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Strategies for Managing Freight Traffic through Urban Areas: Technical Report

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Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE

COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
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16. Abstract

Economic activity in most cities relies heavily on the movement of goods via freight vehicles. The freight transportation system has a direct impact on the livelihood and success of urban areas; however, the presence of trucks on the freeway system further increases congestion as the trucks interact with passenger vehicles. Trucks take up a large portion of roadway space, and the places that rely on freight the most are typically those where there is a high concentration of people and activities. As a result, traffic congestion increases while the safety of the roadway diminishes.

This project examined multiple freight management strategies that are applicable for the largest urban areas in Texas. Researchers used an innovative simulation-based modeling methodology to assess freight flow management techniques, including land- and route-based, time-of-day, intelligent transportation system and active traffic management, and land-use strategies. Researchers developed and calibrated dynamic traffic assignment models of El Paso, Houston, Dallas–Fort Worth, and Austin, as well as a binational model of the El Paso/Juárez border region, to assess the applicability of multiple freight management strategies.

The strategies outlined in this project are specific to the defined urban areas. Researchers developed and outlined guidelines for (a) preferred tools and methods for modeling each strategy; (b) selection and deployment of strategies based on the benefits they can provide and/or the conditions under which they might be employed; and (c) policy implications. Project results presented in this report should benefit the Texas Department of Transportation and other regional stakeholders interested in exploring various strategies to better manage freight in large, populated areas.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Jeff Shelton. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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AADT	Average Annual Daily Traffic
ACC	Adaptive Cruise Control
ADT	Average Daily Traffic
AMS	Anisotropic Mesoscopic Simulation
ATDM	Active Traffic and Demand Management
ATIS	Advanced Traveler Information System
ATM	Active Traffic Management
ATR	Automatic Traffic Recorder
ATRI	American Transportation Research Institute
Avg TT	Average Travel Time
BOTA	Bridge of the Americas
CBD	Central Business District
CBP	Customs and Border Protection
CDS	Central Database Server
CG	Commodity Group
CO_2	Carbon Dioxide
CRIS	Crash Records Information System
DC	Distribution Center
DFW	Dallas–Fort Worth
DMS	Dynamic Message Sign
DOT	Department of Transportation
DSRC	Dedicated Short-Range Communication
DTA	Dynamic Traffic Assignment
DUE	Dynamic User Equilibrium
EB	Eastbound
FHWA	Federal Highway Administration
FRATIS	Freight Advanced Traveler Information Systems
FSP	Freight Signal Priority
GIS	Geographic Information System
GP	General Purpose
GPS	Global Positioning System
HBW	Home-Based Work
H-GAC	Houston-Galveston Area Council
HOS	Hours-of-Service
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
IDS	Information Delivery System
ITS	Intelligent Transportation System

KAB	Fatal, Incapacitated, and Non-Incapacitated
LBJ	Lyndon B. Johnson
LiDAR	Light Detection and Ranging
MPO	Metropolitan Planning Organization
MRM	Multiresolution Modeling
MTO	Marine Terminal Operator
NB	Northbound
NCFRP	National Cooperative Freight Research Program
NCTCOG	North Central Texas Council of Governments
NHB	Non-Home-Based
NHW	Non-Home Non-Work
NTE	North Tarrant Express
OPD	Off-Peak Delivery
OD	Origin-Destination
PAEFA	Parking Availability Estimation and Forecasting Algorithm
PGTRS	Parking Ground Truth Recalibration System
POE	Port of Entry
PM	Performance Measure
RCS	Remote Computer and Storage
RHiNo	Roadway Highway Inventory Network
SAM	Statewide Analysis Model
SB	Southbound
SOCC	System Operations Computer Cluster
SPI	Source of Parking Information
SOV	Single Occupancy Vehicle
TAZ	Traffic Analysis Zone
TDSP	Time-Dependent Shortest Path
TDUE	Time-Dependent User Equilibrium
TFMP	Texas Freight Mobility Plan
TMC	Traffic Management Center
TOT	Truck-Only Toll
TPIMS	Truck Parking Information and Management System
TPP	Transportation Planning and Programming
TSRC	Transportation Sustainability Research Center
TSZ	Traffic Survey Zone
TTI	Texas A&M Transportation Institute
TTR	Travel Time Reliability
TxDOT	Texas Department of Transportation
TX-NAFF	Texas North American Freight Flow
UE	User Equilibrium

V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WB	Westbound

INTRODUCTION AND BACKGROUND

PURPOSE

Most urban areas around the country are facing serious mobility challenges, including an increase in travel demand, limited capital improvement resources, and a need to improve safety. Texas in particular is seeing unprecedented urban traffic growth. Increasing traffic is generally a good sign of improving economic health; however, the limits to capacity of urban highways can often hinder movement of both freight through urban areas and freight deliveries to and from production sites within the cities. The purpose of Texas Department of Transportation (TxDOT) Project 0-6851, Strategies for Managing Freight Traffic through Urban Areas, was to examine the potential of implementing several proven strategies for managing freight movement in specific urban areas through the use of advanced transportation modeling tools and other evaluation methods as described in this final report.

Texas' proximity to Mexico and the Gulf of Mexico, along with its vast agriculture, oil and gas, manufacturing bases and distribution centers (DCs), places Texas as a leader in the country when it comes to economic competitiveness and freight generation. Its unique geographic location puts it at the junction of both east-west and north-south routes for cross-country freight movement. At the same time, Texas is rapidly becoming more urbanized, with current metropolitan areas capturing 88.2 percent of the Texas population growth between 1980 and 2010. The counties comprising the designated metropolitan statistical areas account for 88 percent of the state's population (*1*). The need to move freight increases as population increases, thus translating into the need for more truck movements to and/or transiting through urbanized areas. Additionally, the increased size of the urban areas also increases the interaction with trucks passing through urban areas to their final destinations, especially from the many international border or port gateways.

BENEFITS

While not a substitute for large capacity expansion projects, freight management strategies can be cost-effective methods to prolong the life and maximize the efficiency of the infrastructure, thus postponing the need for major expansion projects. Some freight management strategies can be flexible enough to be implemented under temporary conditions in work zones and later incorporated into the permanent operational infrastructure of a facility. Incorporation of these strategies along with other solutions can improve the ability of the Texas freight system to perform until more capacity can be built or freight can be shifted to alternative modes of transport.

OBJECTIVES

The objectives of Project 0-6851 were to first provide TxDOT transportation planners and traffic operations professionals with an organized list of state-of-the art approaches to manage freight traffic on urban freeways, including novel techniques focused on Texas urban area needs. The second goal was to use these findings to guide the deployment of intelligent transportation systems (ITSs) and/or other technologies to revise policies concerning freight traffic movement through Texas' urban areas. Throughout the course of the project, several existing urban models for Texas areas were either improved or new models were developed. Use of the modeling frameworks developed during this project will ultimately enhance TxDOT's analytical capabilities for managing urban freight traffic.

REPORT OVERVIEW

The following chapters describe how the project was carried out over the past 3 years. The literature review defines several important parameters of the study (such as how urban areas were defined), describes urban freight characteristics in Texas urban areas, and examines the freight management strategies commonly used to address freight congestion. These strategies include:

- Lane- and route-based strategies.
- Time-of-day–based strategies.
- ITS/active traffic management (ATM)-related strategies.
- Connected vehicle and automated freight mobility applications.
- Land-use practices and policies promoting/facilitating freight movement.
- Parking and staging areas.

The next chapter describes how researchers assessed each of these freight flow management techniques in light of the specific problems being faced in selected Texas urban areas. Following this assessment, a description of how criteria-based assessment and comparison of attributes of the strategies for goals of the newly implemented Texas Freight Mobility Plan (TFMP) is presented.

The next major section of the report describes the urban model development process. This section describes the use of differing data types and their processing requirements, model conversion, and development, and the use of mesoscopic modeling for the North Central Texas Council of Governments (NCTCOG), Houston, El Paso, Austin areas was completed. In each region, one or more strategies were examined when using the models and are described in this report. By region, these models include:

- Dallas–Fort Worth (DFW) Region: Freight Advanced Traveler Information Systems (FRATIS) for Incident Management, Off-Peak Freight Incentive on Managed Lanes (TEXpress), and Smart Truck Parking.
- Houston: FRATIS for Incident Management, Off-Peak Freight Incentive on High Occupancy Toll (HOT) Lanes, Freight Bypass Designation, and Grade Separation.

- El Paso: Dedicated/Exclusive Truck Lanes and Incident Management Using Truck Freight-Specific Advanced Traveler Information Systems (ATIS).
- Austin: ATIS and Freight Signal Priority (FSP).

The next section of the report includes a description of freight management strategy selection guidance that outlines the features and criteria each type of strategy is meant to address. The strategies examined in this section of the report are:

- Modeling methodologies.
- Lane- and route-based strategies.
- Time-of-day-based strategies.
- ITS/ATM related strategies.
- Land-use practices and policies promoting/facilitating freight movement.
- Smart parking.
- Incentivized off-peak managed lanes.

The report ends with a section describing the project's findings and conclusions. Appendices describing detailed modeling steps are also presented.

LITERATURE REVIEW

INTRODUCTION

The focus of the literature review is to identify and discuss possible freight management strategies. Each freight management strategy will be thoroughly characterized and combined with an additional in-depth investigation of the strategies outlined in Technical Memorandum 3: Assess Traditional and Non-traditional Freight Flow Management Techniques. During the investigation of each strategy, researchers examined, where applicable:

- Implementation/research.
- Relevant issues related to the state of the art, state of the practice, lessons learned, business processes, system, and technology capability.
- Performance measurement and management, organizational culture, and policies and regulations.

Specific criteria by which to assess each strategy including:

- Reasonableness and feasibility for deployment.
- Legislative and policy requirements to implement the strategies.
- Technology maturity and market penetration requirements.
- Design and operational integration requirements.

The remainder of the literature review documents the characteristics of urban freight. Characteristics include the issues that arise with freight movement through urban areas, how it impacts congestion, and specific strategies in literature. The literature review also outlines specific strategies and how they relate to freight movement in Texas.

DEFINITION OF URBAN AREAS

The scope of this project calls for strategies for managing freight traffic through urban areas. The U.S. Census Bureau identifies two types of urban areas: urbanized areas of 50,000 or more people and urban clusters of at least 2,500 and less than 50,000 people (*2*). Texas has a total of 306 urban areas, according to the 2010 Census, which consists of 34 urban areas and 272 urban clusters. Within this document, metropolitan areas are considered urban areas.

URBAN FREIGHT CHARACTERISTICS

The National Cooperative Freight Research Program (NCFRP) Report 14, *Guidebook for Understanding Urban Goods Movement* (*3*), characterizes 12 different goods and service supply chains typical of many urban environments. These supply chains are used to illustrate common constraints in the urban environment; congestion, of course, is a major constraint to both freight and passenger travel. Freight congestion problems are most visible at bottlenecks where the highway infrastructure consistently experiences congestion. These freight bottlenecks often occur in urban areas near freight terminals (e.g., ports, inland ports, or intermodal facilities) or at major highway interchanges.

Figure 1 demonstrates the supply chain for soft drink beverages. With this supply chain example, all the raw materials and initial production have domestic origins. The entire process is very multimodal in nature, with the truck operations performed by several different sizes of trucks. According to NCFRP Report 14, the major concern for urban goods movement is the manufacture and packaging of the finished product, which is the process demonstrated in Figure 1. The delivery performed by trucks is done with different truck vehicle types for different delivery sizes and functions broken broadly into:

- Bulk (high-volume stores).
- Side Loader (convenience stores and restaurants).
- Fill service (vending machine) retail channels.

The report indicates that "each truck runs a stem route, typically with multiple stops over the course of a trip, optimized around the customer delivery scheduling needs. The stem runs to the far end of the route, and then works its way back to the plants or DC with deliverables along the way, and the truck finishes empty."

Figure 2 presents a second supply chain example, apparel retail. The apparel retail supply chain schematic shows that, unlike the first example, much of the manufacturing is performed overseas and delivered to the United States through major seaports or airports. From these major gateways, the shipments are transferred to container freight stations where they are sorted into truck deliveries bound for regional DCs. NCFRP Report 14 indicates that from these DCs, product is transported by outbound truck either to specific retail locations or, in the case of online or catalog orders, directly to the consumer (*3*). According to the report:

> The primary issues for the company's urban logistics include traffic congestion, timely access to loading docks, and maneuvering space. Megastores are in major metropolitan areas and deliveries are constrained by limited delivery times. Often, deliveries must be made within less than an hour's time at a specific time of day. Because of prolonged morning and evening rush hours and schedule constraints, the company is often forced to operate simultaneous deliveries to megastores, which increases logistics costs. (*3*)

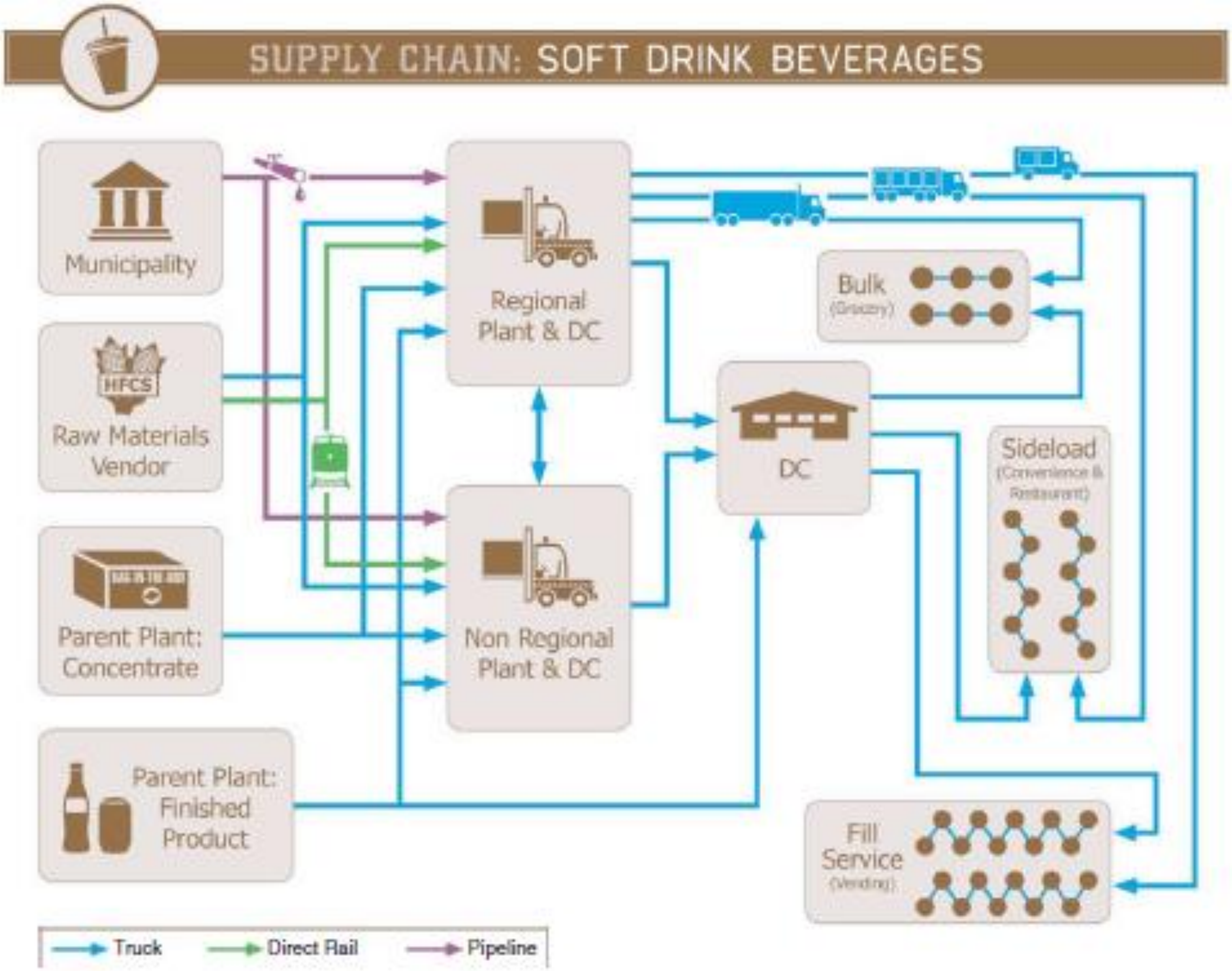


Figure 1. Soft Drink Beverage Flowchart (*3*).

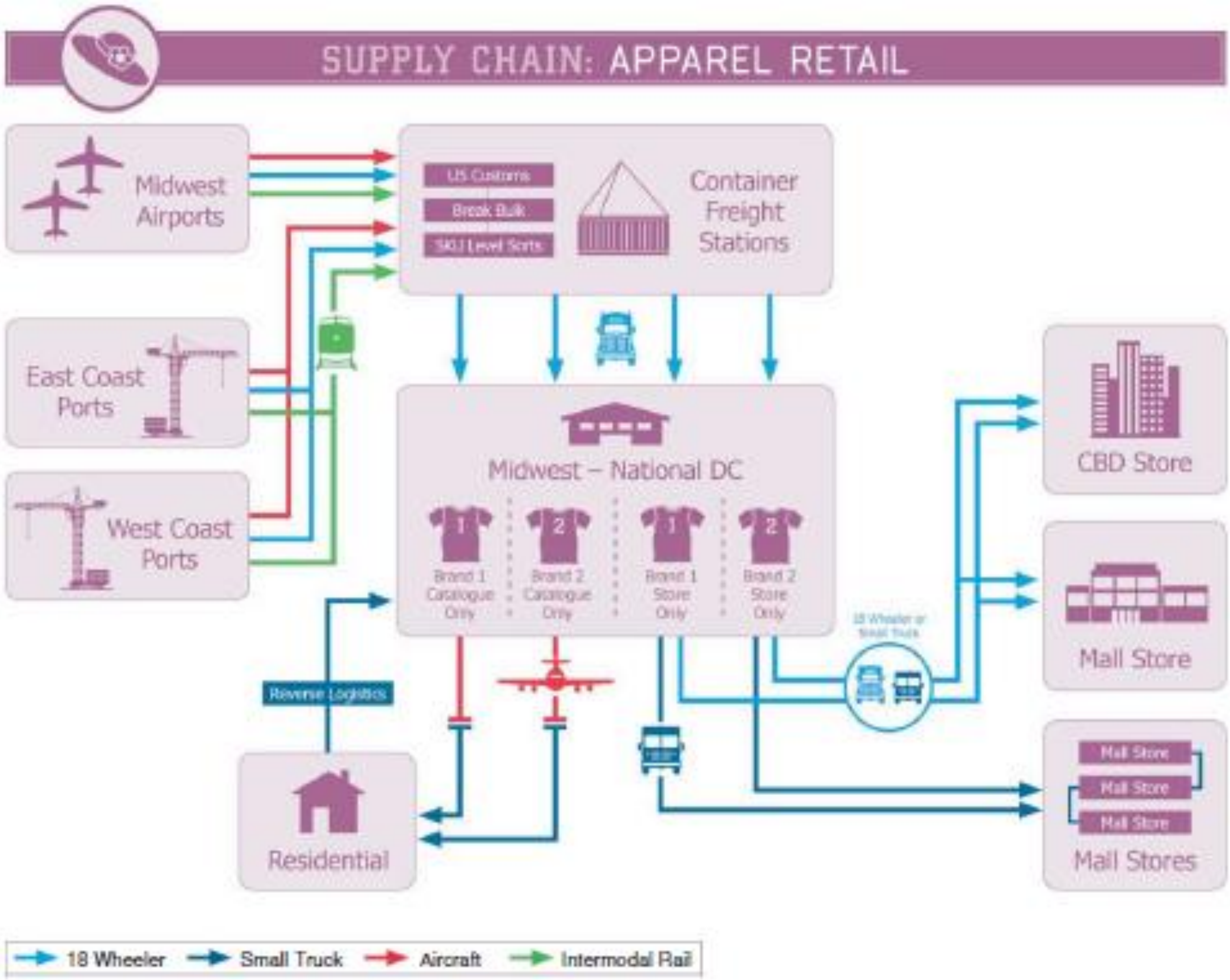


Figure 2. Retail Apparel Flowchart (*3*).

Issues with Freight Movement through Urban Areas

About 3 percent of the U.S. workforce was employed in the transportation and warehouse industry in 2008, entailing 4.5 million jobs. Trucking was the principal employer in the transportation sector, providing approximately 1.4 million jobs (*4*). Since then, traffic in the United States has increased. Freight transportation in urban areas has been affected by traffic growth. Some of the major issues that have impacted the freight movement through urban areas include bottlenecks, air pollution, parking spaces, land uses, and congestion.

According to NCFRP Report 23, freight bottlenecks in the United States cause more than 243 million hours of delay each year. The delay is estimated to cost $26.70 per hour. The Federal Highway Administration (FHWA) has used this value in its Highway Economic Requirements System model to estimate national highway costs and benefits. According to FHWA's model, bottlenecks cost truck drivers approximately $6.5 billion per year.

In order to find a parking space to deliver their cargo, truck drivers have to make several rounds in the same area, which contribute to air pollution. High levels of air pollution are produced in areas where freight corridors, ports, and warehouses are concentrated. Air pollution has become a major health issue. It has been linked to higher rates of asthma and other lung diseases in the general population, especially in children. Noise and carbon emissions are also factors contributing to the negative impacts associated with urban freight movement.

Additionally, the lack of loading and unloading zones for cargo trucks is another major problem truck drivers face in urban cities with high levels of traffic congestion. NCFRP Report 23 examined data for New York and San Francisco and found that insufficient parking spaces to drop off cargo at businesses or residences in peak hours caused congestion. This congestion is caused by trucks that park in restricted areas to deliver their goods, therefore blocking the traffic flow. Both cities have tried to alleviate this issue. New York tried to implement an off-peak delivery (OPD) program to reduce fuel consumption and congestion. The program was a good initiative to reduce traffic congestion due to freight delivery, according to a study by Jose Holguin-Veras, professor at the Rensselaer Polytechnic Institute (6). However, it might be more expensive for businesses to make off-peak deliveries, an increase that stakeholders might not be able to afford. Further, implementing off-peak deliveries requires staff to accept deliveries at night; most companies are constrained by customers who prefer to receive their deliveries during normal business hours. As a result, it has been difficult to implement this program on a long-term basis. San Francisco is exploring demand-based parking pricing, which increases the price in popular parking spaces, as an approach to facilitate cargo delivery (*5*).

Land uses related to residential properties, schools, and hospitals are a common cause of conflict with any freight activity. Some of these conflicts include health and safety issues, air and noise pollution, and congestion. In other to provide efficient freight movement, it is necessary to expand the available freight facilities and corridors, but factors such as insufficient funding, public policy decision, and conflict with land uses have become barriers to accomplishing such goals. Speed limitation, restricted operation hours, height and clearance impacts, and environmental permits are some other factors that affect the production and distribution of expenses in the freight transportation system, all of which result in limiting effective freight movement. If these issues are not addressed, the relocation of freight land use will be necessary (*4*).

A freight transportation system is necessary to economic globalization. It is an important factor in the transportation sector, but at present it has negative impacts. These negative impacts generate community opposition. Ultimately, however, the freight system will have to serve larger areas, reduce the impact of truck traffic, and use less infrastructure space: “In short, the freight transportation system will need to do more with less” (*6*).

Impact of Congestion on Freight Movement

Freight movement throughout urban areas has a significant impact on congestion, especially during peak hours of the day. In some metropolitan areas however, truck traffic contributes to the congested transportation infrastructure all day long. Other factors such as extreme weather conditions, traffic incidents, and changing traffic volumes also have an effect on congested corridors.

According to the Cost of Congestion to the Trucking Industry report by the American Transportation Research Institute (ATRI) in 2013, trucking industry congestion cost $9.2 billion; the total delay was 141 million hours (equivalent to over 51,000 drivers sitting idle for a working year). The average cost for a truck that traveled 12,000 miles was $408, while the cost of a truck that traveled 150,000 miles had an average of $5,094 (see Figure 3). The cost of congestion from 2012–2013 increased by 1.4 percent, which is equivalent to $131.4 million. Figure 4 shows the cost of congestion per quarter during 2012 and 2013 (*7*).

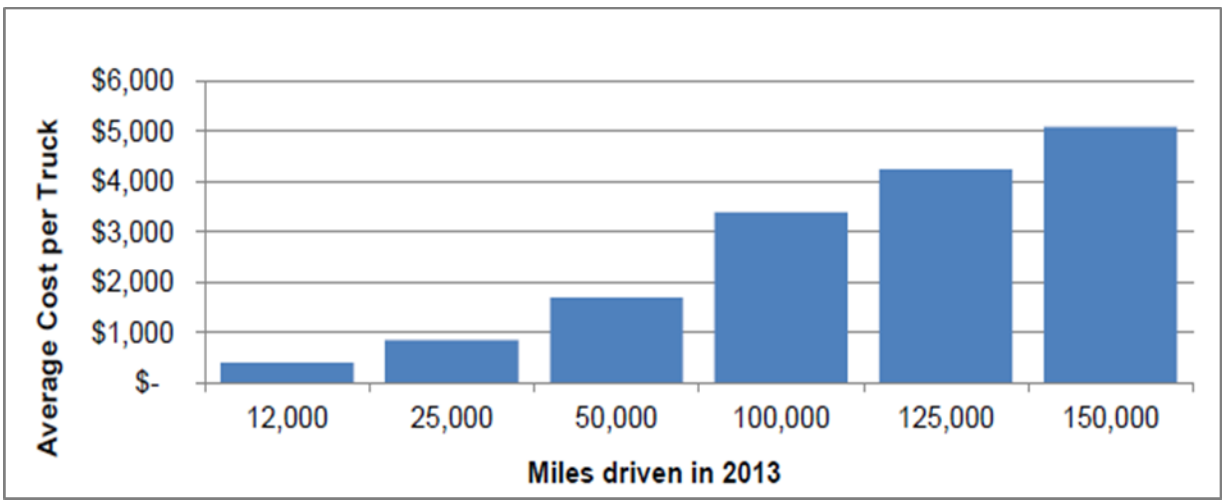


Figure 3. Average Cost of Congestion per Truck by Miles Driven for 2013.

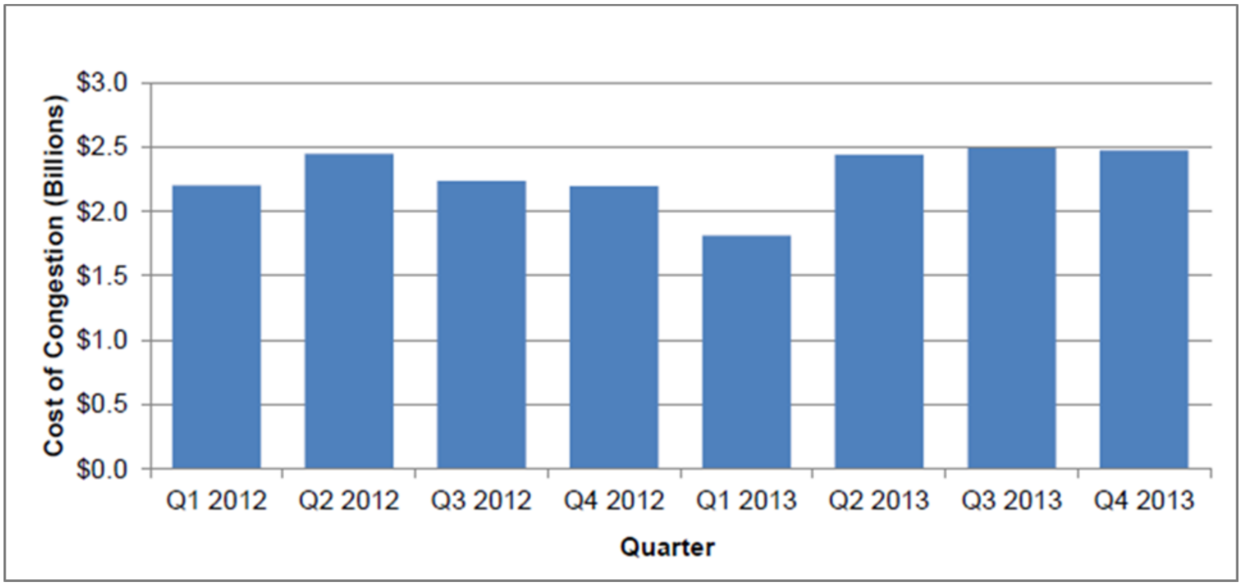


Figure 4. Total Cost of Congestion for Trucks by Quarter.

State analysis reveals that congestion cost is related to the population. States with higher populations will usually have higher congestion cost. Table 1 shows the top/bottom 10 states by the total cost of congestion in 2013. California has the highest cost, with over $1.7 billion, followed by Texas and New York (*8*).

