the SH 71 project. Initial investigative model runs showed that national FAF-to-truck demand tables yielded a useful starting point demand table. O-D estimation, using the MUT count locations shown in Figure 3-2, delivers very close fits to observed data.

The first test of highway validation was conducted using the category of functional class. There are three functional classifications analyzed: Interstates, US Highways and State Highways. Table 5-1 shows the validation results for these three classes plus the total. Overall, the daily assigned volume was -3% different from the observed value. All categories tabulated show a difference of between -2 and -3% from the observed MUT volumes. This overall MUT results are consistent with matrix estimation approach.

Table 5-1: Multi-Unit Truck Validation by Functional Class in Colorado

Link Type	Class	# of Obs.	Counted Volume	Model Volume	Absolute Difference	Percent Difference
Interstate	1	154	338,742	328,441	-10,301	-3%
US Highway	2	120	29,864	28,919	-945	-3%
State Highway	3	66	5,190	5,074	-116	-2%
Total		340	373,796	362,434	-11,362	-3%

Source: SH 71 Study

Table 5-2 reports on the two facilities of interest: SH 71 and I-25. There are 18 observations on SH 71 and 54 on I-25. SH 71 shows a fit of observed to modeled MUT traffic of -4%. I-25 shows a fit of observed to modeled MUT traffic of -2%.

Table 5-2: Multi-Unit Truck Validation by Major Facility

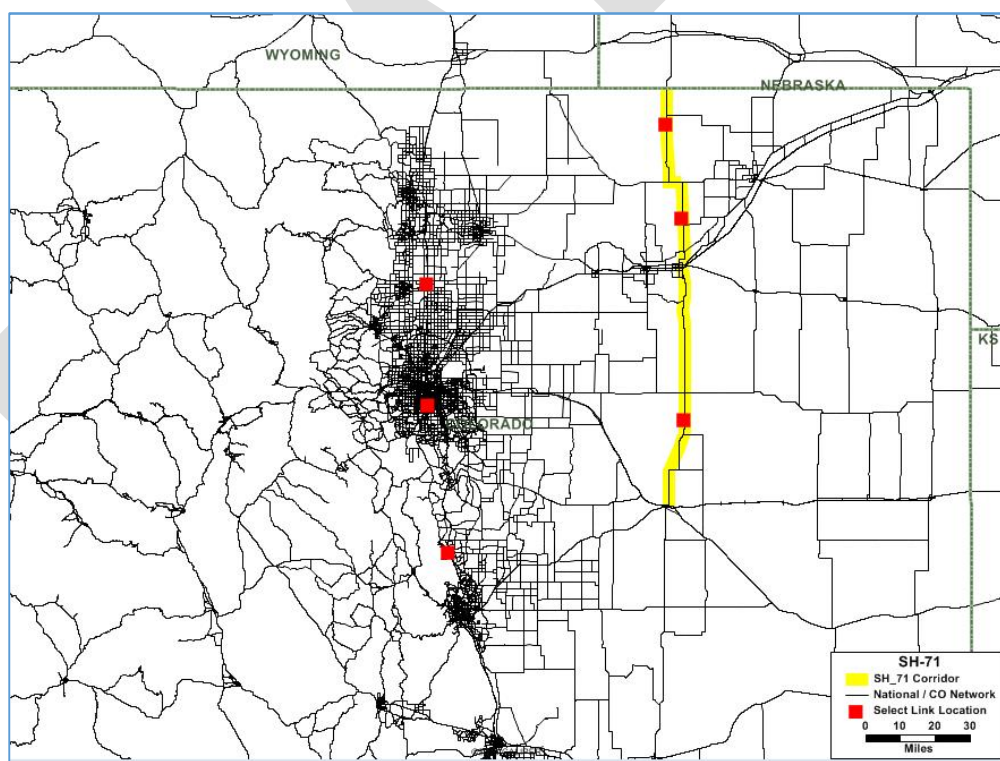
Roadway	Class	# of Obs.	Counted Volume	Model Volume	Absolute Difference	Percent Difference
SH 71	3	18	2,610	2,509	-101	-4%
I-25	1	54	169,800	166,984	-2,816	-2%

Source: SH 71 Study

5.2 Select Link Analysis

Select link analysis was conducted to better understand the patterns of the truck markets active in the SH 71 corridor. Select link analysis provides information of where traffic comes from and goes when it is using certain segments of the road system. Links are bi-directional road segments usually located at typical cross sections of the study corridor. The resulting graphics show the coverage, magnitude and influence of a road segment. Multiple select link points can be established; the result is a sum of the flows, i.e. if trucks traverse point A or point B or point C, or any combination of these points, the truck trip is included. No trucks are counted more than once. Three representative highway locations were identified on both SH 71 and I-25 as shown in Figure 5-1. 2040 MUT traffic was analyzed with select link settings with resulting flows screened for display to exclude very small flows (less than one MUT daily in 2040).