About 96 percent of the total cost of congestion during 2013 occurred in metropolitan areas. Table 2 shows the 10 top/bottom metropolitan areas by the total cost of congestion. The Los Angeles, California, metropolitan area had the highest cost, followed by New York and Chicago. For Texas metropolitan areas, DFW-Arlington placed fourth with approximately $406 million, while Houston-Sugar Land-Baytown placed sixth with more than $373 million in terms of congestion cost (*7*).

Table 1. Top/Bottom 10 States by Total Cost of Congestion in 2013.

Rank	State	2013 Cost	Rank	State	2013 Cost
Top 10			**Bottom 10**		
1	California	$1,706,026,586	49	Maine	$5,147,186
2	Texas	$1,053,129,673	48	Nebraska	$5,228,002
3	New York	$845,521,677	47	Vermont	$7,372,458
4	Illinois	$498,022,538	46	New Hampshire	$7,439,687
5	Pennsylvania	$421,508,565	45	Idaho	$7,684,283
6	Virginia	$330,400,920	44	North Dakota	$8,701,161
7	Maryland	$315,461,693	43	Iowa	$11,007,245
8	Georgia	$304,113,197	42	South Dakota	$12,527,384
9	Massachusetts	$303,355,238	41	Montana	$13,371,783
10	Florida	$256,075,805	40	Delaware	$17,457,490

Hawaii (50) not included in the analysis.

Table 2. Top/Bottom 10 Metropolitan Areas by Total Cost of Congestion in 2013.

Rank	State	2013 Cost
Top 10		
1	Los Angeles-Long Beach-Santa Ana, CA	$1,081,748,940
2	New York-Northern New Jersey-Long Island, NY-NJ-PA	$984,287,793
3	Chicago-Joliet-Naperville, IL-IN-WI	$466,939,275
4	DFW-Arlington, TX	$406,130,727
5	Washington-Arlington-Alexandria, DC-VA-MD-WV	$379,356,852
6	Houston-Sugar Land-Baytown, TX	$373,603,620
7	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	$292,141,937
8	San Francisco-Oakland-Fremont, CA	$288,629,957
9	Boston-Cambridge-Quincy, MA-NH	$278,238,672
10	Atlanta-Sandy Springs-Marietta, GA	$275,126,523

Rank	State	2013 Cost
Bottom 10		
308	Lewiston-Auburn, ME	$24,453
307	Elkhart-Goshen, IN	$33,949
306	Hinesville-Fort Stewart, GA	$53,383
305	Rochester, MN	$54,053
304	Utica-Rome, NY	$65,937
303	Lawrence, KS	$67,378
302	Jefferson City, MO	$69,195
301	Ames, IA	$80,978
300	Muskegon-Norton Shores, MI	$86,278
299	Sumter, SC	$92,340

ATRI now monitors 250 freight locations and has collected multiple years of data analysis. The Congestion Impact Analysis of Freight-Significant Highway Location report provides average delays and inefficiencies of the top 100 locations out of the 250 monitored locations where the congestion has the greatest influence on trucking operations. Table 3 shows the 15 locations in Texas on the top 100 list with the greatest congestion. For each location, the parameters given include the National Ranking by Congestion Index, average speed, peak average speed, and nonpeak average speed (*8*).

Table 3. Texas Locations.

Texas Location	National Ranking by Congestion Index	Average Speed (MPH)	Peak Average Speed (MPH)	Nonpeak Average Speed (MPH)	Nonpeak/ Peak Ratio
Houston: I-45 at US 59	5	39	29	44	1.52
Houston: I-610 at US 290	6	42	34	46	1.34
Austin: I-35	10	36	22	43	1.93
Dallas: I-45 at I-30	12	42	33	46	1.39
Houston: I-10 at I-45	13	46	36	50	1.38
Houston: I-10 at US 59	16	47	36	52	1.46
Houston: I-45 at I-610 (North)	22	48	38	52	1.36
Ft. Worth: I-35W at I-30	27	46	39	49	1.26
Houston: I-10 at I-610 (North)	33	50	42	53	1.25
Dallas: US 75 at I-635	45	48	38	52	1.36
Houston: I-610 at US 59 (West)	50	43	34	48	1.40
Houston: I-45 at I-610 (South)	54	46	36	52	1.44
Houston: I-45 at Sam Huston Tollway (North)	74	51	43	55	1.26
Houston: I-10 at I-610 (East)	96	54	51	55	1.08
El Paso: I-10 at I-110/US 54	98	52	47	53	1.13

According to the data collected, Houston, Austin, and Dallas had the highest values of traffic congestion in Texas. This information provides better understanding to make better decisions when dealing with the congestion and mobility of freight transport for both the private and public sectors. This in turn will help decision makers develop efficient transportation infrastructure investments and distribution strategies (*8*).

Trucks' Impact on Congestion

Trucks also contribute negatively to congestion and the problems arising from it. NCFRP Report 23 found that urban freight contributes disproportionately to externalities. "Commercial vehicles contribute a significant share of nitrogen oxides, particulate matters, and carbon dioxide (CO_2) emission in cities and contribute disproportionately to congestion, noise, and road accident fatalities" (*5*). In a survey of metropolitan planning organizations (MPOs), the most serious metropolitan area challenge related to increased truck traffic cited is congested urban highways, with other serious challenges that include congestion bottlenecks, substandard geometrics, insufficient parking, trucks driving through residential areas, and incompatible land uses (*9*).

Characteristics of Texas Urban Freight Traffic

Texas' proximity to Mexico and the Gulf of Mexico, along with its vast agriculture, oil and gas, manufacturing bases and DCs, places Texas as a leader in the country when it comes to economic competitiveness. The gross state product of approximately $1.4 trillion ranks only behind that of California (*10*). Annually, over $1.6 trillion worth of goods weighing over 1.2 billion tons moves on Texas highways. The importance of trucks is demonstrated by the fact that 73 percent of goods manufactured in Texas and 85 percent of trade between Texas and Mexico is handled by trucks (*11*). Table 4 shows the types of gateway facilities and generators found within the state of Texas. These gateway facilities provide access points for the freight movement that benefits the Texas economy.

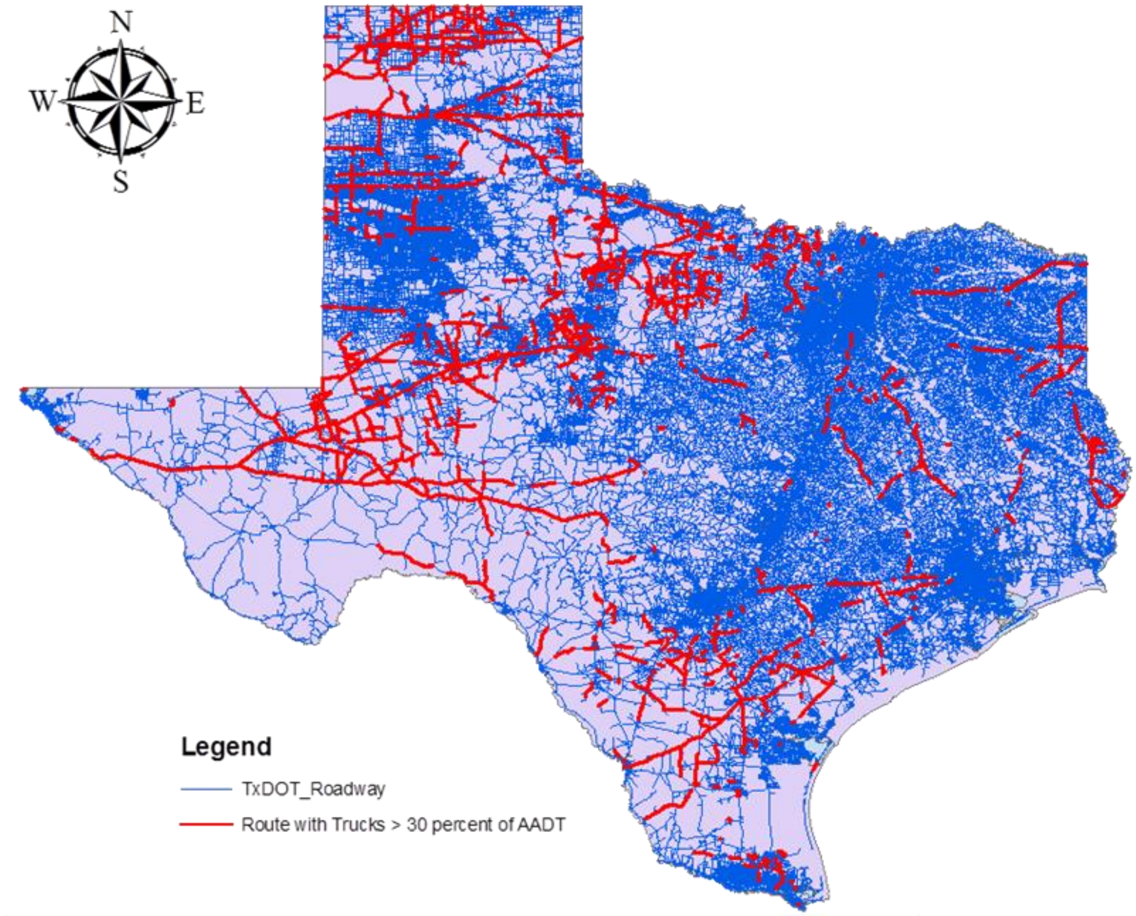
Table 4. Texas Freight Gateways and Generators.

Freight Gateways	Freight Generators
• Ports • Airports • International Border Crossings • Interstate Border Crossings	• Oil and Gas • Agriculture • DCs • Manufacturing

At the same time, Texas is rapidly becoming more urbanized, with current metropolitan areas capturing over 88 percent of the Texas population growth between 1980 and 2010. The counties comprising the designated metropolitan statistical areas account for 88 percent of the state's population (*1*). The need to move freight increases as population increases, thus translating into the need for more urban truck movements. Additionally, the increased size of the urban areas also increases the interaction with trucks passing through urban areas to their final destinations, especially from the many international border or port gateways.

Texas Truck Traffic

Trucks make up a tremendous portion of the freight activity in Texas. Figure 5 is a map showing the roadways in the state in which trucks represent over 30 percent of the total traffic flow. Figure 6 provides closer views of the DFW and Houston areas. In both cases, several roadways located outside the major urban centers have truck volumes representing over 30 percent of the overall traffic volumes. In the urban centers, despite tremendous daily truck volumes, the percentage of truck volumes drops to below 10 percent as a function of the increased non-truck traffic.



Source: Roadway Highway Inventory Network Offload (RHiNo)

Figure 5. Truck Percentages Higher than 30 Percent of Average Annual Daily Traffic (AADT).

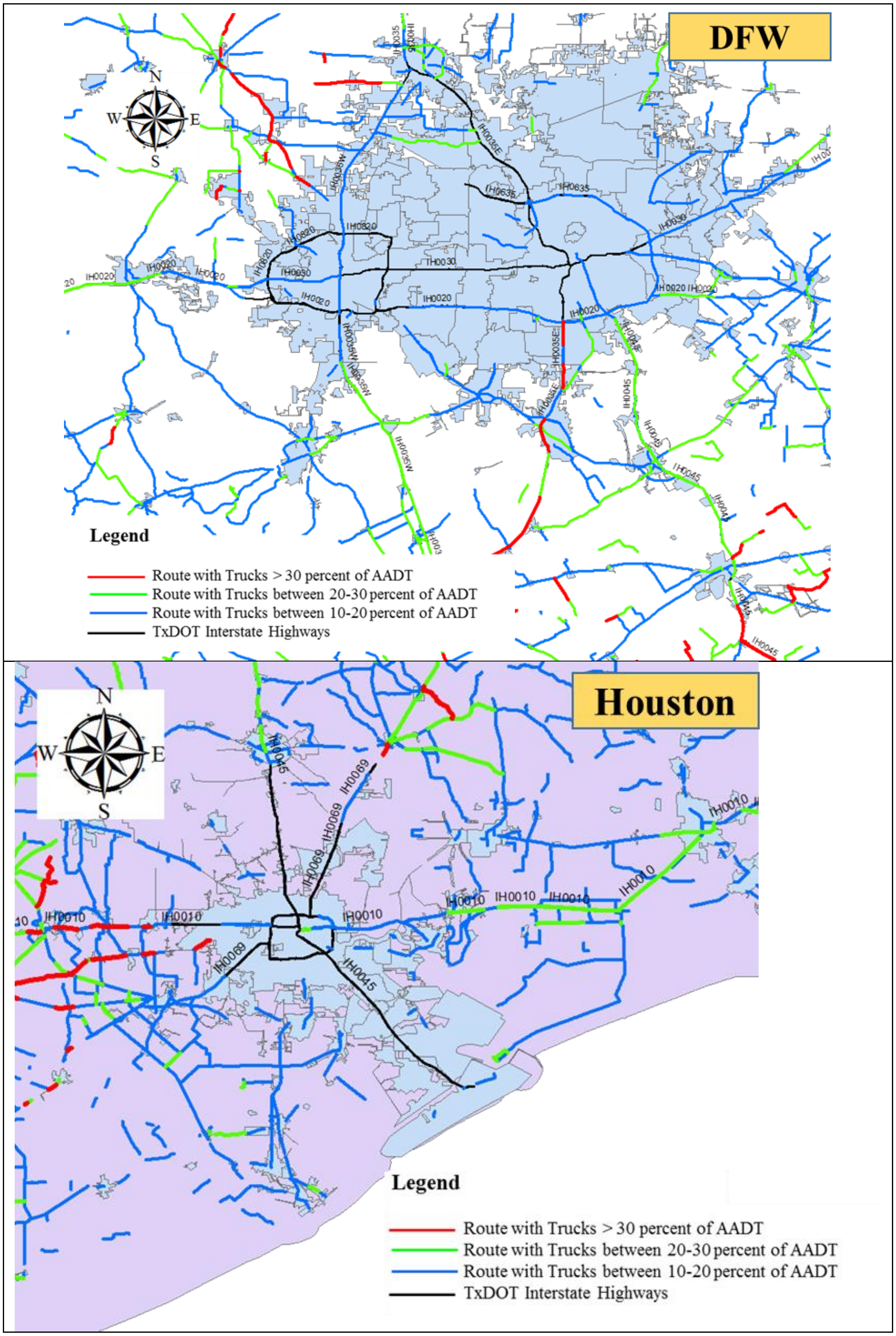


Figure 6. Major Truck Traffic Distribution in the DFW and Houston Areas.

Strategies in Literature

Each freight management strategy will be thoroughly characterized. During the investigation of each strategy, researchers will examine, where applicable:

- Implementation/research.
- Relevant issues related to state of the art, state of the practice, lessons learned, business processes, system, and technology capability.
- Performance measurement and management, organizational culture, and policies and regulations.

Specific criteria by which to assess each strategy include:

- Reasonableness and feasibility for deployment.
- Legislative and policy requirements to implement the strategies.
- Technology maturity and market penetration requirements.
- Design and operational integration requirements.

Lane- and Route-Based Strategies

Many freight-oriented traffic management techniques tend to be lane-based. These strategies attempt to segregate truck traffic from passenger vehicle traffic by either restricting use of specific lanes by commercial fleet vehicles or by providing special dedicated facilities for fleet vehicle operation.

Lane-Use Restrictions

Implementation of lane restrictions (more appropriately termed lane-use restrictions) on an existing highway or freeway is a potential strategy for consideration when addressing a heavy truck emphasis area. The applicability of lane-use restrictions is generally limited to sections of roadway with at least three lanes in one direction. This practice allows trucks to be restricted to the two rightmost lanes, leaving one lane for truck-free operation. Some of the benefits of restricting trucks from the leftmost lane are:

- Increases overall capacity by removing trucks from one or more lanes.
- Positions largest vehicles out of the highest speed lane.
- Reduces the frequency of passenger vehicles getting boxed in.
- Provides additional space for stranded vehicles along median shoulders.
- Allows motorists an unobstructed view from which to see congestion levels ahead, thus providing advanced warning of possible speed changes.

Most often, these roadways are freeway facilities, including interstate routes. While truck lane restrictions are beneficial to non-truck traffic, lane restrictions tend not to favor truck operations.

When lane-use restrictions are imposed, truck traffic often has to comingle with slow moving automobile traffic, restricting the ability for trucks to pass. Also, lane-use restriction often increases merging conflicts with other vehicles as they enter freeway facilities.

Dedicated/Exclusive Truck Lanes

Segregation of truck traffic from passenger traffic by implementing dedicated truck facilities in key economic corridors has potential to mitigate these impacts by reducing car-truck interactions in terms of weaving and passing maneuvers. While only a few exclusive truck facilities have been constructed in the United States (e.g., New Jersey Turnpike, Clarence Henry Truckway, South Boston Bypass, and Los Angeles I-5 truck bypass lanes), some of the initial research shows promising results in terms of improved travel speeds for trucks and safety (*12, 13, 14, 15*).

Truck-Only Toll Lanes

A strategy that has been considered in urban areas to aid truck traffic flow from major traffic generators is urban truck-only toll (TOT) lanes. Urban TOT lanes were proposed in California on SR 60 and I-710; in Miami, where lanes are intended to aid traffic getting into and out of busy ports; and in Atlanta to reduce urban traffic congestion and improve the mobility of freight to and through the region (*16*). TOT lanes have special design and configuration requirements, including pavements to accommodate the heavier/overweight loads, staging areas for assembling and disassembling long combination vehicles, and on/off-ramps specifically designed for safe exit/access of trucks. However, the major challenge is to find optimal system-level toll pricing that does not shift truck traffic to non-tolled facilities, residential neighborhoods, or facilities that are not adequate to support heavy truckloads.

System-Level Toll Strategies

Ideally, toll rates should be set in a way that maximizes toll revenues, achieves an acceptable level of service, achieves a high utilization rate, and diverts a significant number of trucks from local roads to the toll lanes. In reality, it is difficult to achieve all four of these objectives simultaneously because they may work against each other. For instance, if tolls are set higher than the travel time savings that truckers would realize by using the facility, it will discourage truckers from using the toll lanes, thus reducing demand and toll revenues without removing many trucks from congested free lanes. Further, trucker utilization of toll lanes also is affected by the value and time-sensitivity of the cargo (*17*). An optimal toll strategy is the one that provides system-level benefits with acceptable time savings and toll levels.

Truck Route Designations

In urban areas, truck traffic often shares the roads with other modes (e.g., passenger vehicles, bicycles, and pedestrians) and creates some negative impacts, including congestion, emissions, noise, and safety concerns, for other road users and nearby communities. Designating certain roadways for truck traffic is the most common strategy employed by cities to manage freight transportation demand (*18*). Directing truck traffic on specific routes allows local governments to:

- Target infrastructure improvements to primary users by providing more generous turning radii and greater overhead clearance on truck routes.
- Reduce exposure of residents to noise, emissions, and vibration by identifying truck routes that avoid residential areas.
- Separate truck traffic from bicycles and pedestrians by reducing truck traffic on key pedestrian and bicycle thoroughfares.

Literature has examples of various types of truck route restrictions that can allow the city to efficiently meet the needs of all modes of transportation (*19*). Listed below are examples of various truck route designations employed by various state departments of transportation (DOTs):

- **Standard Truck Route Network:** In California, the City of Berkeley's trucks are required to stay on the city's designated network of truck routes as much as possible, but are allowed to travel on streets not designated as truck routes to reach pickup and delivery locations. Beyond the regular truck routes in the city, a number of roads are designated as 3-, 4-, or 5-ton maximum routes. Trucks below these limits can use these roads as truck routes; those who exceed the limits must treat them as regular streets.
- **Turn Restrictions:** The New York City DOT restricted vehicles from turning off of thru streets between the hours of 10 a.m. and 6 p.m. to alleviate congestion attributed to turning movements in Midtown Manhattan. This significantly improves traffic flow by eliminating obstructions created by vehicles waiting for pedestrians before making a turn. Even though thru streets were not specifically designated as truck routes, carriers began to divert to the thru streets, thereby reducing traffic on non-thru streets (*20*).
- **Arterials-Only:** Phoenix, Arizona, classifies its entire arterial street network as truck routes. Trucks may travel on non-arterial streets to make pickups and deliveries as needed but must use the shortest possible route from the arterial network (similar to standard truck routes in Berkeley, California). Phoenix chose to designate all arterial streets as truck routes for the dual purposes of promoting mobility for trucks and spreading out the impact of heavy vehicles over the network to dilute their adverse impacts (*21*). Because no residential areas in the city are located on arterial routes, the neighborhood impacts of truck traffic are limited (*18*). In addition, the city identified two zones in its central business district (CBD) within which truck traffic is restricted during certain hours. It also designated major highways in the area as "through truck routes" on which trucks may travel without restriction, even within the truck-restricted zones (*21*).

Before truck route designations, it is critical to study current trends in truck movement and identify the routes with appropriate road geometries within the city to ensure efficient connectivity to downtown areas (*18*). All planning authorities with responsibilities for roads in the urban area, as well as the freight transport industry, should be involved in identifying truck routes to ensure that they link key destinations, avoid sensitive populations, and are coordinated across jurisdictional boundaries. Additionally, truck routes should be clearly mapped and identified with road signs, and cities should consider adjusting signal timing on truck routes (increasing the yellow and green signal phases to meet increased acceleration and deceleration requirements) to improve the flow of truck traffic (*19*).

Time-of-Day-Based Strategies

These strategies involve implementing special management techniques to provide or facilitate travel by fleet operators during specific times of the day. Examples of these strategies include incentives to promote OPD and nonpeak-hour use of high occupancy vehicle (HOV) lanes. Both strategies are discussed below.

Incentivized OPD or Time of the Day Pricing

Another strategy that can be considered as a means to reduce congestion and increase truck mobility is providing incentives for OPD, such as reduced truck tolls during off-peak hours or a free trip after several paid trips. The PierPASS Off-peak program at the Ports of Long Beach and Los Angeles offer a case study of how off-peak deliveries can work under the right set of circumstances. Under this program, all the international container terminals in the two ports established a night shift from 6:00 p.m. to 3:00 a.m. (Monday–Thursday) and a weekend shift from 8:00 a.m. to 6:00 p.m. on Saturday. To incentivize truckers to use these off-peak hours, a traffic mitigation fee is now required for all cargo movement during the peak period (3:00 a.m.–6:00 p.m. Monday–Friday). The response has been considerable: 30–35 percent of the daily cargo, on average, has switched to the OPD windows (*22*). This strategy is suitable for locations that do not have noise restrictions or restrictions on truck operating hours in residential areas.

Allowing Trucks on HOT/HOV Lanes at Off-Peak Periods

This strategy can leverage the existing HOT/HOV lanes by allowing access to trucks during off-peak periods, especially to access routes to ports and urban corridors. This practice might improve the freight flow through urban corridors and incentivize the trucks to shift to off-peak periods. Although potential benefits in terms of congestion and safety of dedicated lanes are well known, limited studies have explored the benefits of using HOT/HOV lanes during off-peak hours.

ITS/ATM-Related Strategies

ITS strategies involve using modern technology (e.g., computers and communications) to make travel smarter, faster, safer, and more convenient. ITS makes travel safer and more efficient and allows travelers to make more-informed decisions with respect to route, mode of travel, and when to travel. ITS strategies are integral in the freight industry because they help provide more efficient, less costly ways of moving commodities to the marketplace. Successful deployment of ITS technologies to benefit the freight industry will depend on interagency cooperation and strong partnerships with industry stakeholders. ITS-related strategies involve the use of advanced technologies to provide fleet operators with information on impending or developing traffic congestion.

ATM provides the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility. It increases throughput and safety using integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually. ATM tactics focus on influencing travel behavior with respect to lane/facility choices and operations. ATM strategies can be deployed singularly to address a specific need, such as utilizing adaptive ramp metering to control traffic flow, or can be combined to meet system wide needs of congestion management, traveler information, and safety that result in synergistic performance gains (*23*).

The following represent potential ITS/ATM strategies that might be applicable in improving freight flows through urban areas.

Reliable Truck Route Information

Cost savings on a per-mile basis are much higher in urban areas than on intercity routes due to the greater potential for improvement in both average travel time (Avg TT) and travel time reliability (TTR). Recent developments in ITS applications can be leveraged for efficient and reliable freight flow management strategy by:

- Establishing reliable truck routes based on historic and real-time traffic information between ports, railroad intermodal yards, and regional DCs.
- Providing businesses with information on route closures and detours early enough for them to adjust routes or delivery schedules, if required.
- Providing real-time information about incidents that will disrupt traffic operations and offering route guidance using dynamic message signs (DMSs).

Advanced Traveler Information for Truckers

The lack of freight-specific traveler information has many negative effects on the freight industry, affecting, for example, the efficient movement of freight transportation, the planning of freight daily work activities, logistics management systems, energy consumption, the safety of the traveling public, and the environment. Thus, U.S. DOT developed the FRATIS program to promote urban freight mobility. At a high level, FRATIS focuses on integrating regional ITS data, DOT commercial fleet data, third-party truck-specific movement data, and intermodal terminal data and disseminating it to various FRATIS applications.

The following three FRATIS prototypes are under development or recently completed. U.S. DOT has an interest in seeing more commercial applications of the technologies demonstrated by FRATIS (*24*):

- Los Angeles-Gateway Region:
  - Develop FRATIS applications to address dynamic travel planning around the marine terminals and queues to move cargo out of the ports more efficiently.
    - <u>Drayage-Marine Terminal Operator (MTO) Information Exchange.</u> Two-way messaging between the marine terminal and the drayage firm with estimated time of arrival (ETA) for dray approaches and MTO-dispatcher messaging and alerts. This will allow for substantially improved terminal and truck management, and if used on a large scale in the future, it could significantly reduce peak truck congestion at the port terminals across the days/week through dynamic appointments created by automated handshakes of container availability/truck dispatching information between dray firms and MTOs.
    - <u>Freight Traveler Information.</u> Dispatcher dashboard with order entry module, real-time terminal queue information, driver messaging, and traffic; dynamic routing for trucks through in-cab navigation devices; and detailed marine terminal wide micro-queue measurement through anonymous WiFi/Bluetooth detection readers.
    - <u>Drayage Optimization.</u> Daily optimized schedules per driver based on average stop times, predicted travel times, expected terminal wait times, and other constraints. This software system provides Port Logistics Group the planning tool necessary to achieve improvement in truck utilization of potentially up to 15 percent per day, which translates directly into public sector benefits of reduced truck miles and improved air quality.
- DFW, Texas:
  - Incorporate integrated corridor management capability along with size and weight permitting.
  - Test Connected Vehicle Basic Safety Message (Society of Automotive Engineers Standards J2735-2009).

    - Optimize drayage opportunities in coordination with rail and local truck drayage companies.
    - Expand FRATIS capabilities on I-35 between Austin and Dallas (U.S. DOT recently contracted TTI to oversee this expansion).
- South Florida:
    - Employ an optimization algorithm that will allow technologies to work together in a way that optimizes the drayage fleet deliveries and movements based on several key constraints (e.g., time of day, predicted travel times between points on each truck's itinerary, container orders, and available trucks).
    - Improve data reporting and information dissemination capabilities of public sector emergency management officials and key supply chain partners for the delivery of disaster relief and for users of the transportation system.

Dynamic Lane-Use Control

This strategy involves dynamically closing or opening individual traffic lanes as warranted and providing advance warning of the closure(s) (typically through dynamic lane control signs) to safely merge traffic into adjoining lanes. This approach continuously monitors the freeway network and real-time incident and congestion data are used to control the lane use ahead of the lane closure(s) and dynamically manage the location to reduce rear-end and other secondary crashes (*23*). Similarly, dynamic lane-use control can be used upstream of entrance ramps experiencing heavy truck demands to close lanes to automobiles to provide heavy vehicles with unimpeded access to the freeway.

Freight Signal Priority

FSP is another potential ITS application that can result in significant improvement to freight operations. FSP involves providing preferential treatment (e.g., traffic signal priority) for freight and commercial vehicles traveling in urban areas. The goal of FSP is to reduce stops and delays to commercial vehicles at signalized intersections. This practice is expected to increase TTR for freight traffic and to enhance safety at intersections.

Intelligent Speed Adaption/Speed Harmonization/Dynamic Speed Limits

This strategy adjusts speed limits based on real-time traffic, roadway, and/or weather conditions. Dynamic speed limits can either be enforceable (regulatory) speed limits or recommended speed advisories, and they can be applied to an entire roadway segment or individual lanes. In an active traffic and demand management (ATDM) approach, real-time and anticipated traffic conditions are used to adjust the speed limits dynamically to meet an agency's goals/objectives for safety, mobility, or environmental impacts.

Adaptive Ramp Metering

This advanced traffic management system strategy consists of deploying traffic signal(s) on ramps to dynamically control the rate that vehicles enter a freeway facility. This practice eases the flow of traffic onto the mainline, allowing efficient use of existing freeway capacity. Adaptive ramp metering uses traffic responsive or adaptive algorithms (as opposed to pre-timed or fixed time rates) that can optimize either local or system-wide conditions. Adaptive ramp metering can also utilize advanced metering technologies such as dynamic bottleneck identification, automated incident detection, and integration with adjacent arterial traffic signal operations. In an ATDM approach, real-time and anticipated traffic volumes on the freeway facility will be used to control the rate of vehicles entering the freeway facility. Based on the conditions, the ramp meter rates will be adjusted dynamically.

Oregon DOT switched its ramp meters from pre-timed operation to the System-Wide Adaptive Ramp Metering algorithm in 2005 to provide increased efficiency and effectiveness of a traffic-responsive ramp metering algorithm. About 150 ramps in the Portland metropolitan area are under adaptive control during the morning and evening peak periods. The region has seen significant increases in traffic speeds, travel time reduction, and collision reduction benefits, as shown in Figure 7 from FHWA's recent primer, *Ramp Metering: A Proven, Cost-Effective Operational Strategy* (*25*).

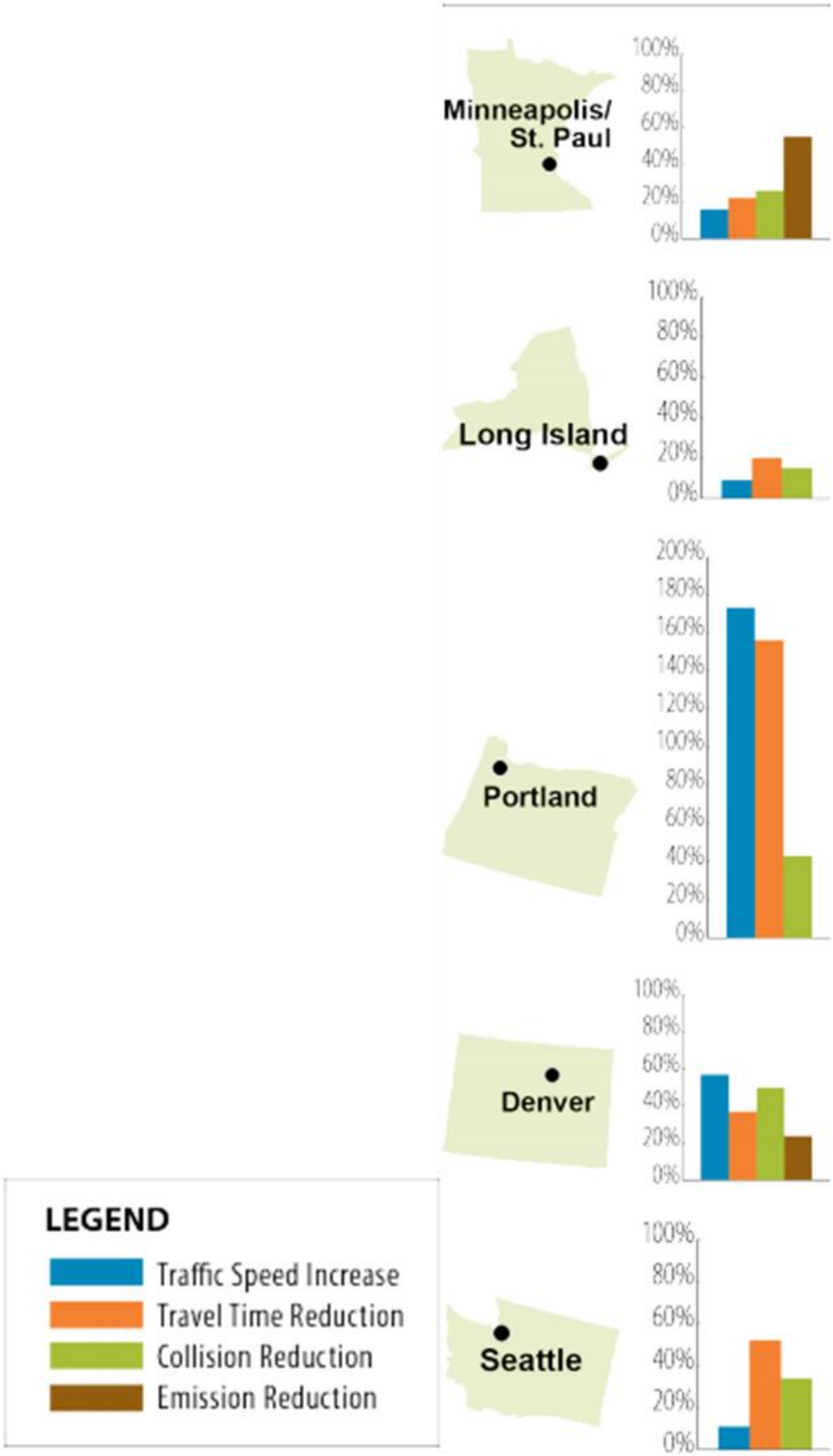


Figure 7. Select Regional Benefits of Ramp Metering (*25*).

Dynamic Merge Control

This strategy (also known as dynamic late merge or dynamic early merge) consists of dynamically managing the entry of vehicles into merge areas with a series of advisory messages (e.g., displayed on a DMS or lane control sign) approaching the merge point that prepare motorists for an upcoming merge and encourage or direct a consistent merging behavior. Applied conditionally during congested (or near congested) conditions, dynamic merge control can help create or maintain safe merging gaps and reduce shockwaves upstream of merge points. In an ATDM approach, conditions on the mainline lanes and ramps approaching merge areas are continuously monitored, and the dynamic merge system will be activated dynamically based on real-time and anticipated congestion conditions.

Dynamic Shoulder Lanes

This strategy, known as hard shoulder running or temporary shoulder use, enables the use of the shoulder as a travel lane(s) based on congestion levels during peak periods and in response to incidents or other conditions as warranted during nonpeak periods. In contrast to a static time-of-day schedule for using a shoulder lane, an ATDM approach continuously monitors conditions and uses real-time and anticipated congestion levels to determine the need for using a shoulder lane as a regular or special purpose travel lane. While generally used to support transit operations only, this concept could potentially be applied to provide preferential treatment to trucks. However, special considerations would need to be explored to make this a viable approach for improving freight mobility performance on freeways.

Dynamic Junction Control

This strategy consists of dynamically allocating lane access on mainline and ramp lanes in interchange areas where high traffic volumes are present and the relative demand on the mainline and ramps change throughout the day. For off-ramp locations, this may consist of assigning lanes dynamically either for through movements, shared through-exit movements, or exit-only movements. For on-ramp locations, this might involve a dynamic lane reduction on the mainline upstream of a high-volume entrance ramp or might involve extended use of a shoulder lane as an acceleration lane for a two-lane entrance ramp that culminates in a lane drop. In an ATDM approach, the volumes on the mainline lanes and ramps are continuously monitored, and lane access will be dynamically changed based on the real-time and anticipated conditions.

Connected Vehicle and Automated Freight Mobility Applications

Connected vehicle technology and other ITS applications are transforming safety and mobility on the nation’s roadways. U.S. DOT, in coordination with major automakers and other public- and private-sector innovators, has been working to advance vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications technology to help prevent traffic crashes before they happen, improve mobility, and lessen the impact of travel on the environment. Congestion and crashes cost the U.S. economy hundreds of billions of dollars a year.

While much of the recent attention has been on automated passenger vehicles (i.e., the Google car and others), automated vehicles applications are also being developed for commercial fleet operators. In fact, commercial fleet operators are viewed by many to be some of the early adopters of connected vehicle and automated vehicle technologies (*26*). According to ITS America, the National Highway Traffic Safety Administration released new regulations on the use of connected vehicle technologies for new heavy-duty vehicles in 2014 (*27*). That decision was a major milestone in the broad scale implementation of V2V and V2I communications systems in the United States. These systems (a) improve traffic safety by reducing driver workload and minimizing human errors due to driver distraction or reduced vigilance; (b) increase mobility through a reduction of congestion in urban areas and on motorways by increasing vehicle density and minimizing speed variations; (c) reduce vehicle emissions and fuel consumption; and (d) provide important individual, organizational, and commercial productivity improvements (e.g., through road-trains for freight distribution).

Automated and Driver Assist Truck Platooning Systems

One clear application of connected vehicle/automated vehicle technology is truck platooning. Caltrans and the California Partners for Advanced Transportation Technology (PATH) tested automated truck platooning system on closed tracks as early as 2003 and conducted real-world testing in Nevada in 2009. In both these studies, researchers found that truck platooning resulted in significant fuel savings (12 to 18 percent reduction in fuel consumption) (*28*).

In Japan, automated truck platooning has been under development since 2008 (*29*). The project specifically examined potential energy savings and global warming prevention with ITS technologies. A platoon of three fully automated trucks drove at 80 km/h with the gap of 10 m on a test truck and along an expressway before public use, under not only steady state driving but also lane changing. The lateral control was based on the lane marker detection by the computer vision, and the longitudinal control was based on the gap measurement by 76 GHz radar and light detection and ranging (LiDAR), in addition to the inter-vehicle communications of 5.8 GHz dedicated short-range communications (DSRCs). The radar and LiDAR also worked as obstacle detectors. The feature of the technologies is the high reliability, aiming at the near future introduction. Fuel consumption measurement on a test track and along an expressway showed about a 14 percent reduction in fuel usage. The evaluation simulation showed the effectiveness of platooning with the gap of 10 m. A 40 percent penetration in heavy trucks showed a 2.1 percent reduction of CO_2 along the expressway.

Recently, FHWA and Auburn University teamed together with industry partners to develop and test automated truck platooning systems in a connected vehicle environment (*30*). The researchers will investigate partial automation—including throttle and braking systems—for two-truck platooning by integrating V2V communications and adaptive cruise control (ACC). Combining the communications system with ACC enables the following truck to travel at a close, yet safe, distance to the truck ahead. The technology, called cooperative ACC, uses radar for longitudinal sensing and DSRC to allow V2V communication. Trucking fleets will benefit from this system by reducing collision-related expenses, fuel costs, and emissions.

Land-Use Practices and Policies Promoting/Facilitating Freight Movement

Land-use practices and policies can promote and/or facilitate freight movement by better pairing the roadway infrastructure with the surrounding land uses.

Land-Use Planning

Integration of land-use policies and freight planning benefits both the public and private sector through reduced congestion, improved air quality and safety, enhanced community livability, improved operational efficiency, reduced transportation costs, and greater access to facilities and markets. Public agencies can encourage this balance through adoption of appropriate and coordinated land-use policies, effective transportation systems and services, effective operations and management policies of transportation infrastructure and terminals, and continuous education and outreach programs to engage community and industry representatives (*31*).

Table 5 lists various strategies or tools that have been tested for integration of freight planning with land-use policies. Various case studies are illustrated along with the goal of each of the strategies. Land use is generally planned and implemented at the local agency level using the comprehensive plan, zoning code, and permitting system. However, there is a growing realization among regional planning agencies like MPOs to leverage the linkages between land-use planning and freight transportation. As such, strategies and tools at the regional level involve guidance in locating major freight-generating uses (manufacturing centers, DCs, etc.) within the region, as well as gaining regional planning consensus and suggesting regionwide policies and approaches. Some strategies and tools implemented by regional agencies include scenario planning, preferential zoning, and tax relief programs.

FHWA encourages and supports scenario planning that is focused on transportation issues. From a freight perspective, changes in demographics (e.g., aging populations or changing population densities), advancements in alternative fuel technologies, fluctuations in fuel prices, climate change and associated policies, and an economic variability can result in radical changes in global supply chains, influencing where raw materials are sourced, where goods are produced, and where and how they are transported to consumer markets.

Table 5. Examples of Freight and Land-Use Integration Strategies and Tools (*31*).

Policy Area	Strategy/Tool	Case Study Examples	Goals
Appropriate and Coordinated Land Use Policies	Regional visioning and scenario planning	Pittsburgh Region "Power of 32"	Sets regional stakeholder goals and gain common understanding between different levels of government
	Incentives to reinvest in existing industrial space – e.g., tax credits	Connecticut Urban and Industrial Reinvestment Tax Credit Program	Offers tax credits as an incentive to (re)develop in urban and industrial areas, provided performance criteria are met
	Creating buffers around freight	Vancouver, Washington pedestrian bridge	Provides safe means for residents to traverse a freight facility
	Using zoning tools to preserve industry and limit freight impacts	Baltimore, Maryland Maritime Industrial Zone Overlay District (MIZOD) Layton City, Utah manufacturing (M) zoning code	Provides space for manufacturing where appropriate infrastructure and adjacent land uses exist, and protect industry from pressures to change use
	Promote context-sensitive site and building design features	Port of Seattle Central Waterfront Project mitigation	Reduces the noise and vibration, light, aesthetic, and local air quality impacts of freight facilities on neighboring land uses
Effective Transportation Systems and Services	Freight-exclusive facilities	I-5 Truck Lanes	Reduces the noise and vibration, light, aesthetic, and local air quality impacts of freight facilities on neighboring land uses
	Effective truck route networks	Arroyo Grande, California truck route network	Ensures truck routes avoid sensitive areas and link with truck routes in neighboring jurisdictions.
Effective Freight Operations and Management	Offering incentives for off-peak delivery	Boston downtown delivery hours	Spreads truck traffic times across a wider timeframe, as well as increase their efficiency because of decreased road congestion
Education and Outreach	Technical assistance to local jurisdictions	Atlanta, Georgia – Atlanta Regional Commission	Ensures that local land use policy-makers are informed of freight needs and can help codify freight and land use integration best practices

Scenario Planning

The Power of 32 is a regional visioning effort launched in 2009 in Pittsburgh, Pennsylvania, that recognized the needs of freight land uses. The process allowed every resident of the four-state (Pittsburgh, Maryland, Ohio and West Virginia) 32-county region and other stakeholders to participate in creating a shared vision for the region's best future. The region's vision includes strategies to help businesses find suitable development sites, including those with existing utilities and transportation facilities and/or in existing industrial or commercial areas. The Power of 32 effort is a good example of how statewide and regional agencies can work together to address multijurisdictional freight and land-use issues. It is also a good example of how private-sector freight stakeholders can participate in the process.

Tax Relief Programs to Preserve Freight-Dependent Land Uses

Tax incentives are another tool that states, regions, and municipalities can use to encourage the preservation of industrial activity on existing industrial sites. Such strategies can limit freight sprawl and associated impacts (*31*). The Urban and Industrial Sites Reinvestment Tax Credit Program in Connecticut is an example of an economic development tool that a state may develop to steer investment to urban centers, economically distressed communities, and existing or former industrial sites.

Zoning

Zoning can be used to guide the development of industrial land uses, such as new freight warehouses or intermodal facilities, near major highway access points. It is recommended to locate new warehousing facilities close to major truck routes, such as interstates. The closer these freight generators are to major highway infrastructure, the fewer miles trucks will need to move on local roads before moving onto highways. The same can be said for intermodal facilities. Airports, rail/truck terminals, and seaports should have proximate and adequate freeway access to avoid truck movements on local roads.

The specific zoning code usage in Layton City, Utah, provides an example of ensuring freight facilities located with appropriate access to infrastructure while avoiding sensitive land uses. The manufacturing/industrial zoning districts are intended to provide areas for manufacturing and industrial uses where they will have the necessary services and facilities and will minimize obtrusions by adjoining uses and districts. These districts shall be located near rail lines and shall be near interstate highway interchanges for ease of transportation of goods.

Creating Buffers between Industrial Land Uses and Other Land Uses

A buffer zone between freight-intensive activities and the rest of the community can insert space between two incompatible land uses. The buffer could lead to incremental increases in land-use intensity over a given area. Intermediate land uses, such as retail or office, may be located between freight-intensive land-use areas and sensitive areas such as residential areas and schools. The intermediate land uses should be less sensitive to industrial and freight activity and impose fewer impacts on sensitive areas. The use of buffers in this manner reduces noise and air quality issues that increase with proximity to heavy industrial and freight-heavy facilities (*31*). The construction of a bike/pedestrian bridge at a major rail yard in Vancouver, Washington, provides an example of how an investment in a pedestrian bridge can effectively connect neighborhoods and provide safe travel for residents over a busy freight facility.

Parking and Staging Areas

Smart Parking

Truck drivers face a critical shortage in truck parking due to a dramatic growth in commercial vehicle truck travel on the nation’s roads. Fatigued drivers who must drive to search for a parking place can become not only a roadway hazard but an environmental hazard because they generate unnecessary diesel emissions (*32*). Commercial truck drivers typically spend 30 minutes or more searching for a place to park their rigs (*33*).

Michigan DOT leveraged $4.48 million in funding from FHWA to develop and install Truck Parking Information and Management System (TPIMS). TPIMS is a smart truck parking network: a virtual environment where information about safe, secure, and convenient truck parking is available in real time to truck drivers. TPIMS is installed along a 129-mile stretch of I-94 in southwest Michigan (*33*). To collect accurate parking availability data, detection cameras and other sensors were deployed at rest areas and private facilities.

In another FHWA-sponsored project, Transportation Sustainability Research Center (TSRC) is partnering with Caltrans to explore possible roles for ITS in alleviating the truck parking problem. The I-5 corridor in California will serve as a test bed for the use of ITS technologies to determine parking availability at participating truck stops. This information, as well as truck stop amenities and the opportunity to make a reservation, will be transmitted to commercial vehicle drivers. This suite of information may allow truckers to better plan and to operate more efficiently when they can bypass a full truck stop and go directly to one that has space available. ParkingCarma[1] and Navigation Technologies Corporation (NAVTEQ[2]) are assisting TSRC with the parking availability, reservations, truck stop amenities, and routing. The information may be collected and disseminated through a variety of means including sensors, the Internet, mobile phones, changeable message signs, and radio.

Establish Staging Areas for Freight Delivery

The FHWA *Freight and Land Use Handbook* indicates that many stores and other facilities receiving shipments do not have staging areas or freight loading docks. Trucks making deliveries must park along the curb in a parking lot, which can impede traffic flow and cause congestion on the streets around the store. One solution calls for municipalities and other zoning authorities to require on-site, and, preferably, off-street staging areas for facilities and businesses that regularly receive freight shipments. In some cases, there may not be sufficient space for on-site/loading docks or parking areas. The establishment of common loading areas in multiple-tenant facilities, and/or regulations to effectively manage curbside truck parking may be more suitable solutions (*31*).

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[1] Smart parking information network that allows drivers to determine the real-time availability of parking spaces.
[2] A Nokia-acquired company that provides GIS data and base electronic navigable maps.

ASSESSMENT OF FREIGHT FLOW MANAGEMENT TECHNIQUES

BACKGROUND

This section assesses both traditional and non-traditional strategies for optimizing and managing freight flow in urban and rural corridors in Texas by leveraging the findings of the literature review. It provides a short list of freight management strategies that are feasible and can be readily implemented within Texas. In the next phase of this project, these strategies were modeled, and their operational impacts were studied and reported. Researchers assessed each strategy using the following criteria:

- Reasonableness and feasibility for deployment.
- Legislative and policy requirements to implement the strategies.
- Technology maturity and market penetration requirements.
- Design and operational integration requirements.

Researchers also considered the goals of TFMP and other various freight-related initiatives. This analysis resulted in the development of a short list to be further evaluated of potential freight management strategies through urban areas. Researchers presented these findings to the TxDOT 0-6851 project panel on November 5, 2015, at the Research and Technology Implementation offices in Austin.

FREIGHT MANAGEMENT STRATEGIES

The literature review identified 16 potential freight management strategies, which can be classified into the following categories:

- Lane- and route-based strategies.
- Time-of-day-based strategies.
- ITS/ATM related strategies.
- Connected vehicle and automated freight mobility applications.
- Land-use practices and policies promoting/facilitating freight movement.

Table 6 lists the freight management strategies identified. It is critical to understand each strategy and its implementation issues before selecting the applicable strategies for Texas. This section briefly discusses each of these strategies and their implementations nationwide.

Table 6. Relevant Freight Management Strategies Identified during Literature Review.

Freight Management Strategies Considered	
1.	**Lane- and Route-Based Strategies**
1.1.	Dedicated Truck Lanes
1.2.	TOT Lanes
1.3.	System-Level Toll
1.4.	Truck Route Designations
2.	**Time-of-Day-Based Strategies**
2.1	Incentivized OPD
2.2	Off-Peak Use of HOT/HOV Lanes
3.	**ITS/ATM Related Strategies**
3.1	Reliable Truck Route Information
3.2	Advanced Traveler Information
3.3	Dynamic Lane-Use Control
3.4	FSP
4.	**Connected Vehicle and Automated Freight Mobility Applications**
4.1	Truck Platooning
5.	**Land-Use Practices and Policies Promoting/Facilitating Freight Movement**
5.1	Land-Use Planning
5.2	Establish Staging Areas
5.3	Zoning
5.4	Smart Parking
5.5	Tax Relief to Preserve Freight-Dependent Land Uses

Lane- and Route-Based Strategies

Many freight-oriented traffic management techniques tend to be lane-based and route-based. These strategies attempt to segregate truck traffic from passenger vehicle traffic through either restricting use of specific lanes by commercial fleet vehicles or by providing special dedicated facilities.

Dedicated/Exclusive Truck Lanes

Segregation of truck traffic from passenger traffic by implementing separate or dedicated truck facilities in key economic corridors has the potential to mitigate operational and safety impacts by reducing car-truck interactions in terms of weaving and passing maneuvers. While only a few exclusive truck facilities have been constructed in the United States (e.g., the New Jersey Turnpike, Clarence Henry Truckway, South Boston Bypass, and Los Angeles I-5 truck bypass lanes), some of the initial research shows promising results in terms of improved travel speeds for trucks and improved safety for both trucks and cars (*13*, *14*, *15*, *34*).

Truck-Only Toll Lanes

A strategy that has been considered in several urban areas to aid truck traffic flow from major traffic generators is urban TOT lanes. TOT lanes were proposed on SR 60 and I-710 in Los Angeles, California; in Miami, Florida, where TOT lanes are intended to aid traffic getting into and out of busy ports; and in Atlanta, Georgia, to reduce urban traffic congestion and improve the mobility of freight to and through the region (*16*). TOT lanes have special design and configuration requirements compared to other toll facilities, including pavements to accommodate the heavier/overweight loads, staging areas for assembling and disassembling long combination vehicles, and on/off-ramps specifically designed for safe exit/access of trucks. The major challenge with TOT lane implementation is to find optimal system-level toll pricing that does not discourage use and unintentionally shift truck traffic to non-tolled facilities, through residential neighborhoods, or to facilities that are not adequate to support heavy truckloads.

System-Level Toll

Ideally, toll rates should be set in a way that maximizes toll revenues, achieves an acceptable level of service, achieves a high utilization rate, and diverts a significant number of trucks from local roads to the appropriate toll lanes. In reality, it is difficult to achieve all four of these objectives simultaneously since they may work against each other in some cases. For instance, if tolls are set higher than the travel time savings that truckers would realize by using the facility, it would discourage truckers from using the toll lanes, thus reducing demand and toll revenues without removing many trucks from the congested, non-tolled, general purpose (GP) lanes. Further, trucker utilization of toll lanes can also be affected by outside factors such as the value and time-sensitivity of their individual cargoes and/or driver hours-of-service limitations. An optimal toll strategy is one that provides system-level benefits with acceptable time savings and toll levels.

Truck Route Designations

In urban areas, truck traffic typically shares the roadway infrastructure with other modes (e.g., passenger vehicles, bicycles, and pedestrians) and creates some negative impacts, including congestion, emissions, noise, and safety concerns, for other types of road users and those in surrounding communities. Designating certain roadways as truck routes to concentrate most traffic along those routes is the most commonly implemented strategy employed by cities to manage freight transportation demand (*16*). Directing truck traffic on specific routes allows local regional governments to:

- Target infrastructure improvements to primary users by providing more generous turning radii and greater overhead clearance along designated truck routes.
- Reduce exposure of residents to noise, emissions, and vibration by identifying truck routes that avoid residential areas.
- Separate truck traffic from bicycles and pedestrians by reducing truck traffic on key arterials that serve as pedestrian and bicycle thoroughfares.

The literature has examples of various types of truck route restrictions that can allow cities to efficiently meet the needs of all modes of transportation (*18*, *19*). As an example, the cities of Berkeley, California; Phoenix, Arizona; and New York City, New York, currently each have varying forms of truck route designations employed by their respective state DOTs.

Before implementing truck route designations, it is critical to study current trends in truck movement and identify the routes with appropriate road geometries within the city to ensure efficient connectivity to downtown areas (*18*). All planning authorities with responsibilities for roads in the urban area and the freight transport industry should be involved in the process of identifying truck routes to ensure that they link key destinations, avoid sensitive populations, and are coordinated across jurisdictional boundaries. Additionally, truck routes should be clearly mapped and identified with road signs, and cities should consider adjusting signal timing along truck routes (increasing the yellow and green signal phases to meet increased acceleration and deceleration requirements) to improve the overall flow of truck traffic (*19*).

Time-of-Day-Based Strategies

This category involves implementing special management techniques that provide or facilitate travel by fleet operators during specific times of the day to improve both freight efficiency and reduce impacts of freight movement on passenger vehicle travel. Examples of these strategies include incentives to promote OPD and nonpeak hour use of HOV lanes. Both these strategies are discussed below.

Incentivized OPD or Time of the Day Pricing

Some successful freight management strategies require providing financial incentives for changing operations to permit off-peak traffic delivery times, such as providing reduced truck tolls during off-peak hours and/or free trips after several paid trips, as a means to reduce overall congestion and provide increased truck mobility and utilization. The PierPASS off-peak program at the Ports of Long Beach and Los Angeles offers a case study of how off-peak deliveries can work under the right set of circumstances. Under this program, all the international container terminals in the two ports established a night shift from 6:00 p.m.–3:00 a.m. (Monday–Thursday) and a weekend shift from 8:00 a.m.–6:00 p.m. (Saturday). To incentivize trucking companies to use these off-peak hours, a traffic mitigation fee is now required for all cargo movement during the peak traffic periods (3:00 a.m.–6:00 p.m., Monday–Friday). The response has been considerable, with 30–35 percent of the daily cargo movements, on average, switching to the OPD windows (*35*). This strategy is suitable for locations that do not have nighttime noise restrictions or residential areas without restrictions on truck operating hours. Accepting off-peak deliveries at a central receiving location could simplify the delivery process dramatically. New York City employs OPD at several commercial traffic generator locations, including sport complexes, convention centers, and universities (*6*).

Off-Peak Use of HOV/HOT Lanes

This strategy can leverage the existing infrastructure of HOT/HOV lanes by allowing access to trucks during off-peak periods. This practice can be especially effective in providing access routes/corridors to ports and other urban freight generators. This strategy may improve the freight flow through urban areas and incentivize shippers and trucking companies to shift their operations to move freight during off-peak periods when they may use these facilities. Although potential benefits in terms of congestion and safety of dedicated lanes are well known, limited studies have explored the benefits of using HOT/HOV lanes specifically for freight movement during off-peak hours.

ITS/ATM Related Strategies

ITS technology involves using technological advances (e.g., interlinked computers and communications, traffic signals) to make travel smarter, faster, safer, and more convenient. ITS makes travel more efficient and allows travelers to make informed decisions with respect to route, mode of travel, and other travel decisions. ITS strategies are integral in the freight industry because they help freight operators and shippers move commodities efficiently, reliably and in a cost-effective way to marketplace. Successful deployment of freight-related ITS technologies to benefit the freight industry will depend upon interagency cooperation and strong partnerships with industry stakeholders. ITS-related strategies involve the use of advanced technologies to provide fleet operators with information related to impending or developing traffic congestion. The following sections represent potential ITS strategies applicable in improving freight flows through urban areas.

Reliable Truck Route Information

The potential of reducing delay and generating cost savings on a per-mile basis within an urban area through implementation of ITS technology is much higher than on non-urban sections of intercity routes. Recent developments in ITS can be leveraged to provide pre-trip and en route information along urban truck routes to produce a more efficient and reliable freight flow management strategy by:

- Establishing reliable truck routes based on historic and real-time traffic information availability and data sharing between ports, railroad intermodal yards, and regional DCs (both pre-trip and en route information).
- Providing businesses and trucking companies with information on route closures and detours early enough for them to adjust routes or delivery schedules, if required (pre-trip information).
- Providing real-time information about incidents that will disrupt traffic operations and offering alternative route guidance using DMSs (both pre-trip and en route information).