Figure 5-1: SH 71 Study Select Link Locations



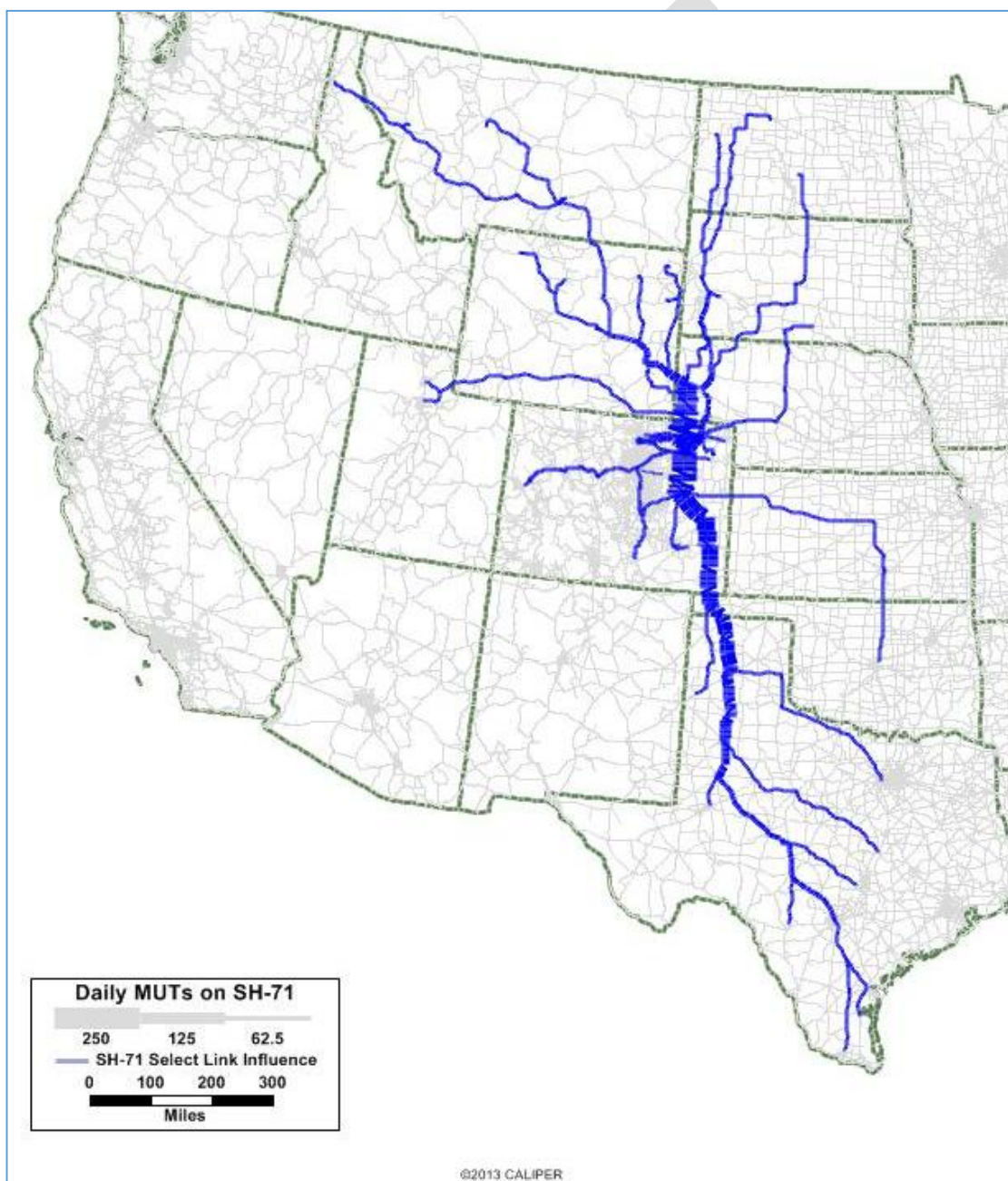
Source: SH 71 Study

SH 71 MUT Select Link

Select link MUT traffic for SH 71 is shown in Figure 5-2. The same information with the interstate system superimposed is shown in Figure 5-3. These graphics show:

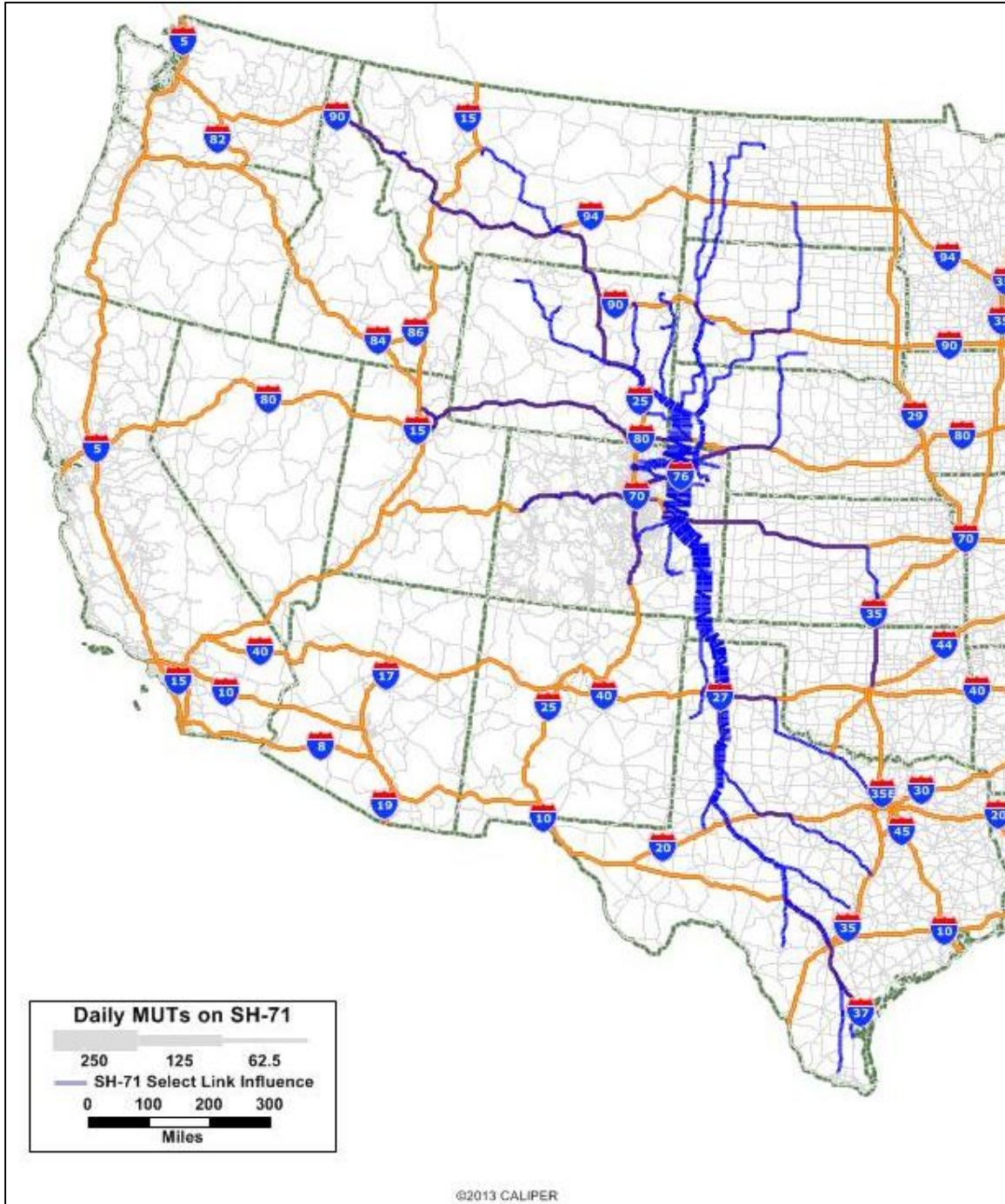
- The truck traffic has a north-south orientation.
- Scale tops out at 250 daily MUTs.
- The truck flows generally access interstates such as I-27 in Texas while using all classes of roadways.
- Strong profile to and from Texas / Ports-to-Plains corridor.