Advanced Traveler Information for Truckers

The lack of freight-specific traveler information that could be provided through ITS has many negative effects on the freight industry, such as reduced efficiency in freight movement, less than optimal planning of daily truck activities, underperforming logistics management systems, increased energy consumption, and negative impacts on roadway safety and the environment. To improve information flow, U.S. DOT developed the FRATIS program to promote improved urban freight mobility. At a high level, FRATIS focuses on integrating regional ITS data, DOT commercial fleet data, third-party truck-specific movement data, and intermodal terminal data and disseminating them to various FRATIS applications. Implementing these systems has the potential to greatly improve the decisions made by both fleet operations planners and individual truck drivers and reduce congestion within urban areas. The three major FRATIS prototypes that are under development or functional are elaborated on in the literature review section of the report. U.S. DOT has also contracted with TTI to expand FRATIS capabilities on I-35 between Austin and Dallas.

Dynamic Lane-Use Control

This strategy involves dynamically closing or opening individual traffic lanes as warranted and providing advance warning of the closure(s) (typically through dynamic lane control signs), to safely merge traffic into adjoining lanes. This approach continuously monitors the freeway network, and real-time incident and congestion data are used to control the lane use ahead of the lane closure(s) and dynamically manage the location to reduce the potential of rear-end and other secondary crashes. Similarly, dynamic lane-use control can be used upstream of entrance ramps experiencing heavy truck demands to close lanes to automobiles to provide heavy vehicles with unimpeded access to the freeway.

Freight Signal Priority

FSP is another potential ITS application that has the potential to significantly improve freight operations. FSP involves providing preferential treatment (e.g., traffic signal priority) for freight and commercial vehicles traveling within an urban area or in a specific area of high-volume freight traffic such as near a port, railyard, or other freight generator. FSP reduce stops and delays to commercial vehicles at signalized intersections by extending the green signal when a truck is nearing the intersection. This practice can increase TTR for freight traffic, enhance safety at intersections, and provide environmental benefits by reducing acceleration and deceleration emissions for trucks.

Connected Vehicle and Automated Freight Mobility Applications

Connected vehicle technologies have the potential to significantly reduce or even eliminate the impact of millions of accidents every year. U.S. DOT, in coordination with major automakers and other public- and private-sector innovators, has been working to advance V2V and V2I communications technology to help prevent traffic crashes before they happen, improve mobility, and lessen the impacts of travel on the environment.

Automated and Driver Assist Truck Platooning Systems

One clear application of connected vehicle/automated vehicle technology is truck platooning, which uses V2V technologies to allow trucks to virtually link and follow very closely the truck in front of it. Caltrans and PATH have tested an automated truck platooning system on closed tracks as early as 2003 and have conducted real-world testing in Nevada in 2009. In both studies, researchers found that truck platooning resulted in significant fuel savings (12 to 18 percent reduction in fuel consumption) (*36, 29*). Another study on truck platooning showed that fuel consumption measurement on a test track and along an expressway can lead to fuel savings of about 14 percent and some reduction of CO_2 (*37*).

Land-Use Practices and Policies Promoting/Facilitating Freight Movement

Land-use practices and policies have the ability to promote and/or facilitate freight movement by better pairing the roadway infrastructure with surrounding land uses.

Land-Use Planning

Integration of land-use policies and freight planning benefits both the public and private sector through reduced congestion, improved air quality and safety, enhanced community livability, improved operational efficiency, reduced transportation costs, and greater access to facilities and markets. Public agencies can encourage this balance through adoption of appropriate and coordinated land-use policies, effective transportation systems and services, effective operations and management policies of transportation infrastructure and terminals, and continuous education and outreach programs to engage community and industry representatives (*31*). A list of various strategies or tools that have been tested for integration of freight planning with the land-use policies is included in the previous chapter. Various case studies have also been described, along with the goal of each of the strategies.

FHWA encourages and supports scenario planning that is focused on specific transportation issues. From a freight perspective, changes in demographics (e.g., aging populations or changing population densities), advancements in alternative fuel technologies, fluctuations in fuel prices, climate change and associated policies, and an economic variability can result in radical changes in global supply chains, influencing where raw materials are sourced, where goods are produced, and where and how they are transported to consumer markets.

Establish Staging Areas for Freight Delivery

The FHWA *Freight and Land-Use Handbook* (*31*) indicates that many stores and other facilities receiving shipments do not have adjoining staging areas or freight loading docks. As a result, trucks making deliveries must often park along the curb, which can impede traffic flow and cause congestion on the streets around the store. One solution calls for municipalities and other zoning authorities to require on-site, and preferably, off-street staging areas for facilities and businesses that regularly receive freight shipments. In some cases, there may not be sufficient space for on-site/loading docks or parking areas. The establishment of common loading areas in multiple-tenant facilities and/or regulations to effectively manage curbside truck parking may be better solutions.

Zoning

Land-use zoning can be used to guide the development of industrial land uses, such as determining appropriate locations for new freight warehouses or intermodal facilities near major highway access points. It is recommended that such facilities be located close to major truck routes, such as interstates. The closer these freight generators are to major highway infrastructure, the fewer miles trucks will need to move on local roads before moving onto highways. Airports, rail/truck terminals, and seaports should have proximate and adequate freeway access to avoid truck movements on local roads.

The specific zoning code usage in Layton City, Utah, provides an example of ensuring freight facilities located with appropriate access to infrastructure while avoiding sensitive land uses. The manufacturing/industrial zoning districts are intended to provide areas for manufacturing and industrial uses, where they will have the necessary services and facilities and minimize obtrusions by adjoining uses and districts. According to city code, these districts are required to be located near rail lines and shall be near interstate highway interchanges for ease of transportation of goods.

Smart Parking

Truck drivers face a critical shortage in truck parking due to a dramatic growth in commercial vehicle truck travel on the nation’s roads. Fatigued drivers who must drive to search for a parking place can become not only a roadway hazard but also an environmental hazard because they generate unnecessary diesel emissions (*32*). According to one study, commercial truck drivers typically spend 30 minutes or more searching for a place to park their rigs.

Michigan DOT leveraged $4.48 million in funding from FHWA to develop and install TPIMS. TPIMS is a smart truck parking network: a virtual environment where information about safe, secure, and convenient truck parking is available in real time to truck drivers. TPIMS is installed along a 129-mile stretch of Interstate 94 in southwest Michigan (*33*). To collect accurate parking availability data, detection cameras and other sensors were deployed at rest areas and private facilities.

Tax Relief Programs to Preserve Freight-Dependent Land Uses

Tax incentives are another tool that states, regions, and municipalities can use to encourage the preservation of industrial activity on existing industrial sites rather than moving to new, non-desired locations on the transportation network. Such strategies can limit freight sprawl and associated impacts (*31*). The Urban and Industrial Sites Reinvestment Tax Credit Program in Connecticut is an example of an economic development tool that a state or local government might develop to steer investment to urban centers, economically distressed communities, and existing or former industrial sites.

ASSESSMENT ACTIVITY AND OUTCOME

After identifying plausible freight management strategies and their effectiveness, researchers short-listed the freight management strategies that are feasible and can be readily implemented in Texas. To accomplish this goal, researchers examined each strategy for ease of implementation, relevant associated issues, potential for establishing performance measurements, and required policies and regulations related to the strategy. Researchers leveraged knowledge of subject matter experts within TTI and conducted an assessment poll using a ranking system for both (a) specific criteria identified in the project and (b) criteria listed in TFMP.

Criteria Based Assessment

A set of four criteria were used to assess each strategy. These included:

- Reasonableness and feasibility for deployment.
- Legislative and policy requirements to implement the strategies.
- Technology maturity and market penetration requirements.
- Design and operational integration requirements.

TTI subject matter experts were asked to rank each of the strategies using a ranking method where H equals high, M equals medium, and L equals low. For example, if the expert assessed that the deployment feasibility of a dedicated truck lane is high, then they entered H. Experts followed this process for all mentioned strategies and criteria.

In order to develop a single rating for each strategy per criterion from the seven subject matter expert assessments, researchers developed an averaging index to understand the disposition of ranking by the seven subject matter experts. For example, if 40 percent of the experts thought that the deployment feasibility of a strategy was high, and 50 percent thought it was medium, and 10 percent believed it was low, the general assessment is that the strategy was ranked as medium to high (M–H). If more than the threshold level (70 percent in our study) of the experts believed the deployment feasibility was of a particular rank, then it was assumed to be of that rank. For example, if 70 percent of experts believed deployment feasibility was high, then it was reported as high (H). If there was a tie in opinion on a criterion (e.g., 33 percent had H, 33 percent had M, and 34 percent had L for a strategy), then it was reported as no consensus. Table 7 shows the results of subjective ratings of freight management strategies using this set of criteria.

Next, researchers combined the results for each of the strategies and specific criteria to get an overall assessment of strategy. Table 8 shows the results of the overall assessment based upon criteria. This assessment was done by summing up the criteria results for each strategy and determining an overall score. If the results showed generally positive criteria, such as high deployment feasibility and low policy requirements, low technology or market penetration needs, and low operational requirements, then it was selected as a strategy with a strong beneficial impact. If a strategy required high market penetration and high significant efforts for legislative approval and design requirements were medium or low for deployment feasibility, it was assessed as having low beneficial impact. The strategies that had mixed ratings were assessed as moderate.

There are several caveats to consider about the criteria assessment presented in Table 8:

- The assessment is subjective and based on specific criteria.
- A technical or in-depth literature search would be required to more thoroughly assess each of these strategies.
- The scope of this task was limited and focused upon short-listing several strategies for advancement that did not allow time for performing a full assessment of national and international strategies.

The strategies that were assessed positive in terms of selected criteria were:

- Dedicated truck lanes.
- Truck route designations.
- Off-peak use of HOT/HOV lanes.
- Reliable truck route information.
- Advanced traveler information and smart parking.
- Tax relief to preserve freight-dependent land uses.

Table 7. Subjective Ratings of Freight Management Strategies Using Specific Criteria by Subject Matter Experts.

Freight Management Strategy	Deployment Feasibility	Legislative and Policy Requirement	Technology Maturity and Market Penetration Needs	Design and Operational Requirement
Lane- and Route-Based Strategies				
Dedicated Truck Lanes	H	H	L	M
TOT Lanes	M	H-M	M-L	M
System-Level Toll	H-M	H	NC*	H
Truck Route Designations	H	H-M	L-M	M
Time-of-Day-Based Strategies				
Incentivized OPD	H	M-H	M-L	M-H
Off-Peak use of HOT/HOV Lanes	H	M-H	L-M	M-H
ITS/ATM-Related Strategies				
Reliable Truck Route Information	H-M	L-M	M-L	L
Advanced Traveler Information	H	L-M	M-H	M-L
Dynamic Lane-Use Control	M	M-L	H-M	M-L
FSP	NC	M-L	M-L	M-H
Connected Vehicle and Automated Freight Mobility Applications				
Truck Platooning	M-L	H	H	H
Land-Use Practices and Policies Promoting/Facilitating Freight Movement				
Land-Use Planning	M-L	M-H	L	L
Establish Staging Areas	M-H	M-L	H-M	M-H
Zoning	L-M	H	L	L
Smart Parking	M-H	L-M	M-L	M-H
Tax Relief to Preserve Freight-Dependent Land Uses	M	H	L	L

NC*= No consensus

Table 8. Overall Assessment of Freight Management Strategies Based on Specific Criteria.

Freight Management Strategy	Overall
Lane- and Route-Based Strategies	
Dedicated Truck Lanes	+
TOT Lanes	~
System-Level Toll	0
Truck Route Designations	+
Time-of-Day-Based Strategies	
Incentivized OPD	~
Off-Peak use of HOT/HOV Lanes	+
ITS/ATM Related Strategies	
Reliable Truck Route Information	+
Advanced Traveler Information	+
Dynamic Lane-Use Control	0
FSP	~
Connected Vehicle and Automated Freight Mobility Applications	
Truck Platooning	0
Land-Use Practices and Policies Promoting/Facilitating Freight Movement	
Land-Use Planning	~
Establish Staging Areas	0
Zoning	~
Smart Parking	+
Tax Relief to Preserve Freight-Dependent Land Uses	+

~ Assessed Moderate
+ Assessed Positive
0 Assessed Low **(Needs more research)**

Assessment Based on Freight Mobility Plan Goals

Apart from assessing various strategies based upon the specific criteria, researchers also looked at the TFMP's listed goals (*38*). These goals are aligned with national freight goals and are consistent with the TxDOT 2015–2019 Strategic Plan and the Texas Transportation Plan 2040. TFMP coordinates many of the freight-planning activities across the state and will help Texas compete for federal transportation funds by meeting federal criteria and integrating existing state modal plans into a single statewide freight plan. Its nine goals and associated objectives are as follows:

- **Goal 1: Safety**—Improve multimodal transportation safety. The safety objectives are to:
  - Reduce rates of crashes, fatalities, and injuries on the Texas Highway Freight Network.
  - Increase the resiliency and security of the state's freight transportation system.
- **Goal 2: Asset Management**—Maintain and preserve infrastructure assets using cost-beneficial treatment. The asset management objectives are to:
  - Achieve and maintain a state of good repair for all freight transportation modes.
  - Improve the overall ratings of bridges on the Texas Highway Freight Network.
  - Improve the pavement conditions on the Texas Highway Freight Network.
  - Use technology to provide for the resiliency and security of the state's freight transportation system.
- **Goal 3: Mobility and Reliability**—Reduce congestion and improve system efficiency and performance. The mobility and reliability objectives are to:
  - Reduce the number of Texas Highway Freight Network miles at unacceptable congestion levels.
  - Improve TTR on the Texas Highway Freight Network.
  - Use the most cost-effective methods to improve system capacity (including technology and operations).
  - Partner with federal and Mexican officials to resolve border crossing challenges.
- **Goal 4: Multimodal Connectivity**—Provide transportation choices and improve system connectivity for all freight modes. Multimodal connectivity objectives are to:
  - Increase Texas supply chain efficiencies by improving connectivity between modes.
  - Improve first/last mile connectivity between freight modes and major generators and gateways.
  - Improve connectivity between rural and urban freight centers.
  - Improve access into and out of Texas' ports to facilitate projected future growth.
  - Improve ground access to cargo airports to enhance truck access and connectivity.
  - Improve highway and rail connectivity to major freight gateways and generators through increased capacity improvements or additional rail connections.
  - Improve connectivity to Texas-Mexico border crossings through increased modal options.
- **Goal 5: Stewardship**—Manage resources responsibly and be accountable in decision making. Stewardship objectives are to:
  - Lead efforts to foster greater coordination among the agencies responsible for freight system investment.
  - Reduce project delivery delays.
  - Coordinate project planning and delivery with all planning partners and stakeholders.
  - Reduce adverse environmental and community impacts of the freight transportation system.

- **Goal 6: Customer Service**—Understand and incorporate citizen desires in decision-making processes and be open and forthright in all agency communications. Customer service objectives are to:
  - Implement a performance-based prioritization process for freight system investment.
  - Develop and sustain partnerships with private-sector industries, communities, agencies, and other transportation stakeholders.
  - Increase freight expertise in TxDOT districts, across departments, and among elected officials.
  - Enhance workforce recruitment and retention in the transportation and logistics industry.
- **Goal 7: Sustainable Funding**—Identify and sustain funding sources for all modes. Sustainable funding objectives are to:
  - Identify potential public and private revenue sources to fund priority freight projects.
  - Identify and document the needed transportation investment costs to meet the state's future freight transportation needs.
  - Educate the public and stakeholders on the costs associated with constructing and preserving the freight transportation system.
  - Improve predictive capabilities for revenue forecasting and long-term needs assessments.
- **Goal 8: Economic Competitiveness**—Improve the contribution of the Texas freight transportation system to economic competitiveness, productivity, and development. Economic competitive objectives are to:
  - Strengthen Texas' position as a trade and logistics hub by improving and maintaining Texas Freight Network infrastructure and connectivity to enhance trade routes and increase the flow of goods.
  - Expand public-private partnerships to facilitate investments in freight projects that enhance economic development and global competitiveness.
  - Identify critical freight infrastructure improvements necessary to support the capacity requirements of future supply chain, logistics, and consumer demands.
  - Conduct outreach activities and develop an educational campaign to increase awareness of the importance of freight to the Texas economy.
  - Support strategic transportation investments to address the rapid increase in key industries, such as energy, agriculture, and automotive production.
- **Goal 9: Technology**—Improve the safety and efficiency of freight transportation through the development and utilization of innovative technological solutions. Technology objectives are to:
  - Integrate existing traffic management centers (TMCs) to facilitate statewide dissemination of real-time traveler information to improve safety and TTR.
  - Support development and deployment of integrated border crossing management through the integration of ITS systems across international borders.

- Support deployment of innovative technologies to enhance the safety and efficiency of the Texas Freight Network.
- Improve management and operations of the existing transportation system to enhance freight network performance and to improve safety and TTR.

Seven out of nine goals in the TFMP were selected to assess the freight management strategies identified. The asset management goal and stewardship goal seemed to be operational level goals that were inconsistent with this planning-level exercise. Further, it was challenging for subject matter experts to rate these goals; for efficient assessment of the strategies, researchers used the remaining seven goals that were more easily understood and ratable. Table 9 shows the results of this assessment. The methodology used to narrow down the ratings of the strategies with respect to TFMP goals is the same as described in the earlier section.

Table 9. Assessment of Freight Management Strategies Using TFMP Goals by Subject Matter Experts.

Freight Management Strategy	Safety	Mobility and Reliability	Multimodal Connectivity	Customer Service	Sustainable Funding	Economic Competitiveness	Technology
Lane- and Route-Based Strategies							
Dedicated Truck Lanes	H-M	H	M	H-M	L	H	M
TOT Lanes	H-M	H	M-H	M	H	H-M	H-M
System-Level Toll	L	H-M	NC	M-L	H	NC	H-M
Truck Route Designations	H-M	H-M	M-H	M-H	L	M-H	H-M
Time-of-Day-Based Strategies							
Incentivized OPD	M-H	H	L-M	M-H	L	M-H	NC
Off-Peak use of HOT/HOV Lanes	H-M	H	H-M	M	H-M	H-M	M
ITS/ATM Related Strategies							
Reliable Truck Route Information	M	H	H-M	M-H	L	M-H	H-M
Advanced Traveler Information	M	H	H-M	M-H	L	H-M	H-M
Dynamic Lane-Use Control	M	M-H	L	M-H	L	L-M	H-M
FSP	M	M-H	M-L	M-L	L	L-M	M-L
Connected Vehicle and Automated Freight Mobility Applications							
Truck Platooning	M	H-M	M-L	M	L	M-L	H-M
Land-Use Practices and Policies Promoting/Facilitating Freight Movement							
Land-Use Planning	NC	H-M	H-M	M-H	M-L	M-H	M
Establish Staging Areas	M-H	H	H-M	M-H	L	M-L	L-M
Zoning	NC	H-M	H	M-H	M	H-M	L-M
Smart Parking	M-H	M	L	H-M	M-L	L-M	H
Tax Relief to Preserve Freight-Dependent Land Uses	NC	H-M	H	H-M	M-L	M-H	L

Table 10 lists the overall assessment of freight management strategies based on TFMP goals. Freight management strategies such as dedicated truck lanes, TOT lanes, and truck route designations, off-peak use of HOT/HOV lanes, reliable truck route information, advanced traveler information, and land-use planning zoning meet most of the expectations of these seven goals. The strategies that were assessed as moderate means they do not meet all seven goals to the extent that strategies that were assessed positive do. This assessment does not necessarily mean that the moderate strategies do not meet any of the TFMP goals.

Table 10. Overall Assessment of Freight Management Strategies Based on TFMP Goals.

Freight Management Strategy	Overall
Lane- and Route-Based Strategies	
Dedicated Truck Lanes	+
TOT Lanes	+
System-Level Toll	~
Truck Route Designations	+
Time-of-Day-Based Strategies	
Incentivized OPD	~
Off-Peak Use of HOT/HOV Lanes	+
ITS/ATM Related Strategies	
Reliable Truck Route Information	+
Advanced Traveler Information	+
Dynamic Lane-Use Control	~
FSP	~
Connected Vehicle and Automated Freight Mobility Applications	
Truck Platooning	~
Land-Use Practices and Policies Promoting/Facilitating Freight Movement	
Land-Use Planning	+
Establish Staging Areas	~
Zoning	+
Smart Parking	~
Tax Relief To Preserve Freight-Dependent Land Uses	~

+ Assessed Positive
~ Assessed Moderate

Overall Assessment of Strategies

The final goal was to complete the short list of freight management strategies that are feasible and can be implemented in Texas. Table 11 provides the combined overall assessment based upon both specific criteria and TFMP goals. Strategies such as dedicated truck lanes, truck route designations, off-peak use of HOT/HOV lanes, reliable truck route information, and advanced traveler information seem to rank highest and be the most appropriate for Texas based upon these evaluations.

Table 11. Assessment Based on Specified Criteria and TFMP Goals.

Freight Management Strategy	Overall
Lane- and Route-Based Strategies	
Dedicated Truck Lanes	+
TOT Lanes	~
Truck Route Designations	+
Time-of-Day-Based Strategies	
Incentivized OPD	~
Off-Peak use of HOT/HOV lanes	+
ITS/ATM Related Strategies	
Reliable Truck Route Information	+
Advanced Traveler Information	+
FSP	~
Land-Use Practices and Policies Promoting/Facilitating Freight Movement	
Land-Use Planning	~
Zoning	~
Smart Parking	~
Tax Relief to Preserve Freight-Dependent Land Uses	~

+ Assessed Positive

~ Assessed Moderate

Another challenge to short-listing a group of these strategies is determining the ability to appropriately model them and their applicability to specified urban areas within the state. Table 12 shows modeling and strategy applicability assessment done by researchers in urban areas. The results of this analysis follows.

Dedicated truck lanes and TOT lanes can be modeled using dynamic traffic assignment (DTA) or multiresolution modeling (MRM) depending on whether they are barrier separated or not. DTA models can be used to model strategies such as truck route designations, off-peak use of HOT/HOV lanes, reliable truck route information, advanced traveler information, land-use planning, and zoning. Strategies such as incentivized OPD, land-use planning, and zoning can be modeled either by sketch planning or DTA models. Sketch planning models are deterministic and do not account for uncertainty in traffic conditions; however, they are good for quick, large-scale analysis. Tax relief to preserve freight-dependent land uses can only be performed by sketch planning tools, whereas the FSP strategy can be modeled only in microsimulation platforms, such as VISSIM, AIMSUN, and others.

Assessment of freight strategy applicability in a particular urban area (as shown in Table 12) is based on urban dynamics, available infrastructure, traffic conditions, and existing trends. For example, FSP may be viable and effective near a port or freight facility terminals in Houston. Similarly, a tax relief freight management strategy for El Paso would probably require consideration of transportation reinvestment zones (TRZs).

Table 12. Assessment Based on Modeling Feasibility and Strategy Applicability in Urban Areas.

Freight Management Strategy	Modeling Feasibility	Strategy Applicability			
	DTA/MRM/Sketch/Micro	AUS	ELP	HOU	DFW
Lane- and Route-Based Strategies					
Dedicated Truck Lanes	MRM*	No	No	Yes	Yes
TOT Lanes	MRM*	No	No	Yes	No
Truck Route Designations	DTA	Yes	Yes	Yes	Yes
Time-of-Day-Based Strategies					
Incentivized OPD	DTA/Sketch	Yes	Yes	Yes	Yes
Off-Peak Use of HOT/HOV Lanes	DTA	No	No	Yes	Possible
ITS/ATM Related Strategies					
Reliable Truck Route Information	DTA	Yes	Yes	Yes	Yes
Advanced Traveler Information	DTA	Yes	Yes	Yes	Yes
FSP	Micro	Yes	No	Yes^	No
Land-Use Practices and Policies Promoting/Facilitating Freight Movement					
Land-Use Planning	Sketch/DTA	Yes	Yes	Yes	Yes
Zoning	Sketch/DTA	Yes	Yes	Yes	Yes
Smart Parking	MRM	Yes	Yes	Yes	Yes
Tax Relief to Preserve Freight-Dependent Land Uses	Sketch	Yes	Yes**	Yes	Yes

*Depends on whether they are barrier separated: if yes, then can use DTA, if not, then need MRM.
**May need to consider TRZs already in place—research needed on this.
^ Around port or freight facility terminals.

CONCLUSIONS

Typical freight management strategies can be classified into the following categories:

- Lane- and route-based strategies.
- Time-of-day-based strategies.
- ITS/ATM related strategies.
- Connected vehicle and automated freight mobility applications.
- Land-use practices and policies promoting/facilitating freight movement.

The strategies that seem to be positive in terms of researchers' analysis of deployment feasibility, legislative and policy requirements, technology maturity and market penetration needs, and design and operational requirement are:

- Dedicated truck lanes.
- Truck route designations.
- Off-peak use of HOT/HOV lanes.
- Reliable truck route information.
- Advanced traveler information and smart parking.
- Tax relief to preserve freight-dependent land uses.

The strategies that meet most of the expectations of the selected goals of the TFMP (safety, mobility and reliability, multimodal connectivity, customer service, sustainable funding, economic competitiveness, technology) are:

- Dedicated truck lanes.
- TOT lanes.
- Truck route designations.
- Off-peak use of HOT/HOV lanes.
- Reliable truck route information.
- Advanced traveler information.
- Land-use planning zoning.

Strategies that are most effective based on combined ranking of both selected criteria and TFMP goal applicability are:

- Dedicated truck lanes.
- Truck route designations.
- Off-peak use of HOT/HOV lanes.
- Reliable truck route information.
- Advanced traveler information.

DTA modeling can be used to model most of the presented freight management strategies. MRM can only be used if dedicated truck lanes and TOT lane scenarios are not the barrier-separated forms of these strategies. Sketch planning tools should be used for determining the effectiveness of OPD and land-use strategies, whereas FSP can only be modeled in a microsimulation platform.

Researchers believe the assessment performed during this task was effective in developing a short list of potential freight management strategies but advise consideration of the following caveats:

- Assessment is subjective and based on specified criteria described in this report.
- In-depth literature/technical review would be required to more fully assess some of the strategies.
- Scope was limited and dealt with development of a short list of a few strategies for more detailed analysis.
- TTI subject matter experts did the assessment, and further TxDOT district staff input may be needed for determination of strategy applicability in selected Texas urban areas.

MODEL DEVELOPMENT

DATA TYPES AND PROCESSING REQUIREMENTS

This section documents the existing and new data sources that were explored to perform the required analysis of potential freight management strategies through urban areas. Researchers used the available data to calibrate and validate model baseline conditions of DTA models and to perform any sketch planning analysis, as needed. Two types of traffic data needs were envisioned for this project to conduct the model calibration: speed and volume data. Speed data were used to perform visual inspections of speed patterns on major corridors for each major city being analyzed. This process ensured that the modeled behavior represents current traffic conditions (e.g., hot spots). Daily average vehicle volume served as the baseline to calibrate the regional models. This calibration allowed researchers to compare and reduce the absolute percent error between the simulated traffic and the screen line data at different locations (e.g., major arterials, highways, and freeways) throughout the region. In addition, commodity data for the Houston region were analyzed to determine the traveling characteristics of trucks in large metropolitan areas. Researchers investigated data availability and evaluated their appropriateness for modeling.

Roadway Highway Inventory Network Offload Data

The Roadway Highway Inventory Network Offload (RHiNo) data set is maintained and routinely updated by the Transportation Planning and Programming Division (TPP) of TxDOT to support planning and other functions at TxDOT. The RHiNo data set is a part of the Texas Reference Marker legacy data system and a more advanced data system known as the Geospatial Roadway Information Database. Currently, the RHiNo data set includes over 96,000 state highway records that include 137 highway attributes representing a wide range of items. Examples include reference marker displacement, highway status and type, functional classification, maintenance responsibility, AADT over the last 10 years, truck percentage, urban/rural status, shoulder width, median width, roadbed width, posted speed limit, surface type and characteristics, and load limits (*39*). Originally, RHiNo data only included information about on-system roadways. The current RHiNo data also include relatively comprehensive coverage of off-system roadways. Researchers requested and acquired 2013 RHiNo data sets from TxDOT, which were available during the beginning of this task in March 2015.

Researchers evaluated the RHiNo data set and considered its suitability for model calibration purposes. The RHiNo data set has extensive data on traffic volume (e.g., current and historic AADT) and traffic composition (e.g., truck percentages) over homogenous roadway segments, which are critical for model calibration. However, there are two caveats with the RHiNo data:

- The traffic data are taken from a limited number of statewide automatic traffic recorder (ATR) sites and generally extrapolated over many roadway segments between sites and long corridors, which may not accurately reflect field data at specific locations.
- The directional distribution factor (D-factor) in the RHiNo database does not provide direction-specific information. For example, the database provides the value of the D-factor as 54 percent on a particular roadway segment but does not indicate the direction to which the percentage applies. According to TxDOT staff, the traffic counts are performed at a two-directional level and summed to a centerline total. Hence, there is no way to get the volume data by roadway direction.

However, the RHiNo data are helpful for planning purposes by providing insights into traffic patterns, particularly freight traffic. For example, Figure 8 shows the roadways' percentage of truck traffic in comparison to the total traffic within Texas. The red lines show routes where truck traffic is more than 30 percent of total traffic. Although the truck traffic appears to be high on rural or long corridors, trucks also cause congestion on urban arterials and local roads due to high demand on city streets.

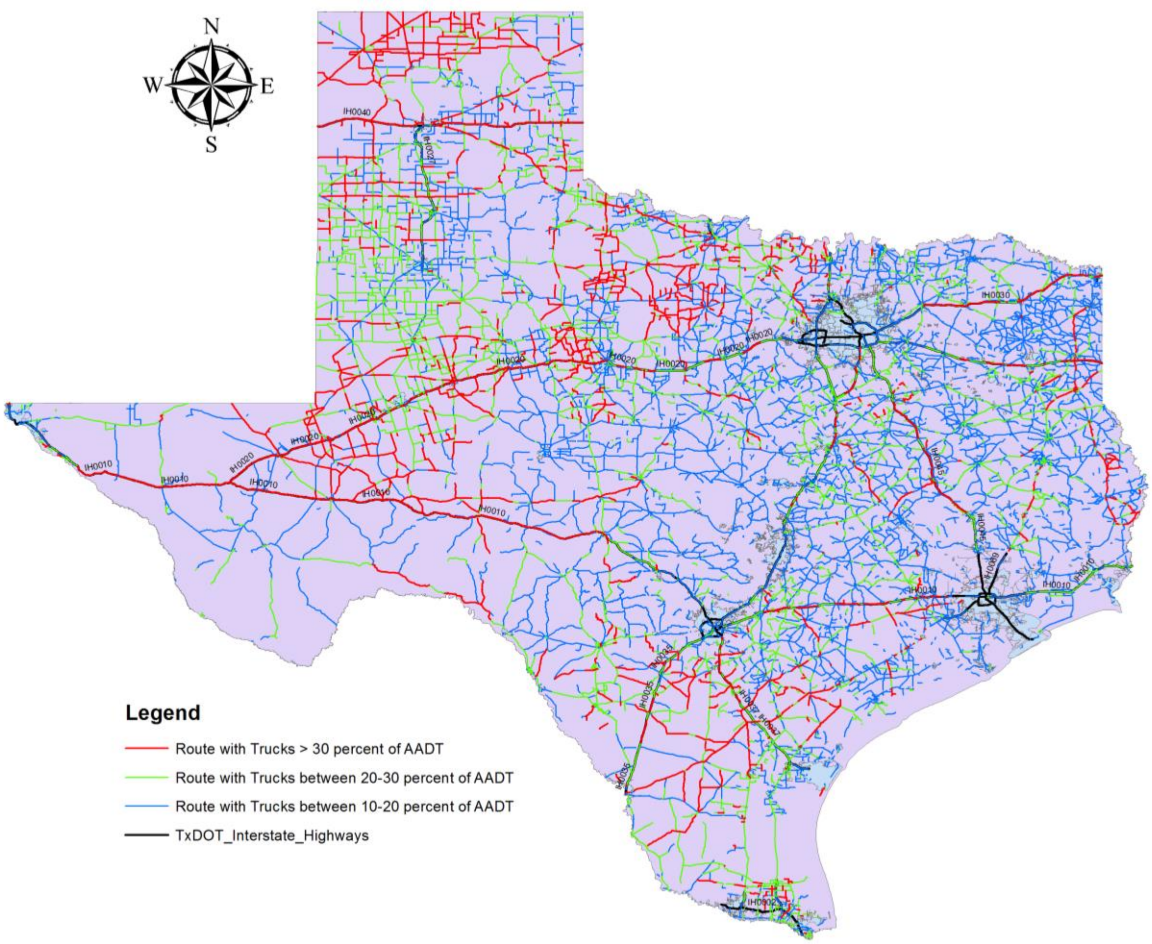


Figure 8. Texas Roadways with Truck Percentages Relative to AADT.

Speed Data

Although, the RHiNo data set provides a lot of planning-level information, it does not have traffic operational data, such as traffic speed. Researchers leveraged the 2013 INRIX®[3] speed data that were used to create the 2014 Texas' Most Congested Roads list (*40*). During the start of this task, only 2013 INRIX speed data were available that were also consistent with 2013 RHiNo data acquired by researchers. These speed data were used for identifying traffic and freight bottlenecks and validating the calibrated regional models. The speed data were available for all passenger and truck traffic in Austin, Houston, El Paso, and the DFW region. Researchers developed geographic information system (GIS)-based visual speed maps for Austin, Houston, and the DFW region by combining the 2013 RHiNo data set with the 2013 INRIX speed data. Figure 9 shows the detailed process to create color-coded maps for each region.

[3] INRIX is a registered trademark of INRIX, Inc.

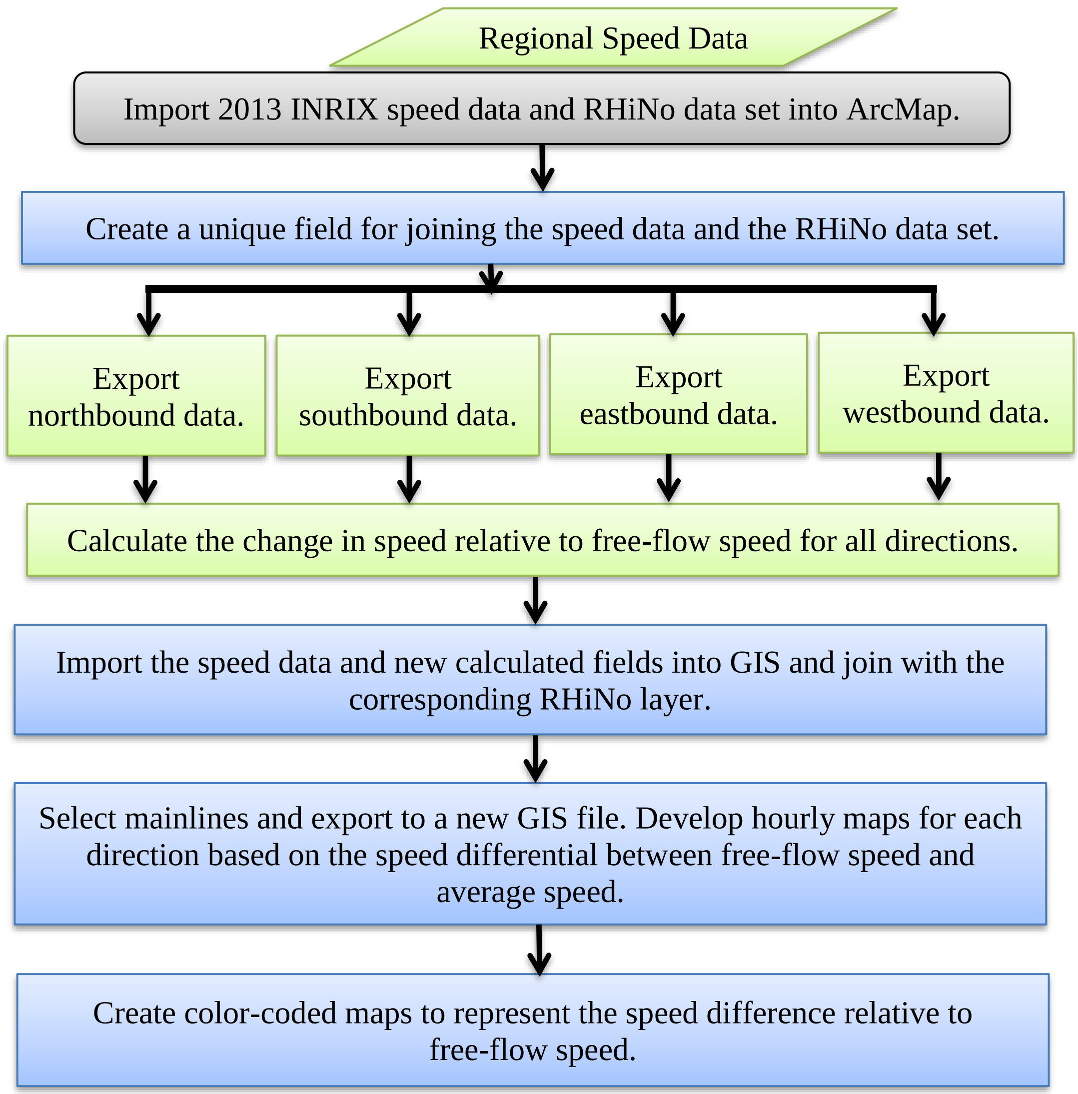


Figure 9. Data Processing To Create Color-Coded Speed Maps for All Cities.

A visualization approach was used to represent truck traffic speed within the region in the form of time/space/speed diagrams (also known as heat diagrams). The truck speed data were combined with RHiNo segments to develop color-coded maps. The color-coded road segments were shown separately to avoid overlap of color on any opposite segments and for ease in differentiating directional speed. Figure 10 shows the color-coding scheme for traffic speeds adopted in this study. The speed segments were coded green if the difference between free-flow speed and average speed during a particular time slice was less than 10 mph. Furthermore, if the difference was between 10 and 30 mph, the speed was coded orange. Higher speed discrepancies (e.g., more than 30 mph) were coded red. This scheme allowed researchers to quickly identify and visualize hot spots at major arterials/freeways/highways and validate current traffic conditions with the modeled baseline scenarios. In addition, each link/corridor in the map has existing speed information by time of day for model calibration and verification.

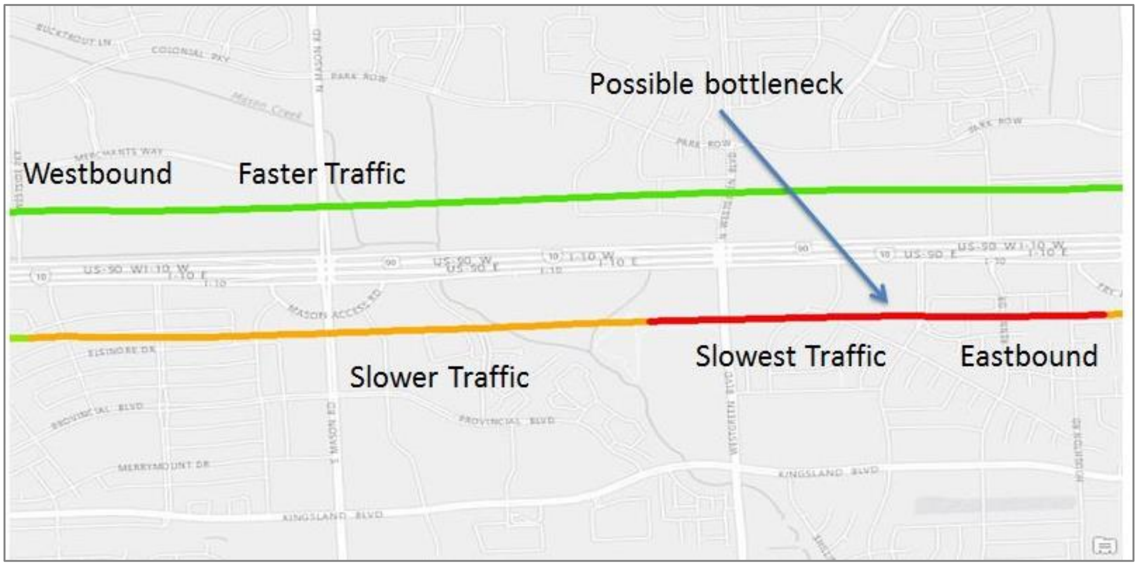


Figure 10. Color-Coding Scheme for Traffic Speeds.

Data Processing

The data were post-processed and combined to develop directional, color-coded speed maps for Austin, Houston, and the DFW region. The INRIX speed data were processed for each RHiNo segment for 15-minute periods for the average weekday (an average of Tuesday, Wednesday, and Thursday) between 5:00 a.m. and 9:00 p.m. The supplemental volume data were used where the traffic detectors did not have any volumes or speed information. In order to develop the regional maps, the route ID, beginning mile point, and ending mile point were used to confirm the road segments.

The speed data were joined with RHiNo segments using unique identifiers, such as the distance from origin field and route ID (RIA_RTE_ID). The FROM_DFO and TO_DFO fields in the RHiNo data set do not specify directionality. As a result, researchers had to manually post-process the data to include directionality. Next, the speed data were filtered for freeway mainlines and major corridors to reduce data representation complexity and improve map readability.

Separating and translating the RHiNo file into north, south, east, and west directions have some advantages, including reduced file size and faster processing. Moreover, color-coded speed differentials could be separated by direction using the offset function. This process was helpful for researchers because road congestion might differ at different times of day and by direction. The specific details of post-processing and translating the speed data are in Appendix A.

Map Development

Figure 11 shows how speed was separated to show directionality in the maps. The northbound (NB) traffic is shown on the right side of the centerline, the southbound (SB) traffic is shown on the left, the westbound (WB) traffic is shown on the top, and the eastbound (EB) traffic is shown on the bottom.

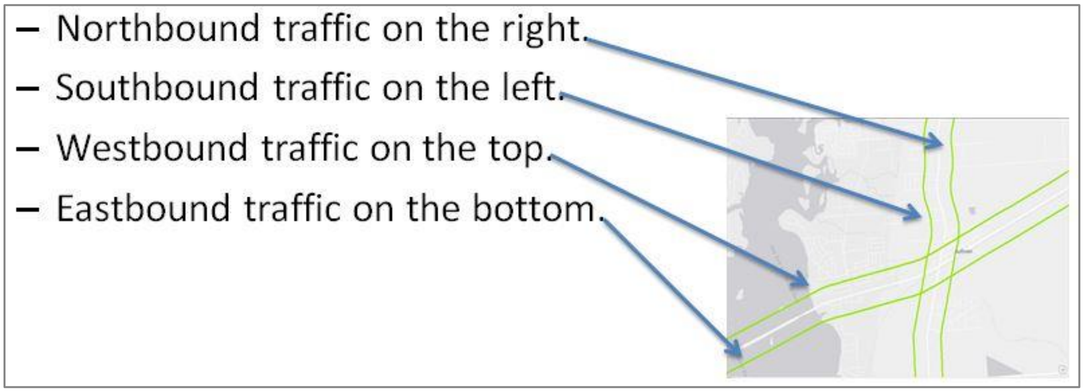


Figure 11. Map Representing Speeds by Direction.

Figure 12 shows an example of a color-coded speed map representing truck speeds for Houston during a particular hour of the day. These types of maps were created for an average weekday with hourly data between 5:00 a.m. and 9:00 p.m. A portion of the hourly speed segments analyzed may show some inaccuracies due to lack of data for that particular segment/hour. Therefore, discretion should be applied when interpreting the speed maps used for model validation. Each link/corridor has average speed information by time of day for verification.

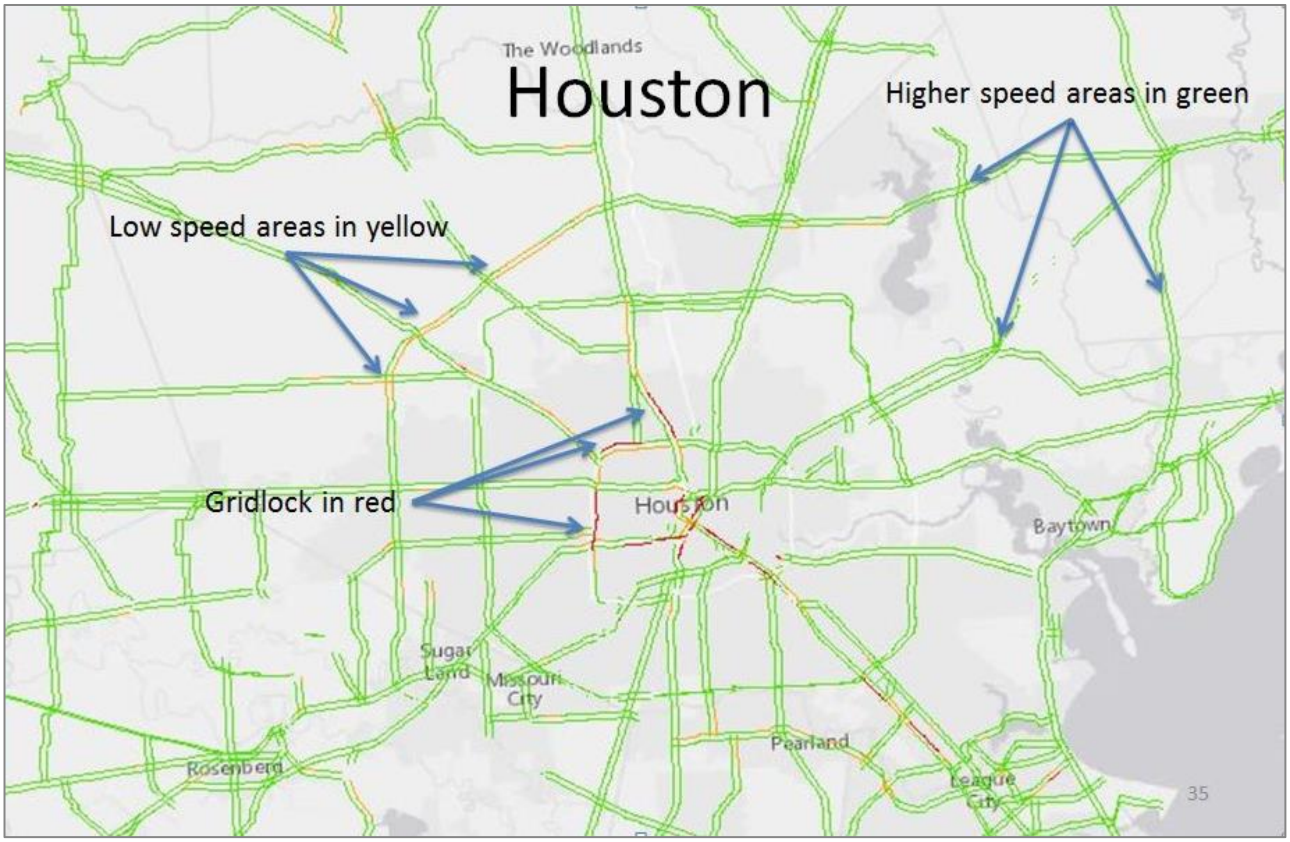


Figure 12. Time-Dependent Truck Speeds—Houston Region.

Volume Data

TTI researchers requested and obtained volume detector data for Austin, Houston, and the DFW region. The detector data for each of these cities come from roadway detectors, such as the nearly 300 Wavetronix sensors within the Dallas District, and loop detectors, or ATRs. Researchers understand that TPP uses most of the ATR data to extrapolate average daily traffic (ADT) on all the RHiNo segments within Texas. Further, researchers leveraged 24-hour field counts (in El Paso), 8-hour counts on the corridors and ramps (in Houston), and other available data to develop a more realistic picture of the traffic.

Researchers weighted the reliability and accuracy of volume data based on the data sources. The field volume data (where available) were considered the most accurate, followed by detector data, and then RHiNo data. Researchers short-listed available detectors based on data quality checks performed as part of monitoring efforts by TTI urban offices. The ADT information in the RHiNo data is developed and maintained by TPP, which uses detector data to extrapolate the traffic volume on nearby corridors. The lack of documented procedures for extrapolation of detector data in RHiNo and lack of confidence in the ADT volumes on longer corridors led researchers to consider RHiNo data only for filling in the gaps from missing data.

Field Count Data

The TTI El Paso office recently performed traffic counts for the City of El Paso as part of its MPO effort, which can be leveraged for model calibration. Traffic counts were located on major traffic volume highways and arterials. Figure 13 shows the count locations in El Paso. The daily traffic data were collected by three mechanisms:

- Using pneumatic road tubes connected to a mechanical counter.
- Manually counting the vehicles at each site.
- Using a camera traffic recorder.

The traffic counts were conducted for 24 hours and classified as either passenger cars or trucks. Table 13 shows the results of these counts at various locations.

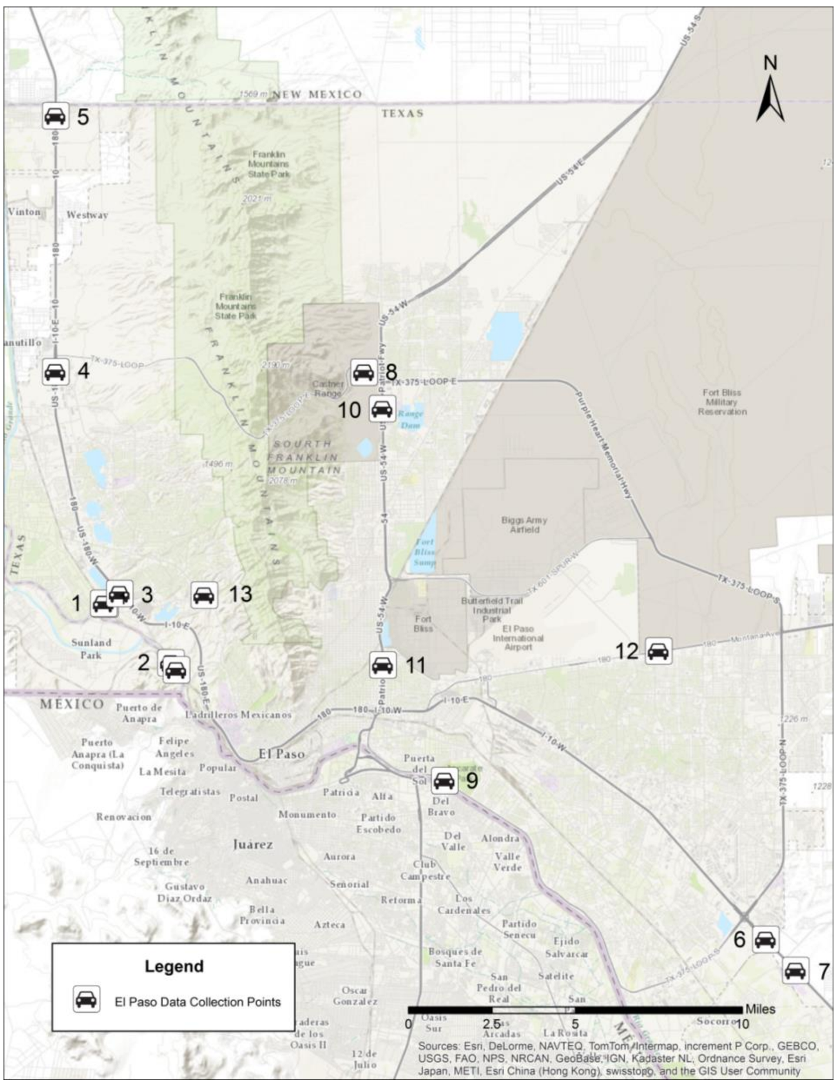


Figure 13. El Paso Traffic Count Locations.

Table 13. Results of the Data Collected at Each Location in El Paso.

Station Number	Street Name	Direction	24-Hour Vehicle Count (2014) Passenger Cars	Trucks
1	Doniphan at Atlantic	SB	8,485	25
		NB	13,608	38
2	Paisano at Cemex Plant	EB	13,207	40
		WB	18,658	56
3a	I-10 at Resler	EB	43,911	5,515
		WB	48,260	5,169
3b	I-10 at Resler Ramp	EB	11,831	91
		WB	12,609	88
4a	I-10 at Transmountain (Loop 375)	EB	21,865	4,609
		WB	22,351	4,173
4b	I-10 at Transmountain (Loop 375) Ramp	EB	3,537	112
		WB	3,822	115
5a	I-10 at Antonio	EB	9,116	2,688
		WB	11,790	2,428
5b	I-10 at Antonio Ramp	EB	4,079	626
6a	I-10 at Horizon	EB	6,949	3,199
		WB	7,085	3,058
6b	I-10 at Horizon Ramp	EB	1,424	1,181
		WB	1,167	920
7a	I-10 at Eastlake	EB	22,222	4,485
		WB	19,254	3,050
7b	I-10 at Eastlake Ramp	EB	5,525	266
		WB	8,083	1,094
8a	Transmountain (Loop 375) at US 54	EB	4,343	258
		WB	4,005	210
8b	Transmountain (Loop 375) at US 54 Ramp	EB	6,708	173
		WB	6,522	127
9a	César Chávez (Loop 375) at Fonseca	EB	15,036	1,120
		WB	18,006	1,416
9b	César Chávez (Loop 375) at Fonseca Ramp	EB	3,150	138
		WB	2,960	112
9c	César Chávez (Loop 375) at Fonseca Toll	EB	440	0
		WB	878	1
10a	US 54 at Diana	SB	29,190	985
		NB	32,936	909
10b	US 54 at Diana Ramp	SB	2,018	28
		NB	1,553	17
11a	US 54 at Trowbridge	SB	27,165	1,270
		NB	20,974	1,153
11b	US 54 at Trowbridge Ramp	NB	6,539	119
12	Montana at Lee Trevino	EB	22,935	592
		WB	22,926	486
13	Mesa at Festival	SB	20,465	273
		NB	20,757	193

Detector Data

Researchers also obtained an inventory of detectors in Austin, Houston, and the DFW region to filter the non-functional detectors from the list. Researchers short-listed functional detectors based on data quality checks performed as part of monitoring efforts by TTI urban offices. Traffic data from functional detectors were requested and processed. A weekly average of hourly volumes was calculated after excluding federal holidays for all stations. Figure 14 shows the locations of detectors in the Austin metropolitan area that collect traffic data.

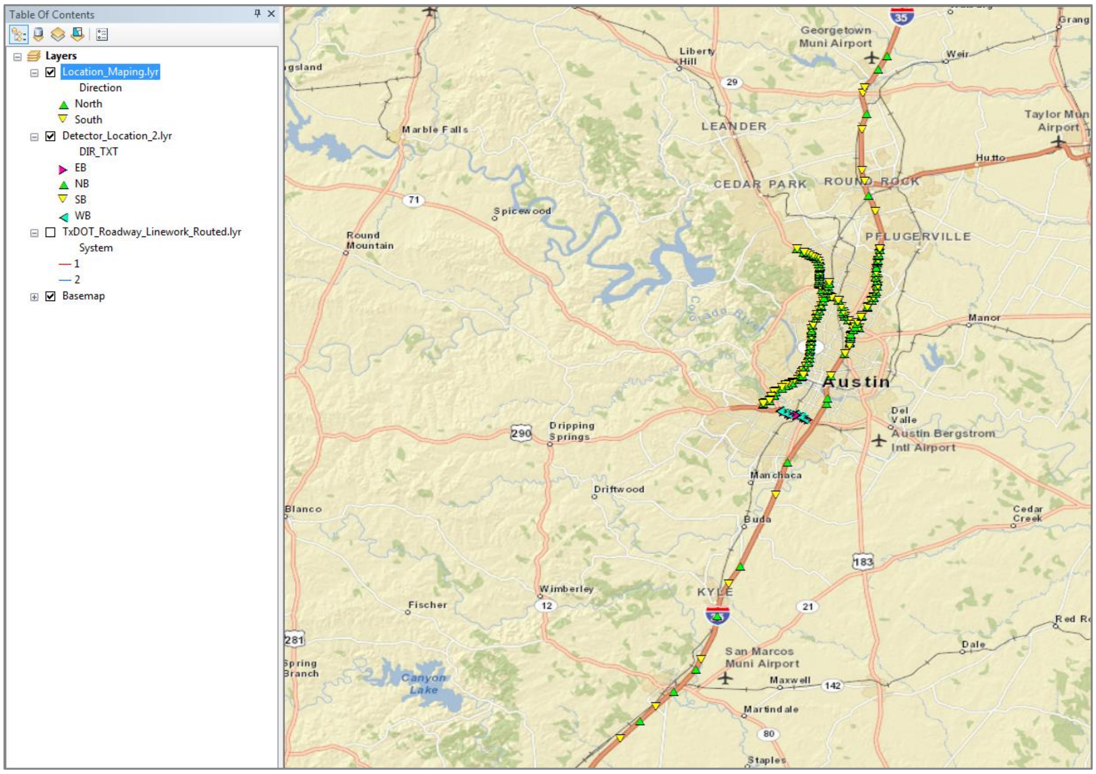


Figure 14. Location of Detectors in Austin by Direction.

For Houston, researchers identified the current radar locations where manual main lane classification counts were performed for 8 hours to update the truck lane restriction effort in 2012 and 2013. Figure 15 shows the location of radar (or traffic detectors) and field counts in Houston. Figure 15 does not represent the exact locations of the detectors; the markers are placed near the intersection based on which detector is identified. However, there are multiple caveats with this data set related to detector reliability; a list of issues is in Appendix B.