Figure 5-2: SH 71 MUT Select Link Traffic



Source: SH 71 Study

Figure 5-3: SH 71 MUT Select Link Traffic with the Interstate System



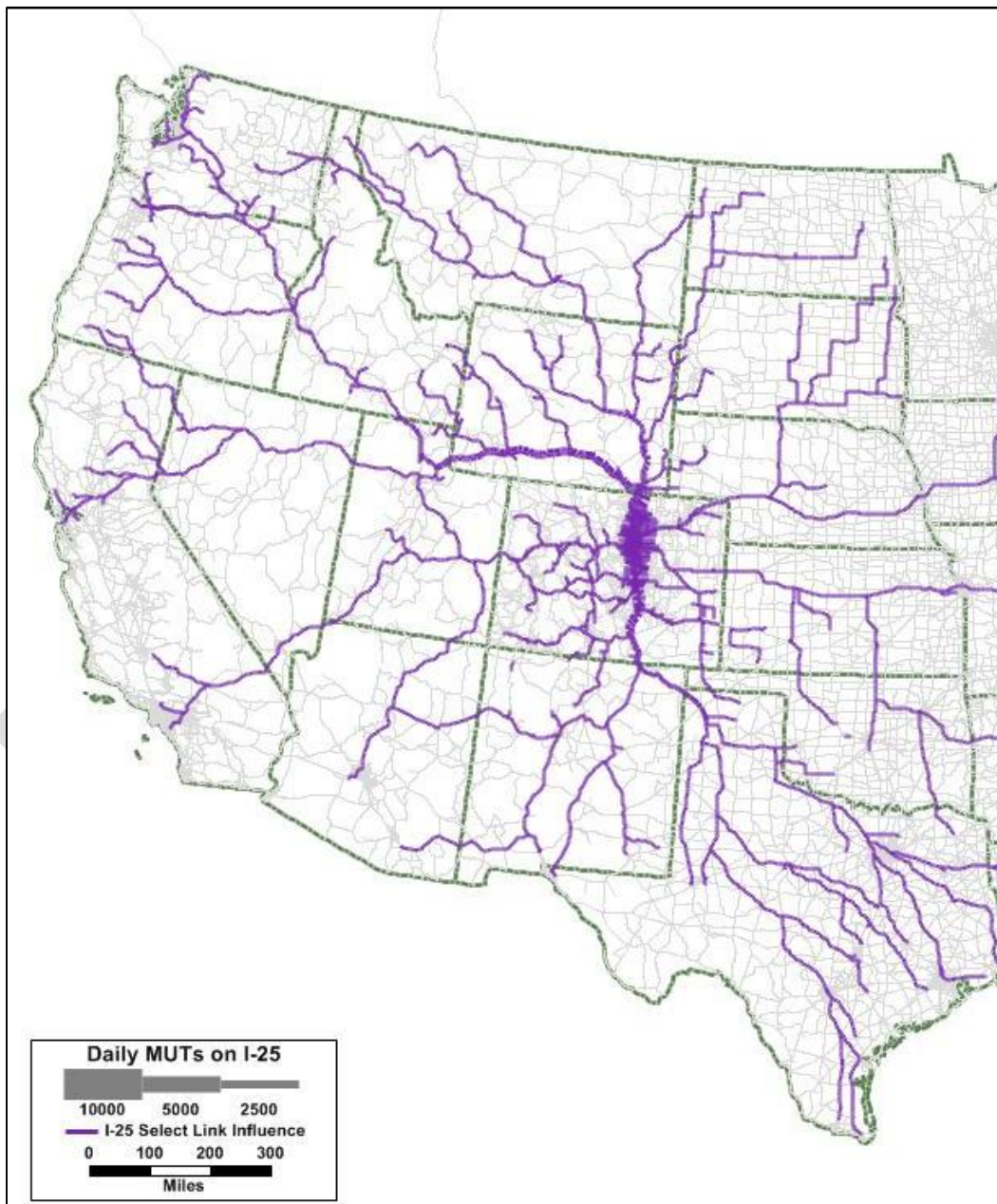
Source: SH 71 Study

I-25 MUT Select Link

Select link MUT traffic for I-25 is shown in Figure 5-4. The same information with the interstate system superimposed is shown in Figure 5-5. These graphics show:

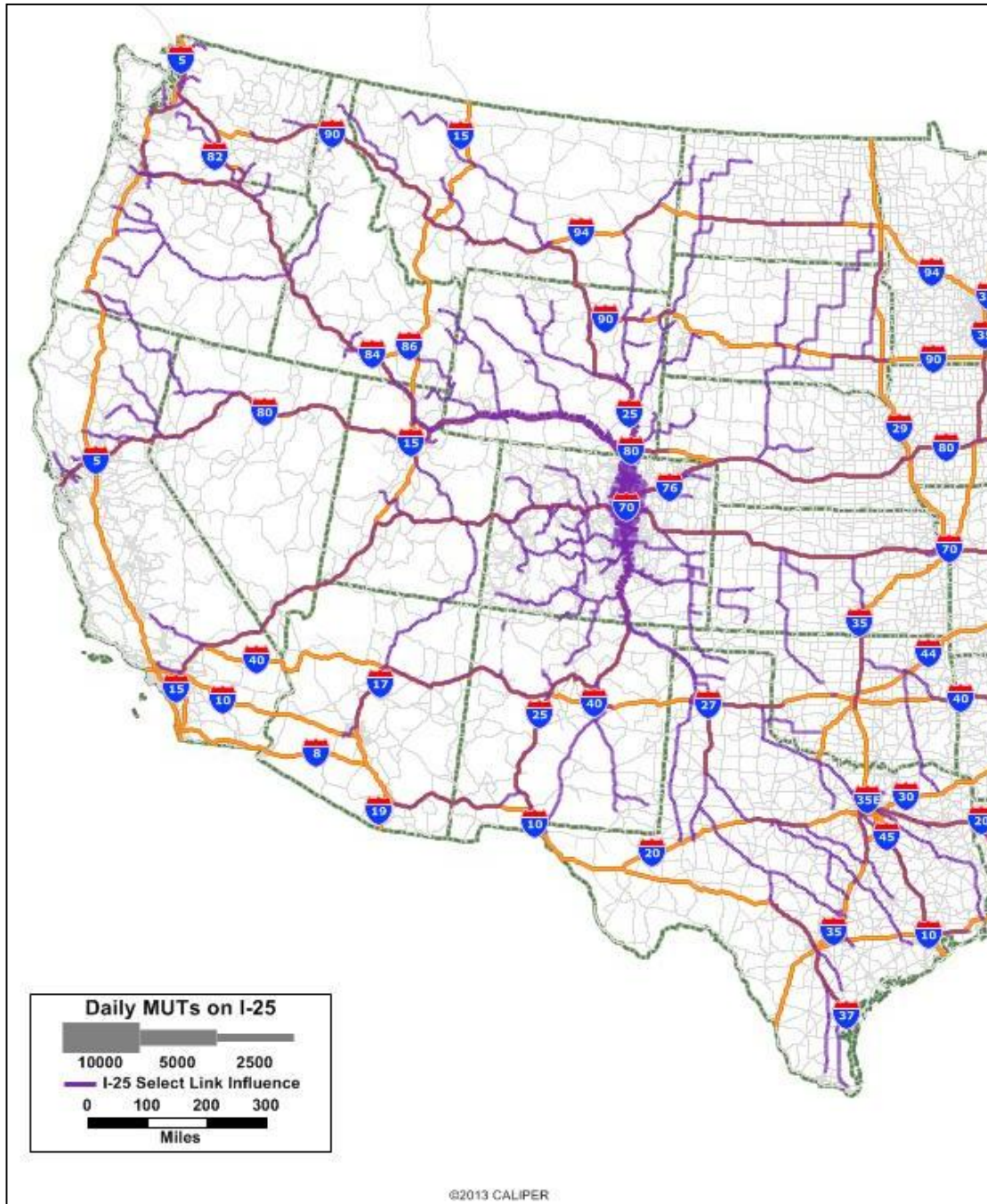
- Universal orientation with strong showing on I-80 (Wyoming) west of I-25.
- Generally using interstates.
- Strong profile to and from the west coast.

Figure 5-4: I-25 MUT Select Link Traffic



Source: SH 71 Study

Figure 5-5: I-25 MUT Select Link Traffic with the Interstate System



Source: SH 71 Study

6. Summary

In closing, the SH 71 Multi-Unit Truck Traffic Model was designed as a “sketch” level approach to estimate future daily MUT traffic on the roadway under differing speed and I-25 congestion scenarios. The components such as zones and highway network were selected to provide focus on the SH 71 corridor. The model approach leveraged available datasets from CDOT, FHWA, as well as SH 71 special traffic counts. Front Range area congestion in 2040 was included by assuming an asserted blanket 90-93% regional speed reduction in keeping with the study resources. A future year was established and applied. The resulting MUT traffic on SH 71 for the base and future year are consistent with a model useful for MUT alternative testing on SH 71.

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