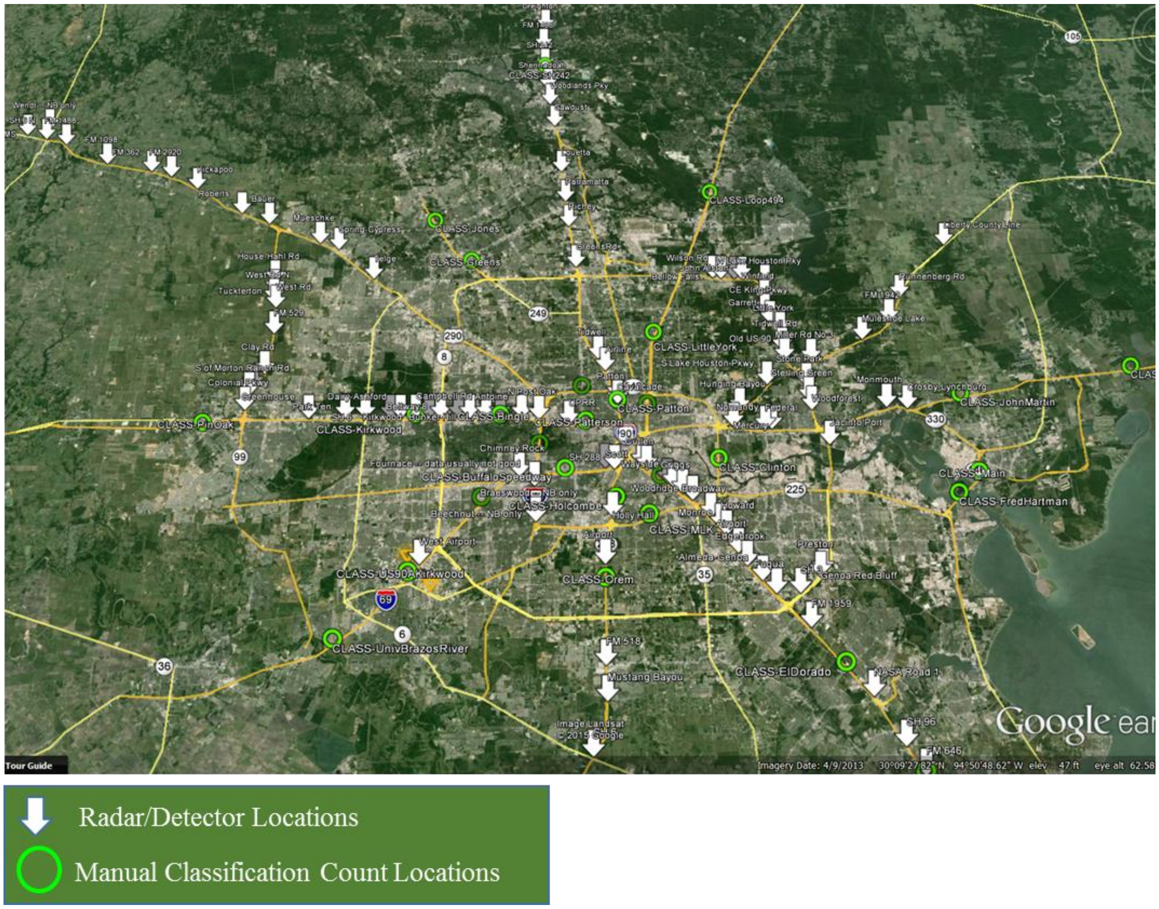


Figure 15. Radar/Detector and Manual Classification Count Locations—Houston Region.

Data Processing

Post-processing of volume data was done using Microsoft Access and Excel® depending on the size of data. Figure 16 shows the methodology used to process and import the detector data. The data set for Austin was obtained in a spreadsheet format, which included passenger cars and truck volumes, truck percentages, and hourly average speeds for 2013. The DFW region and Houston data sets were provided with speed and traffic volume only. Researchers developed pivot tables from all the data sets that were later imported into the GIS.

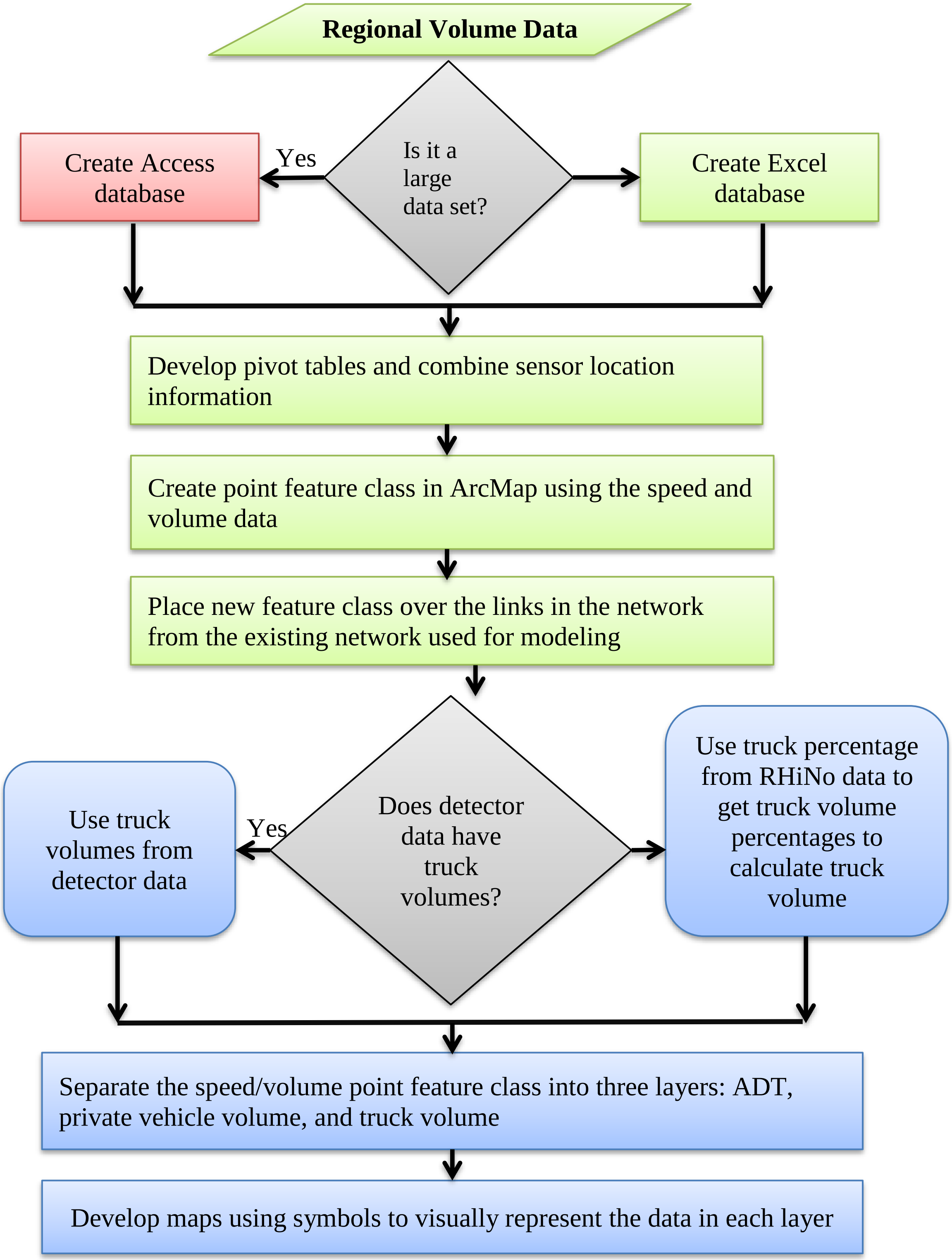


Figure 16. Data Processing for Volume Data from Detectors.

Map Development

Figure 17 shows an example of post-processed maps for Houston. On the left side of the map, there are several layers that represent different features of the data set:

- The first set of layers shows the traffic volume measured from the detector data.
- The second set shows color-coded hourly speed data.
- The third set shows the base maps for Houston.

The first three layers of the volume data set consist of measured and calculated detector traffic volume data, which include total ADT as well as passenger car and truck ADT.

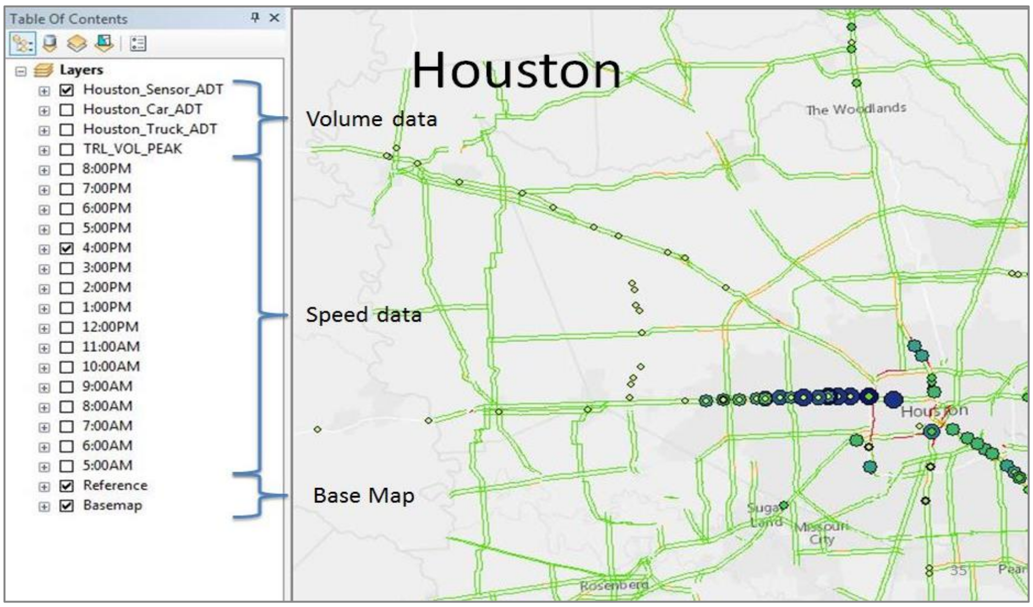


Figure 17. Houston Post-Processed Data—Traffic Volume, Speed, and Sensor Location.

The location for each detector is shown as points in the map. The circular symbols represent the magnitude of ADT for that particular location for 2013 (larger means higher ADT). The magnitude of ADT can be seen by clicking on the circular symbol in the map. The truck volume for Austin was obtained from the detector data, and truck volumes for Dallas and Houston were calculated using the truck percentage field in the RHiNo database.

Figure 18 shows another example of volume data in Houston and patches of heavy and moderate volume within the region, which, if used in conjunction with speed data, can help identify some bottlenecks and assist in model calibration.

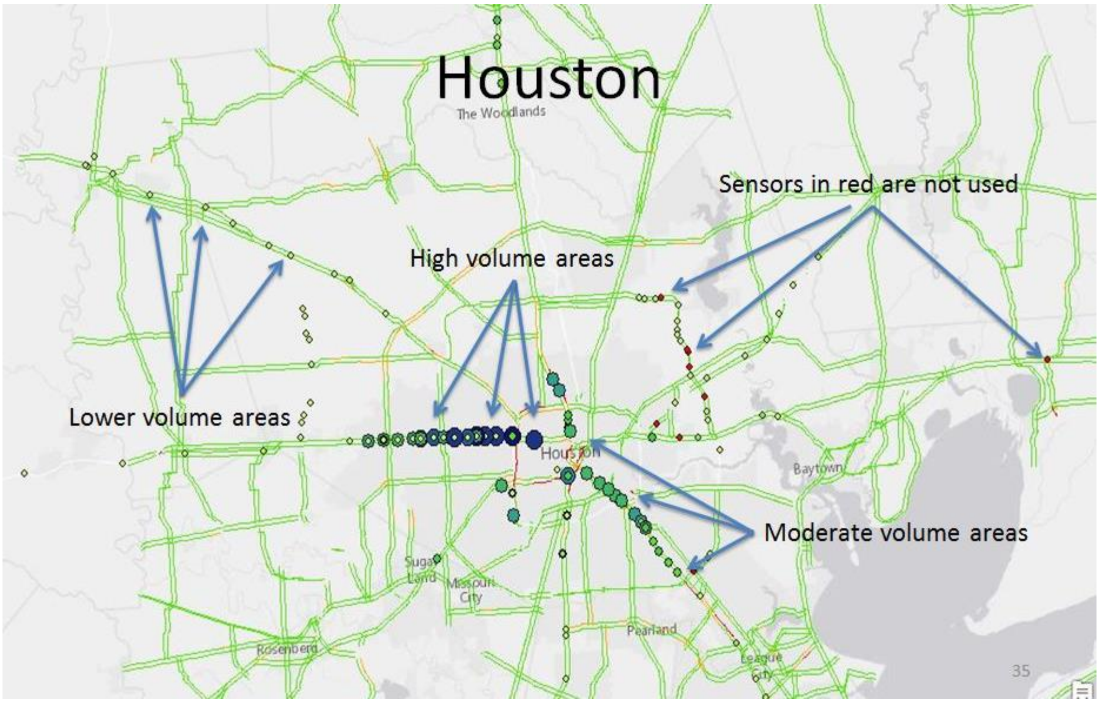


Figure 18. Traffic Volume Data in Houston.

Commodity Data

Through discussions with TxDOT, there was a strong desire to evaluate freight traffic data and any applicable freight strategies (e.g., time-of-day delivery) by the different commodity types. Researchers investigated readily available commodity data and evaluated their appropriateness for modeling purposes.

TxDOT's Statewide Analysis Model

TxDOT maintains a robust statewide model, named the Statewide Analysis Model (SAM). SAM-V3 is a state-of-the-practice multimodal travel demand model that provides traffic forecasts for highway passenger travel and freight transport, intercity and high-speed passenger rail ridership, freight rail tonnage and train forecasts, and air passenger travel to and from Texas airports. SAM-V3 forecasts are typically suitable for comparative analyses of large-scale transportation corridor projects and other large-scale investments.

Texas North American Freight Flow

The Texas North American Freight Flow (TX-NAFF) model is a part of SAM-V3. The TX-NAFF model contains freight trip tables by commodity types developed from the TRANSEARCH freight flow database, which is a comprehensive database of U.S. freight movements that is updated annually. However, the trip tables are only at the county level, which is not a sufficient resolution needed for the DTA models in this project.

Houston-Galveston Area Council Cargo Model

The Houston-Galveston Area Council (H-GAC) developed a regional freight model between 2008 and 2013. This freight model was intended to facilitate the analysis of intraregional and interregional freight flows for both truck and rail. This model was developed in Citilab's Cube Cargo modeling framework and integrated into the region's existing travel demand modeling structure. The 2015 truck flows for the eight-county region were provided in daily tonnage (long- and short-haul trucks) between the 5,185 traffic analysis zones (TAZs) and by 16 commodity types. Researchers worked with H-GAC staff to extract the truck flows for the Harris and Fort Bend Counties, as shown in Table 14. These two counties represent the area covered in the existing DTA model for the Houston region. The coal commodity group (CG) flow is zero for Harris and Fort Bend Counties because it is transported via rail.

Table 14. 2015 Commodity Flows for Fort Bend and Harris Counties.

No.	Commodity Group	Daily Tons (Millions)
1	**Petroleum/Coal Products**	**34.4***
2	**Chemicals/Allied Products**	**9.39**
3	Nonmetallic Minerals	6.27
4	Crude Petroleum/Natural Gas	0.29
5	Coal	0**
6	**Durable Manufacturing**	**12.91**
7	Primary Metal Products	5.55
8	Clay, Glass, Concrete, Stone, and Leather	9.1
9	Farm/Fishing Products	2.85
10	Food or Kindred Products	3.37
11	Consumer and Non-durable Manufacturing	3.69
12	Lumber or Wood Products	3.99
13	Transportation Equipment	0.36
14	Metallic Ores	0.17
15	Miscellaneous Freight	0.1
16	Waste or Scrap Materials except Hazardous Materials	0.04
Total		**92.48**

Note: See page 3-3 of H-GAC cargo documentation for equivalent Standard Transportation Commodity Classification 2 codes.
* Illogical negative flows were removed from the CG 1 H-GAC table.
** All coal is transported by rail.

The resolution of commodity data was deemed adequate for the DTA model. However, the H-GAC Cargo model is structured such that CG flows are produced in tonnage and not trips. Researchers attempted to manually convert tonnage to trips using available Cargo documentation, but the results were not consistent with the final truck trip total of the H-GAC Cargo model application. Researchers chose to analyze commodity flow movements by tonnage instead of trips.

Researchers focused on the three commodities with the highest total tonnage (bold and italicized in Table 14) and used aggregated “Sector90” TAZs to show desire lines (flows) between subareas of the two-county area. Figure 19 through Figure 21 show the top 20 desire lines and some possible shortest paths for each commodity analyzed. Figure 22 shows the top 20 desire lines for all CGs combined.

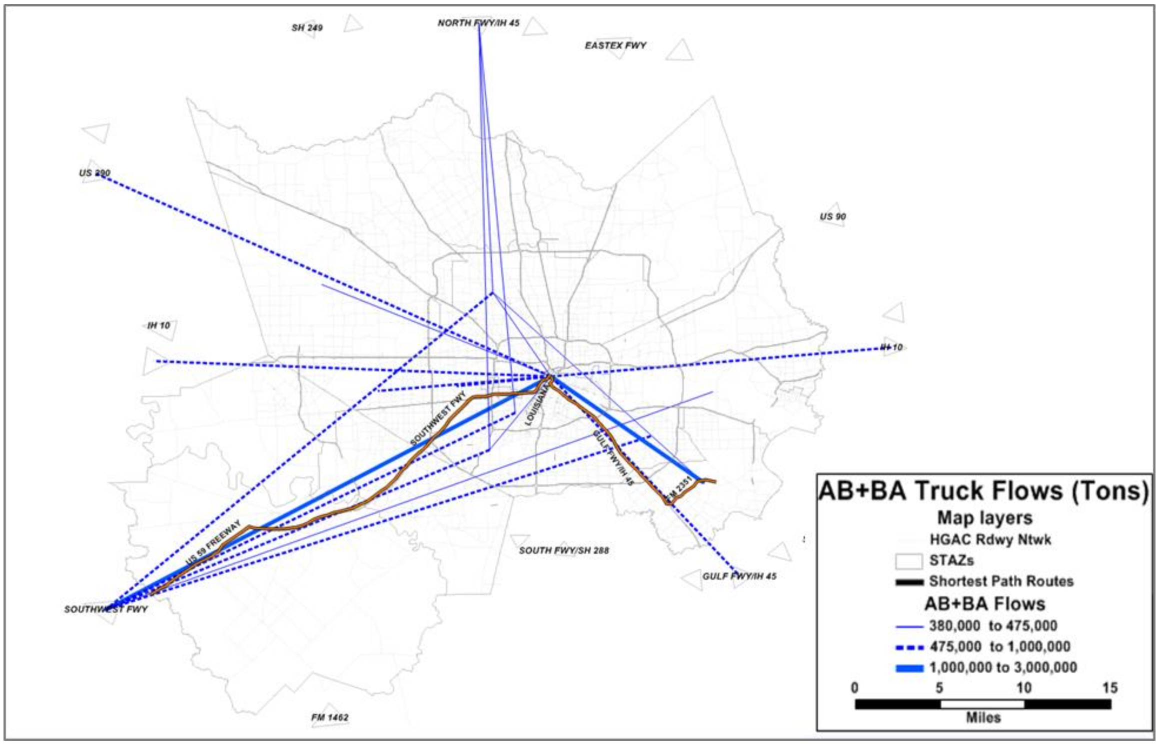


Figure 19. 2015 Petroleum/Coal Products Top 20 Desire Lines (CG1).

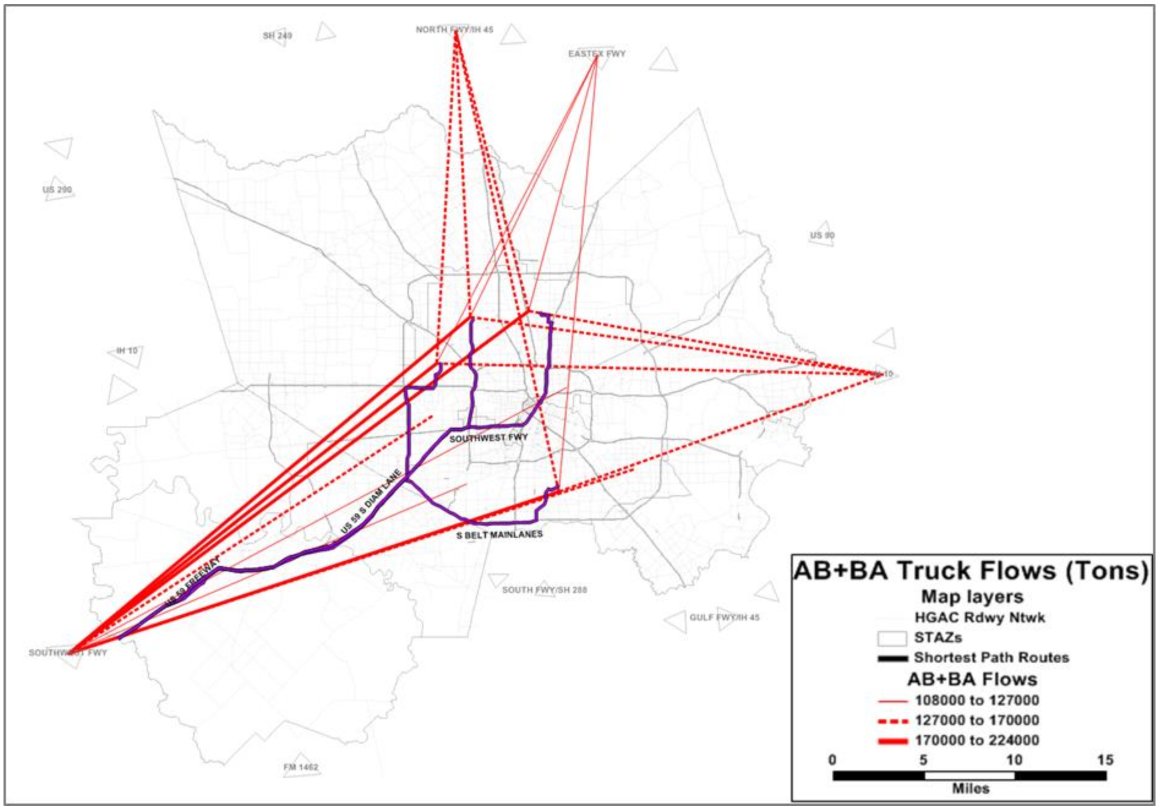


Figure 20. 2015 Durable Manufacturing Top 20 Desire Lines (CG6).

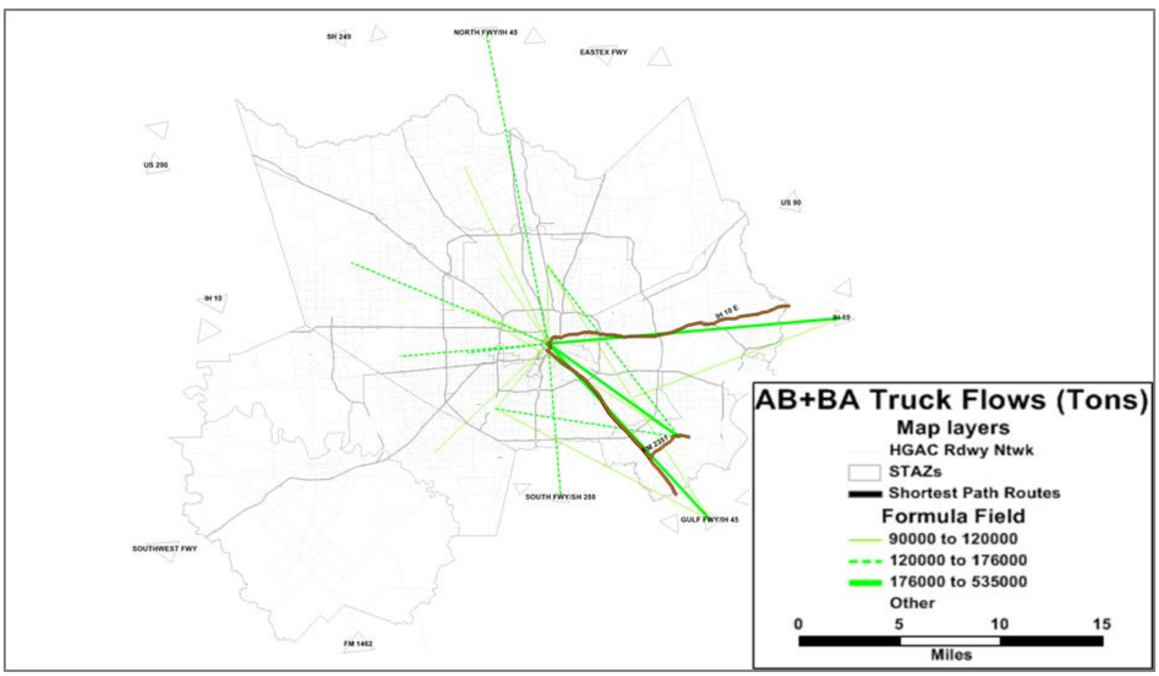


Figure 21. 2015 Chemical/Allied Products Top 20 Desire Lines (CG2).

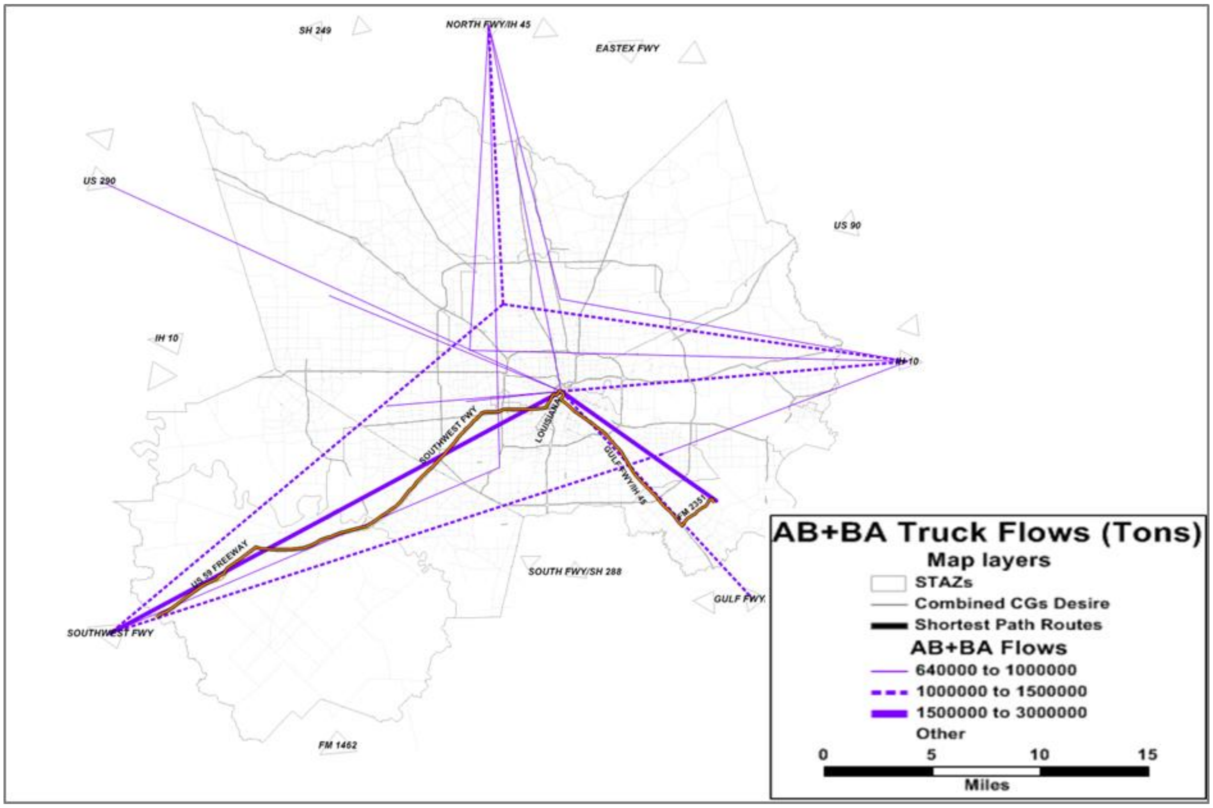


Figure 22. 2015 All CGs Combined Top 20 Desire Lines.

Desire lines for petroleum/coal products in Figure 19 were counterintuitive, particularly the highest flows shown by the thicker lines, because they went to and from Houston's CBD. Upon further investigation, it may be due to truckers misreporting the corporate office addresses (which are in the CBD) in their logs instead of actual job site addresses. Figure 23 shows all of the coarse TAZs with greater than 1 million tons of petroleum—the zones pointed out by black arrows are associated with port and refinery areas, and the green arrow is the CBD. These three coarse zones make up the highest portion of petroleum workers in the region. The Cargo model generates tons based on North American Industry Classification System employment, which might explain why CG 1, petroleum/coal products, shows the highest truck flows to/from the CBD. TTI has experienced similar issues with employment data sets when building urban travel models. This anomaly also applies to Figure 22 since petroleum/coal products make up 37 percent of the total tonnage for the two-county area.

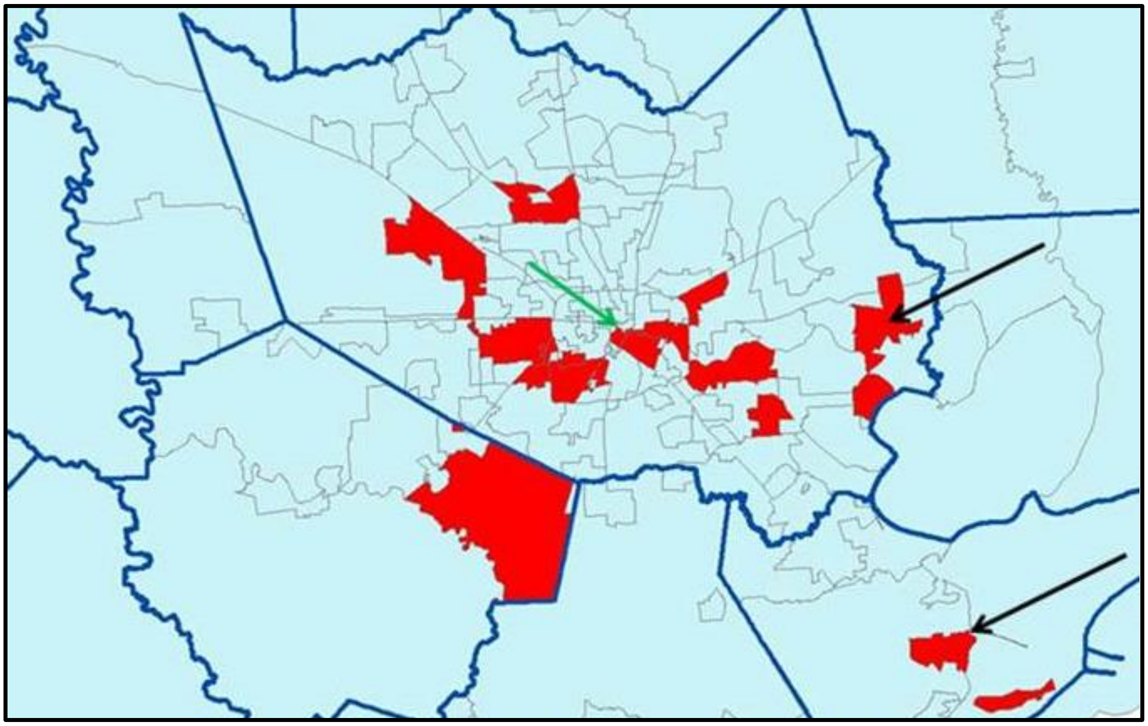


Figure 23. 2015 TAZs with More than 1 Million Tons of Petroleum/Coal Products Desire Lines (CG1).

Findings

In this section, researchers explored the existing and new data sources to calibrate and validate DTA model baseline conditions for four regions: Austin, Houston, El Paso, and the DFW region. Typically, two types of traffic data are needed for DTA model calibration: speed data and volume data. The traffic volume data for planning purposes are in the TxDOT RHiNo data set; however, it lacks traffic operation-level information, such as speed by time of day. Moreover, some caveats are associated with the accuracy of RHiNo data, which can limit the accuracy of the DTA models. Thus, researchers obtained new data sources, including the 2013 INRIX speed data and detector/field traffic volume data. The speed data were used to develop time-of-day-based speed maps and heat maps for truck traffic and passenger traffic. The speed patterns on major corridors for each region were used to ensure that the modeled behavior represents current traffic conditions.

Further, the available detector data at TTI urban offices or recently collected field data were acquired to develop accurate traffic and truck volume profiles. This acquisition allowed researchers to compare and reduce the absolute percent error between the simulated traffic and the screen line data at different locations (e.g., major arterials, highways, and freeways) throughout the region. RHiNo data were leveraged for filling in the gaps from missing data. GIS-based visual maps were developed for the regions to allow identification of bottlenecks and fine-tuning of the DTA models.

In addition, commodity data were investigated to determine if they could be used for this study. TxDOT's TX-NAFF model contains freight trip tables by commodity but was not useable in its current form because it only contained data at the county level. The H-GAC Cube Cargo model was also investigated. The resolution of commodity data was deemed adequate for the DTA model. However, commodity flows are in tonnage and not trips. Thus, researchers were only able to analyze commodity flows by tonnage. The top three commodity flows for the Houston region are petroleum/coal products, durable manufacturing, and chemicals/allied products, respectively. The highest petroleum/coal product flow movements were counterintuitive because they went to and from Houston's CBD. Upon further investigation, it appears this anomaly may be due to truckers misreporting the corporate office addresses (which are in the CBD) in their logs instead of actual job site addresses.

MODEL CONVERSION AND DEVELOPMENT

This section documents the conversion of the DFW travel demand model to a simulation-based mesoscopic DTA model format. TTI, in conjunction with the NCTCOG, has been working on the conversion of a fully functional DFW model in DTA format to be used as a simulation tool to analyze freight management strategies.

Mesoscopic Modeling

In the context of traffic simulation models that can be used for the evaluation of the performance of freight transportation systems, there are three levels of model resolutions: macroscopic, mesoscopic, and microscopic. In the macroscopic resolution, vehicular traffic is represented as indivisible flow, and conditions are characterized by aggregated speed, density, and flow throughout the entire network. Macroscopic models are best suited for planning applications involving large networks and long time periods. Microscopic resolution models capture the behavior of individual drivers and the interactions between vehicles at high levels of detail. They render elemental features of drivers and driver behavior, such as lane changing, car following, and instantaneous reaction (fractions of a second to 1-second response time) to roadway conditions from the individual driver's perspective (e.g., acceleration, deceleration, gap acceptance, and lane position). A microscopic resolution model is effectively suitable for a network corridor or a subarea due to the portrayal of individual drivers and driver behavior rather than the aggregated representation of traffic flow from a macroscopic resolution model.

In examining traffic simulation models, macroscopic and microscopic models are on opposite ends of the spectrum. A mesoscopic resolution model is somewhat of a hybrid between the macroscopic and microscopic resolutions. A mesoscopic model is the rendering of macroscopic traffic flow properties, such as speed, density, and flow, but describes in greater detail the decision rules of the individual traveler, such as time-dependent route decisions and departure time. In other words, decision rules have been updated from an aggregated context to a time-dependent context with time-varying conditional changes. However, rather than representing traffic in the averaged context of macroscopic models of flow, the mesoscopic model explicitly simulates individual vehicles, much like a microscopic model. To be more precise, the mesoscopic model captures individual driver conditions in a lowered time resolution from fractions of a second to fractions of a minute (typically a tenth of a minute, or every 6 seconds). In summary, a mesoscopic resolution model is a suitable model to simulate the time-varying conditions (e.g., speed, density, and flow) of a large-scale model and is efficient in depicting the behavior and choices of the individual driver in adapting to the speed/density conditions surrounding the individual vehicle. Because of the effective representation of traffic dynamics in the framework of large-scale applications, mesoscopic resolution simulation models have been a fundamental part of DTA modeling in recent years.

DTA is a time-dependent methodology that captures travelers' route choice behaviors as they traverse from origin to destination. The typical objective function known as dynamic user equilibrium (DUE) is based on the idea of drivers choosing their routes through the network according to their generalized travel cost experienced during the simulation. A generalized cost includes travel time and any monetary costs (e.g., tolls) or other relevant attributes (preferences) associated with a roadway. An iterative algorithmic procedure attempts to establish DUE conditions by assignment of vehicles departing at the same time between the same origin-destination (OD) pair to different paths. At any given point and after many iterations, travelers learn and adapt to the transportation network conditions. In literature, there are two major DTA model categories: analytical and simulation-based DTA. Most of the existing commercially available models are simulation-based approaches because simulation-based DTA models are generally more flexible than analytical DTA models in accounting for various network traffic conditions, such as existing traffic signals, incidents, or driver routing behaviors.

A simulation-based DTA model typically consists of two principal model components: a simulation model and a traffic assignment model. The simulation model is aimed at evaluating the quality of the assignment solution, and the assignment model uses the simulation results to further generate improved vehicle path assignments to get close to the DUE condition over the iterations. The outputs are time-based vehicle flows (volume) through each link, travel time, vehicle trajectories, densities, and speeds.

Mesoscopic Components

Simulation Model

Most existing DTA models adopt a mesoscopic traffic simulation approach in which individual vehicles' positions and speeds are calculated based on average traffic conditions on the link following either macroscopic speed-density relationships, headway distributions, or queuing processes. Mesoscopic simulation models generally have coarser simulation time resolutions (on the order of 5- to 10-second resolution as opposed to 0.5- to 1-second resolution in microscopic models). At times, some driver responses to roadway configurations (e.g., lane changing, roadside parking) are also simplified through changing the capacity of either links for intersections. With the simplified simulation logics and coarser time resolution, the mesoscopic models are able to accommodate a much larger network with more vehicles and longer simulation time periods than microscopic models. In addition, all DTA models are path-based simulations, meaning that vehicles follow an assigned path from the origin to the destination. Diversion in response to roadway traffic condition changes or information provided to the drivers may also be modeled.

The anisotropic mesoscopic simulation (AMS) model used in the DTA logic is a vehicle-based, micro-like mesoscopic traffic simulation model that is capable of realistically capturing the time-varying traffic conditions (e.g., speed, density, queue, and shockwaves) but at computational speeds hundreds of times faster than microscopic models (*41*). This makes DTA well suited as a fast-response model for large-scale regional/corridor applications. In other words, one does not need excessive wait time to receive scenario results from a DTA model, even on a fairly sizable network.

The AMS model is based on two intuitive concepts and traffic characteristics: (a) at any time, a vehicle's prevailing speed is influenced only by the vehicles in front of it, including those that are in the same or adjacent lanes; and (b) the influence of traffic downstream upon a vehicle decreases with increased distance. These two characteristics define the anisotropic property of the traffic flow and provide the guiding principle for AMS model design. The realistic traffic simulation from AMS is illustrated in the following vehicle trajectory diagram (Figure 24) generated from a freeway segment with lane drops and closures (*42*).

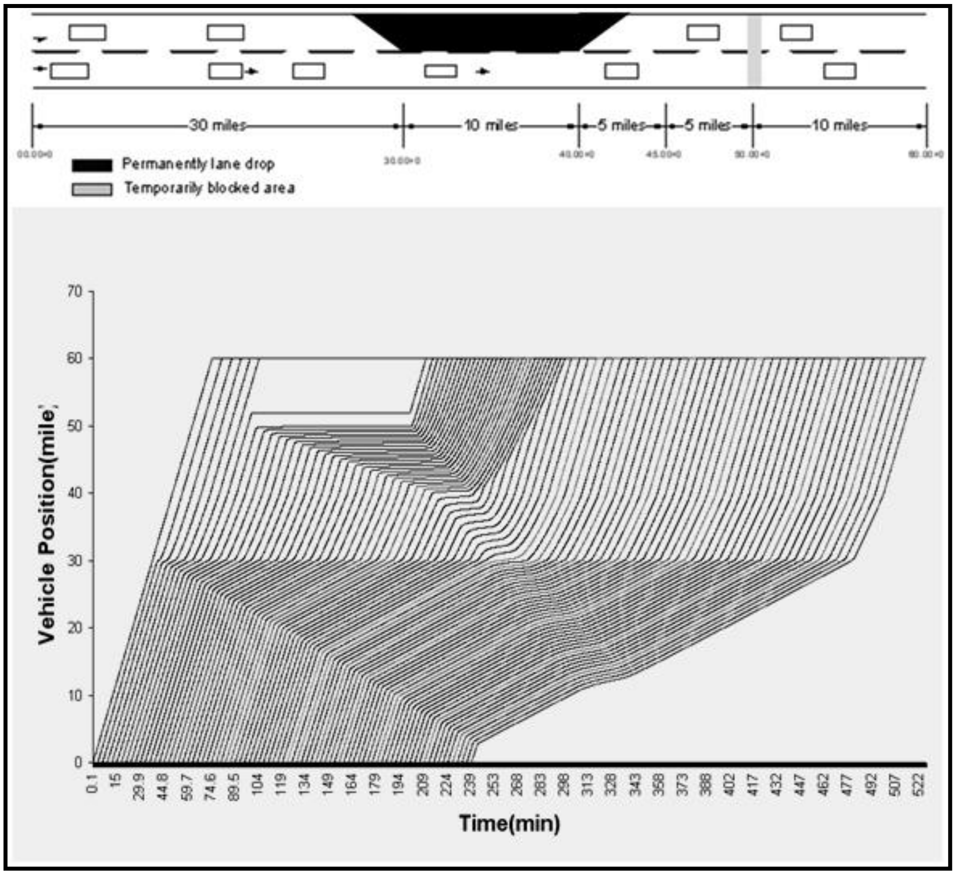


Figure 24. AMS Model Simulation Results of Roadway Blockage (*42*).

Traffic Assignment Model

The traffic assignment model is another critical component of the DTA model. The term "assignment" can be interpreted as assigning vehicles to routes following a specific objective. Vehicles with different routing objectives may be assigned to different routes computed based on respective objectives. The assignment model is generally an iterative numerical procedure involving both analytical calculations and heuristics that are aimed at achieving a dynamic or time-dependent user equilibrium (TDUE) condition. The TDUE condition can be generally defined as the traffic condition in which travelers with the same departure time and OD pair will experience an equal travel time on all the used routes. In other words, no one can unilaterally improve his or her travel time without increasing the travel time on other routes at the TDUE condition. This definition highlights the key features required by the assignment model. First, experienced travel time needs to be captured. This means that not only is a traffic simulation approach needed but also a time-dependent (experienced) shortest-path (least-cost) algorithm is needed to compute the shortest path with least experienced travel time or cost. The traditional instantaneous shortest-path algorithm relies on the link travel time at the time instance at which the shortest path is calculated. Second, the traffic state temporal interdependence needs to be captured. This interdependence is critical from the traffic dynamic continuity modeling standpoint. All traffic simulation models maintain such temporal continuity; however, certain time-sliced static traffic assignment approaches fall short in maintaining the temporal state interdependence, which may produce inconsistent and counterintuitive results when examined from the traffic flow perspective.

NCTCOG Travel Model

TTI obtained the most recent regional travel demand model from NCTCOG and converted the NCTCOG model to DTA format. The base NCTCOG model is a four-step, trip-based travel demand model that is currently in TransCAD© 4.8 platform. Table 15 shows the travel demand model parameters and coefficients used by NCTCOG for model calibration. The NCTCOG travel model accepts input files from these various sources of information, including demographic data, transit supply systems (rail and park-and-ride), roadway network (HOV and toll roads) and airport and external stations forecasts. In addition, the data sources produce traffic volumes and speeds on roadways and transit usage data. The data sources also provide a unique system for performing model runs and generating extensive reports.

Table 15. DFW Regional Model Data Sources.

Source	Year
External stations survey	1994
Workplace survey	1994
DFW household survey	1996
Fort Worth Transportation Authority onboard survey	1996
Dallas Area Rapid Transit onboard survey	1998
TxDOT traffic saturation counts	1999
Automatic traffic count stations	1999
SkyComp freeway density, speed, and volume study	1999
DFW International Airport survey	2001

Modeling Area

The modeled area includes the counties of Dallas, Denton, Rockwall, Collin, and Tarrant, the western portion of Kaufman County, the eastern portion of Parker County, and the northern portion of Ellis and Johnson Counties, as shown in Figure 25. It has three distinct time periods and includes both airport and truck components (*43*).

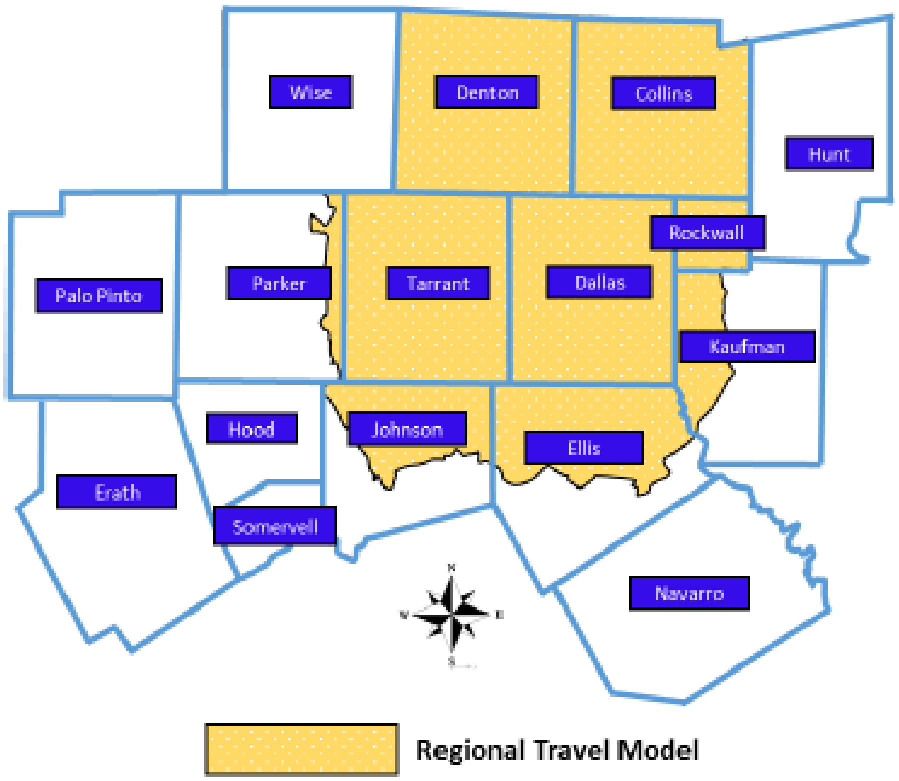


Figure 25. NCTCOG Regional Modeling Area.

Zone Structure

The NCTCOG regional travel model consists of 4,874 (4,813 internal and 61 external) traffic survey zones (TSZs), covers approximately 5,000 square miles, and contains five full urban counties and nine non-attainment counties. The process of creating internal TSZs started with the aggregation of 76,336 census blocks into 6,399 zones. To improve the speed of the execution of the model while maintaining accuracy, the 6,399 zones were aggregated into 4,813 zones. The structure also includes 61 external zones to represent gateway roads to and from the modeling area. NCTCOG has many zones in the modeled area to avoid the need for splitting zones for subarea and corridor analyses. Most of the internal model components directly use the TSZ structure, except for the income and household size distribution component in the trip generation module. The distribution of households among income groups and household sizes is based on the aggregation of the TSZs into 720 regional area analysis zones, as shown in Figure 26 (*44*).

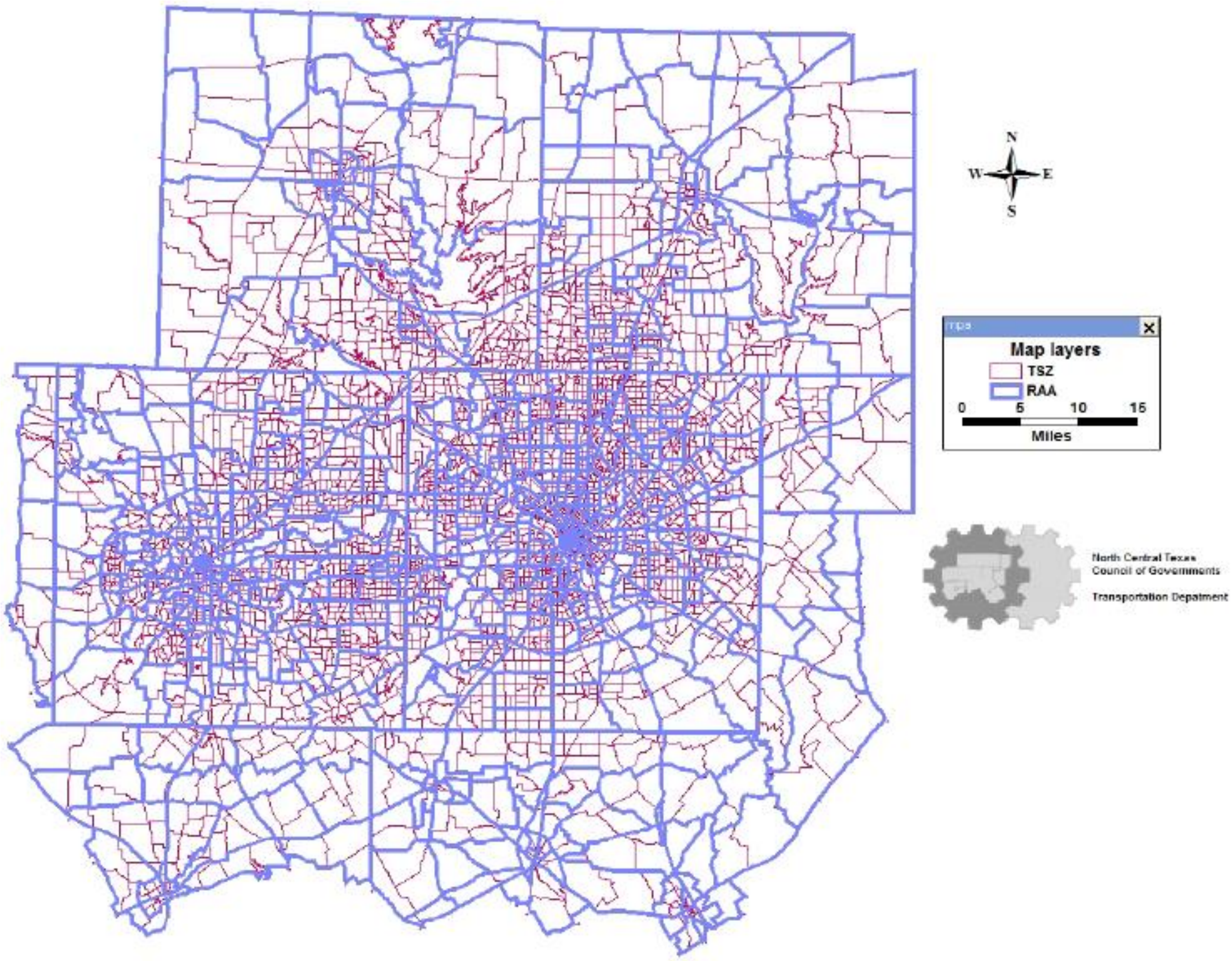


Figure 26. TSZs and Regional Area Analysis Zones in Modeled Area (*44*).

Roadway Network

Roadway representation is coded at the local street level, and all transit networks are included[4] in the regional travel model. The model can analyze HOVs, toll lanes, managed lanes, and transit routes. Roadways are defined in terms of functional classification, which is a system of categorizing roadways and highways by their function in the network hierarchy. The NCTCOG regional model uses eight functional classes, as shown in Table 16. Calibration factors are used by the volume-delay function to determine how sensitive volume on a link is to travel cost for each defined functional class.

[4] The DTA model only runs assignment and does not include mode choice; therefore, transit analysis is not included.

Table 16. NCTCOG Travel Model Functional Classification.

Functional Classification	Facility Type
1	Freeway
2	Principal Arterial
3	Minor Arterial
4	Collectors
6	Freeway Ramps
7	Frontage Roads
8	HOVs
9	Rail

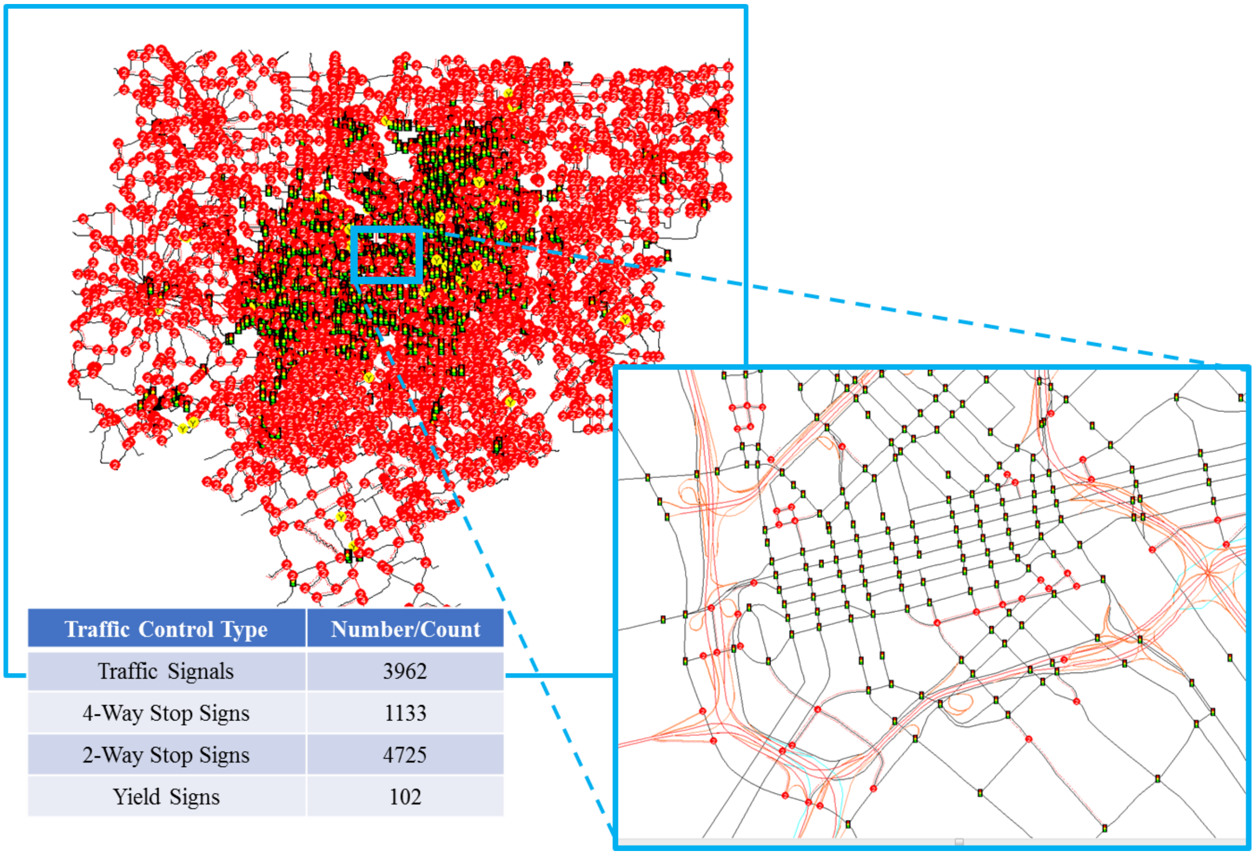
Conversion Process

The base DTA model was derived from the NCTCOG official regional travel demand model by exporting link characteristics, including functional classifications, link lengths, node identifications,[5] link direction, street name, speed limit, roadway capacity/saturation flow, toll lanes and HOV lanes, X-Y node coordinates, and all zonal information, which were converted to ArcView format.

Traffic Control

There is also a point layer embedded in the travel model that defines traffic control at each node junction, and it includes 3,962 traffic signals in the current NCTCOG model. Researchers contacted NCTCOG and discussed the availability of signal timing data that are required for the DTA model. NCTCOG stated that it intended to incorporate signal timing data into its regional travel model, but each county and jurisdiction covered by the model had its own data sheet format, and the sheer amount of signal timing plans would have needed to be entered manually. Therefore, it was decided to use a default two-phase 90-second signal timing plan for all signalized intersections within the DTA model. Once the model has been completed and is ready for the analysis of freight management strategies, researchers may revisit specific corridors where more realistic or actual signal timing plans are warranted. Researchers used aerial imagery to code in all two-way and four-way stop signs manually. At two-way stop locations, Google Maps™ was used to determine major and minor approaches to the intersection (*45*). Figure 27 depicts the spatial locations of all traffic control in the DTA model.

[5] Node identification refers to the beginning and end points used to define a link.



Traffic Control Type	Number/Count
Traffic Signals	3962
4-Way Stop Signs	1133
2-Way Stop Signs	4725
Yield Signs	102

Figure 27. DFW Traffic Control Types and Count.

Generation Links and Destination Nodes

After the initial conversion, all centroids and centroid connectors were removed from the base model. Centroids are points representing the geographical center of the TSZ, and centroid connectors are artificial links where vehicles make their way onto the network. In regional travel demand models, travel times are calculated with the time needed to traverse through these artificial links. In many instances, this construction gives false and overinflated travel times. The DTA model does not load vehicles at centroids but on generation links within the network. Generation links are defined as roadways where vehicles can start a trip, or the trip origin (see Figure 28). Vehicles can start trips on all link types except those defined as a freeway or tolled classification.[6] However, freeway links originating at external stations (e.g., at model boundaries) are allowed to generate trips. The DTA model allows each generation link to be associated with a maximum of five TAZs. Vehicles exiting the network terminate trips at destination nodes (see Figure 29) within the TAZ. Each destination node can also be associated with up to five TAZs. Care must be taken to ensure that no destination nodes are on freeway/tolled links. At least one generation link and destination node must be assigned to each TAZ.

[6] Freeway/tolled links originating at external stations are allowed to generate trips.

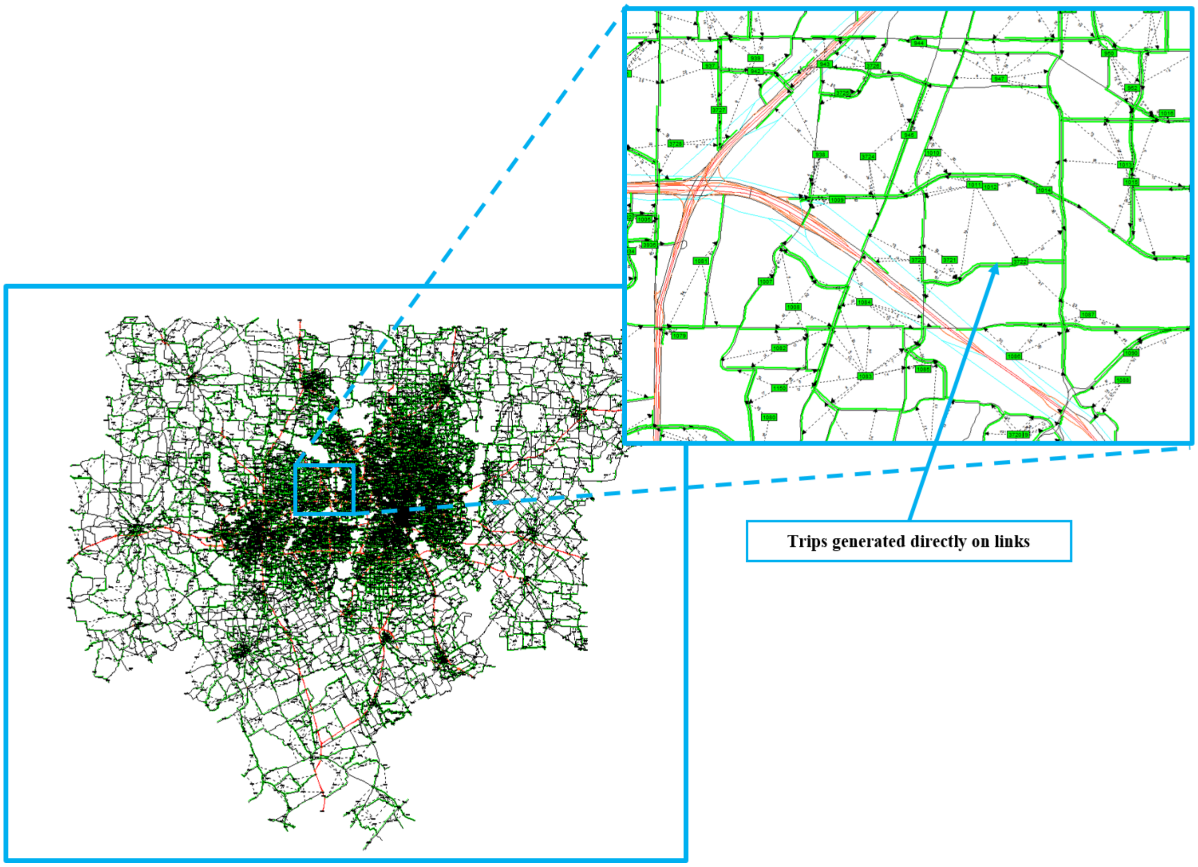


Figure 28. Generation Links.

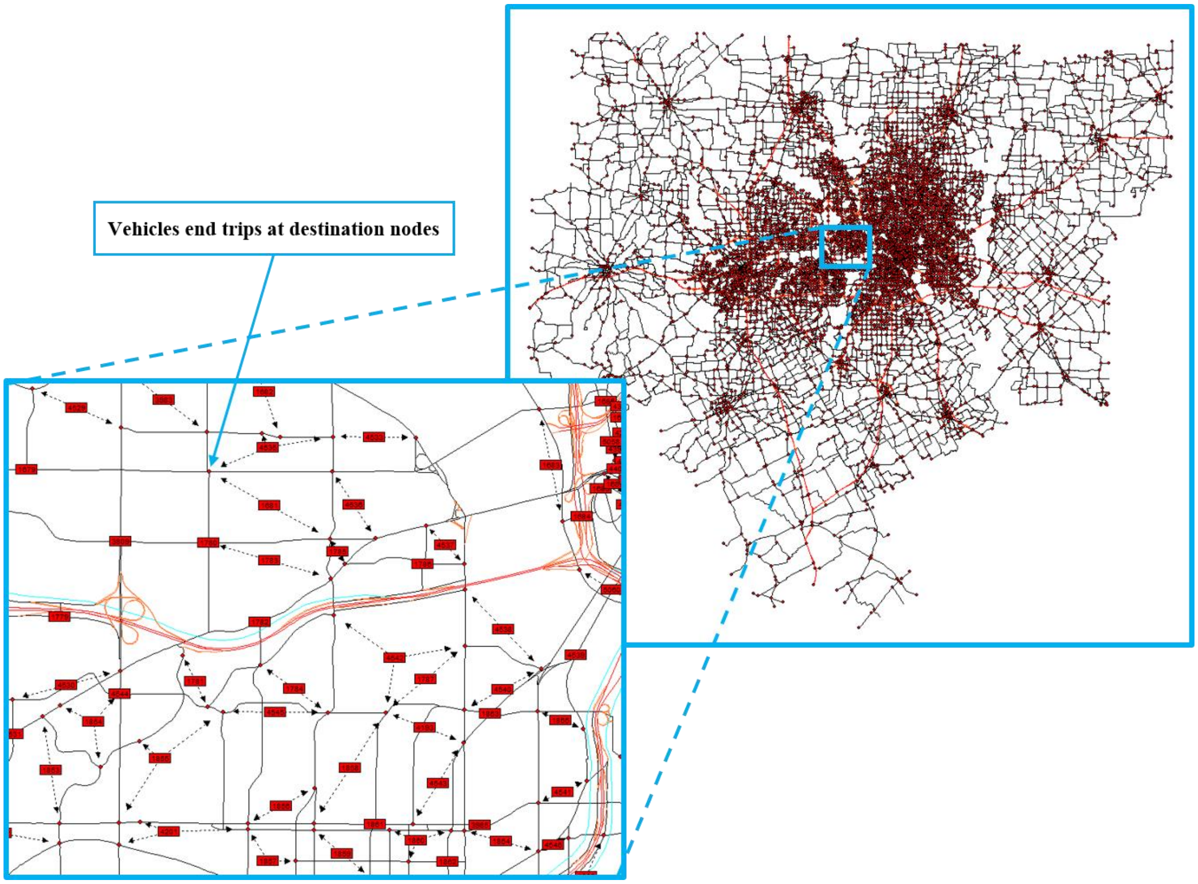


Figure 29. Destination Nodes.

OD Matrix

The NCTCOG travel demand model is comprised of an OD matrix, which is associated with individual TAZs. The original travel demand model matrix contains multiple individual matrices aggregated into a single matrix based on production and attraction trips. However, the NCTCOG model is static, so there is no time component, and it is therefore unable to show directionality, queuing, and so forth. In order to convert the static aggregate matrix into temporal (hourly) matrices, researchers first needed to disaggregate the main matrix into its subcomponents based on trip purposes. NCTCOG outlines seven trip purposes:

- Home-based work trips for low income households (HBW1).
- Home-based work trips for low-median income households (HBW2).
- Home-based work trips for high-median income households (HBW3).
- Home-based work trips for high income households (HBW4).
- Home-based non-work trips (NHW).
- Non-home-based trips (NHB).
- Other, mainly service truck trips (OTHER).

In order to have time-based OD matrices in DTA format, each trip purpose was multiplied by the corresponding diurnal factors[7] for each equivalent time period, as shown in Figure 30. Researchers are testing runtime and computational resources to see if smaller matrix time intervals (e.g., 30 minutes) are possible.

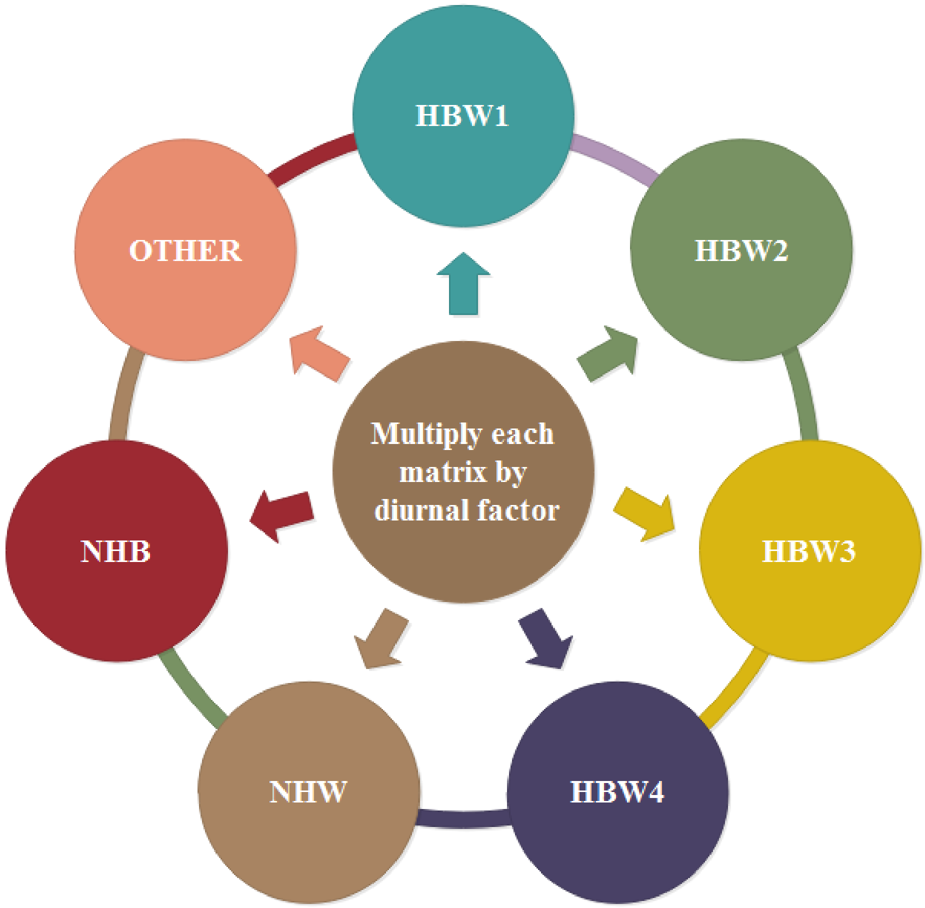


Figure 30. Development of OD Hourly Matrices.

The formulation for matrix conversion is expressed as:

$$\sum(\psi_k^j)(\theta^j) \qquad \forall\, k \in i \qquad 0 \leq \psi_k^j \leq 1 \qquad \text{Eq. 1}$$

where:

ψ_k^j = diurnal factor for time period i within trip purpose j.

θ^j = matrix for trip purpose j.

k = all selected time periods within a 24-hour day.

j $\in$ {HBW1, HBW2, HBW3, HBW4, NHW, NHB, OTHER}.

[7] Diurnal factors provided by NCTCOG.

Traffic Flow Model

The use of a simulation-based DTA model requires the development and calibration of traffic flow models that coincide with the respective link types. Freeway links have higher speeds and flow rates than arterial streets. For this study, a traffic flow model was calibrated based on data sets collected from previous studies to derive theoretical speed/density relationships. Traffic counts were converted to flow rates, and the density was calculated by taking $k = q/v$, where k = density, q = flow, and v = speed. The flow model used in the simulation model is referred to as the modified Greenshield's model, which follows basic traffic engineering principles and relationships of speed, density, and flow. There are two types of traffic flow models identified in the time-dependent shortest-path algorithm, as shown in Figure 31 (solid lines show speed-density relationship, whereas dotted lines show speed-flow relationship). Type 1 better dictates freeway traffic flow behavior because freeway links have greater capacity than arterials and can hold larger densities near free-flow speeds. Type 2 is more suited for arterial-type links, which are more sensitive to density changes due to interrupted flows (e.g., traffic control signals) and less capacity. It was anticipated that a separate traffic flow model would be needed for managed/tolled lanes since speed limits are set higher than on GP freeway lanes (e.g., the North Tarrant Express [NTE] corridor speed limit is 75 mph).

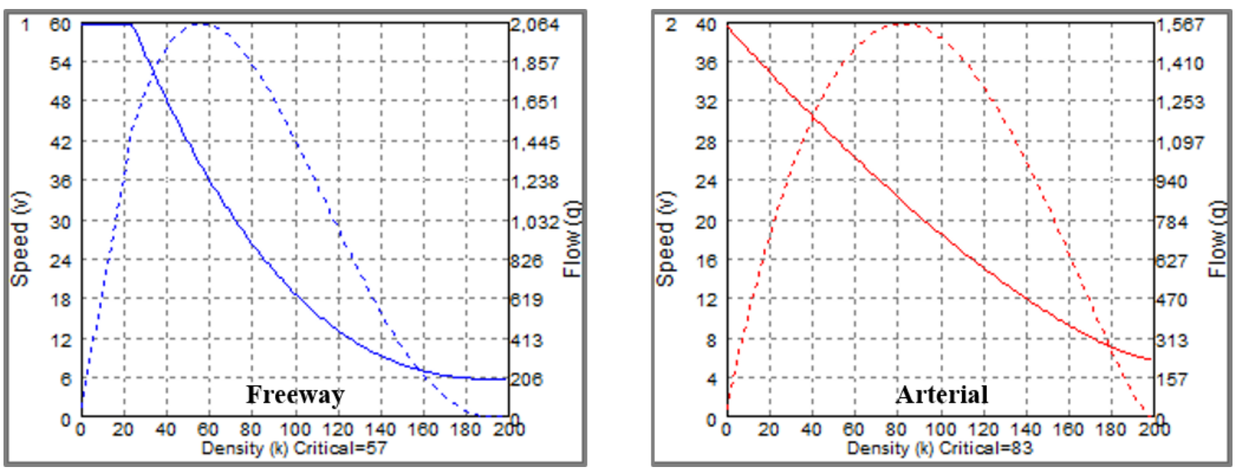


Figure 31. Traffic Flow Models.

DTA MODEL CALIBRATION

For the DTA model calibration, demand matrices for passenger cars and trucks were disaggregated based on trip purpose and then converted to time-dependent mesoscopic format (typically in 1-hour increments). Demand matrices were calibrated using a linearized quadratic optimization algorithm with an objective function which minimizes the absolute deviation between simulated and actual screen line counts (e.g., field data). The algorithm is used to adjust counts on specific links by adjusting the OD pairs that travel through those links. The calibration tool was run up to a specific number of iterations until convergence up to a specified threshold was reached. Calibrated trips can be further refined by increasing the number of iterations in the algorithm; however, the computational time can vary significantly (hours to days) with no guarantee of reaching the optimal solution.

Houston Model Calibration

Prior to calibrating the regional model, all HOV/HOT lanes on the area were updated to represent current operating schedules and rates. The same process was applied to all the toll road systems under the Harris County Toll Road Authority. A total of 35 AADT locations were selected for calibration throughout the whole region, as depicted on Figure 32.

Figure 32. Data Collection Points Used for OD Calibration.

The calibration iterative process was run for 20 iterations.[8] The results can be seen on Figure 33 and Figure 34, with a ±10 percent absolute error range that is represented by the dashed lines. The resulting final calibrated demand for auto, truck, and HOV were used to model the three freight strategies case studies.

[8] Running additional iterations does not guarantee better results because the tool has its limits (i.e., error percentages between simulated and actual traffic counts stop improving) when modifying the individual class-specific OD pairs.

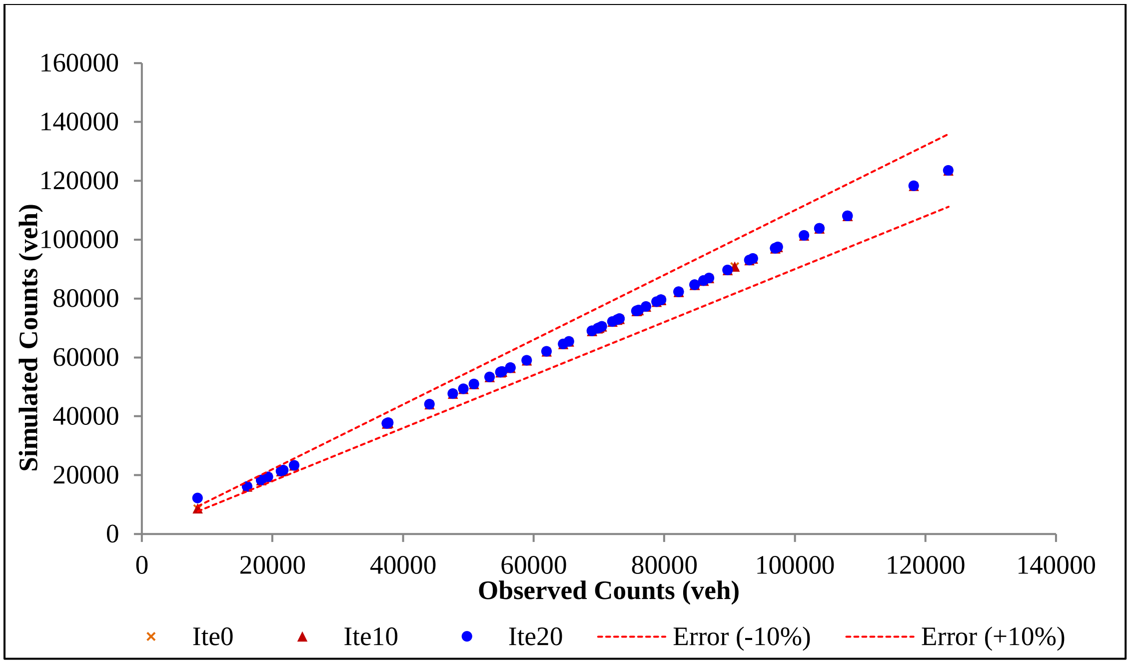


Figure 33. Houston—Auto OD Calibration Results.

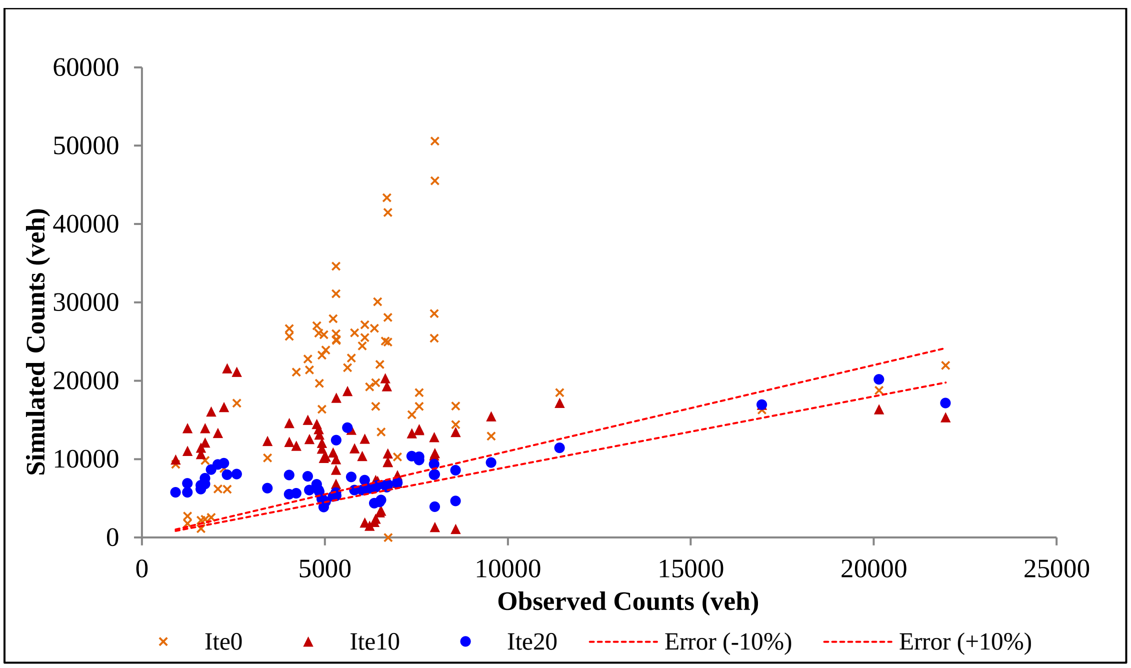


Figure 34. Houston—Truck OD Calibration Results.

El Paso Model Calibration

To develop a detailed DTA-based model that also captures freight movement, researchers used the El Paso MPO official travel demand model as a basis for conversion to a simulation-based DTA model. Once the model was converted to DTA format, a series of calibration tests were performed. The El Paso calibration tool was run for 16 iterations (Ite16). Figure 35 and Figure 36 show calibration was reasonable, with only one outlier OD trip (error more than 10 percent).

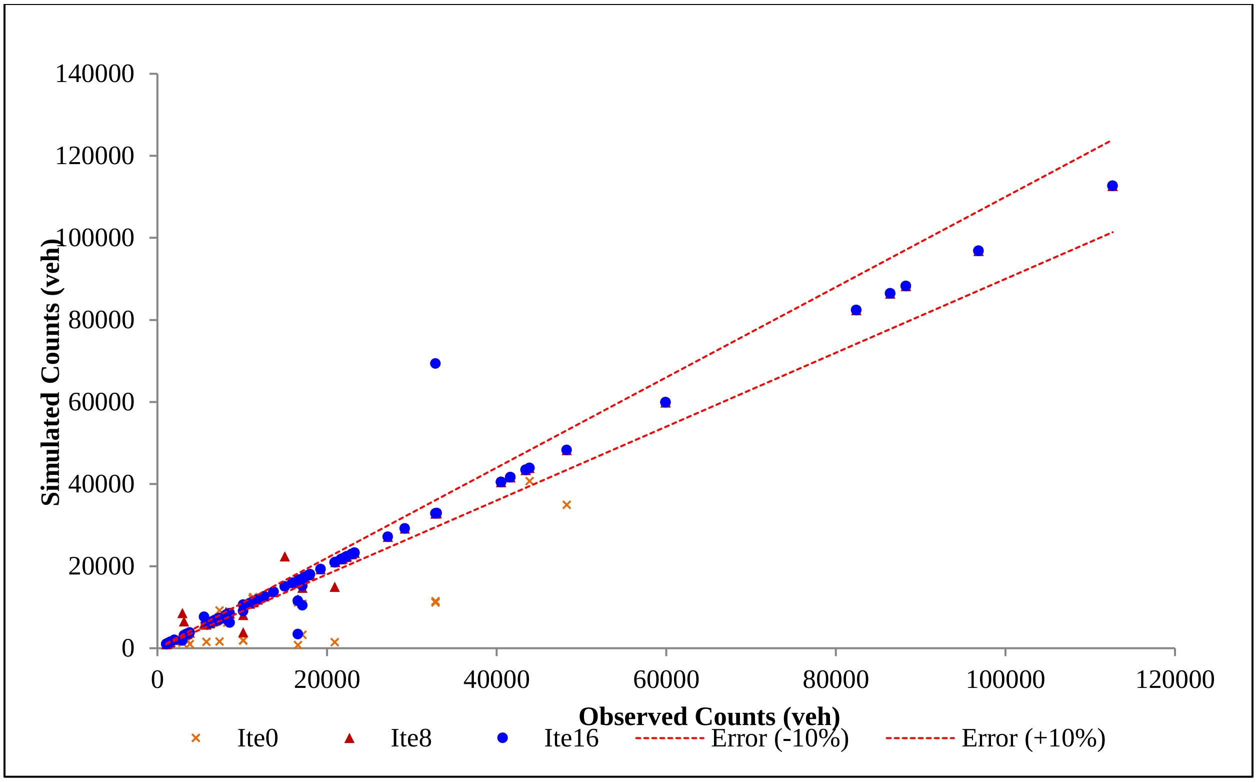


Figure 35. El Paso—Auto OD Calibration Results.

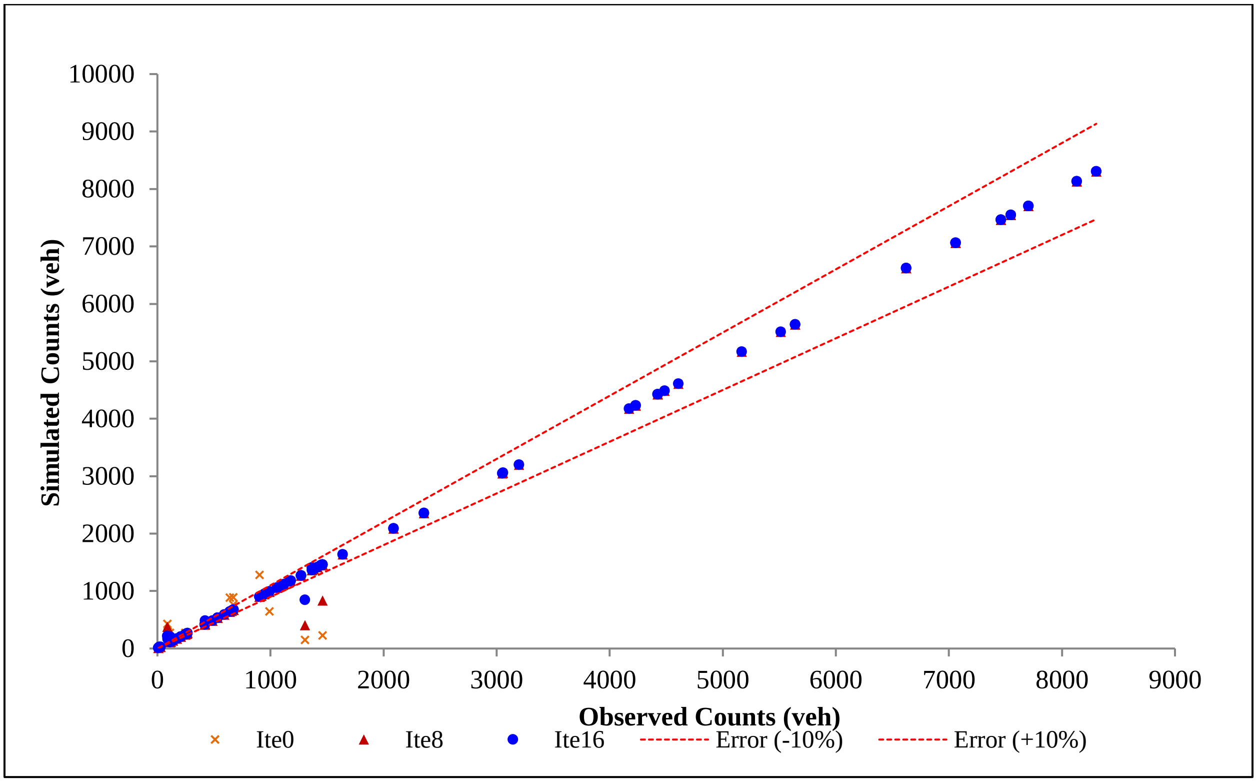


Figure 36. El Paso—Truck OD Calibration Results.

Austin Model Calibration

Similar to the El Paso and the Houston region, the OD matrices were calibrated by using the iterative tool to adjust demand pairs based on absolute error percentages from simulated and actual counts. For the Austin network, 85 traffic data points were used to perform the calibration, as seen in Figure 37. All ADT was obtained from the 2014 TxDOT's roadway inventory database, as described earlier in this chapter.

Figure 37. Austin—Data Collection Points Used for OD Calibration.

Figure 38 and Figure 39 show the calibration model was run for 19 iterations, and the results can be seen, with a ±10 percent absolute error range, for passenger cars and trucks, respectively.

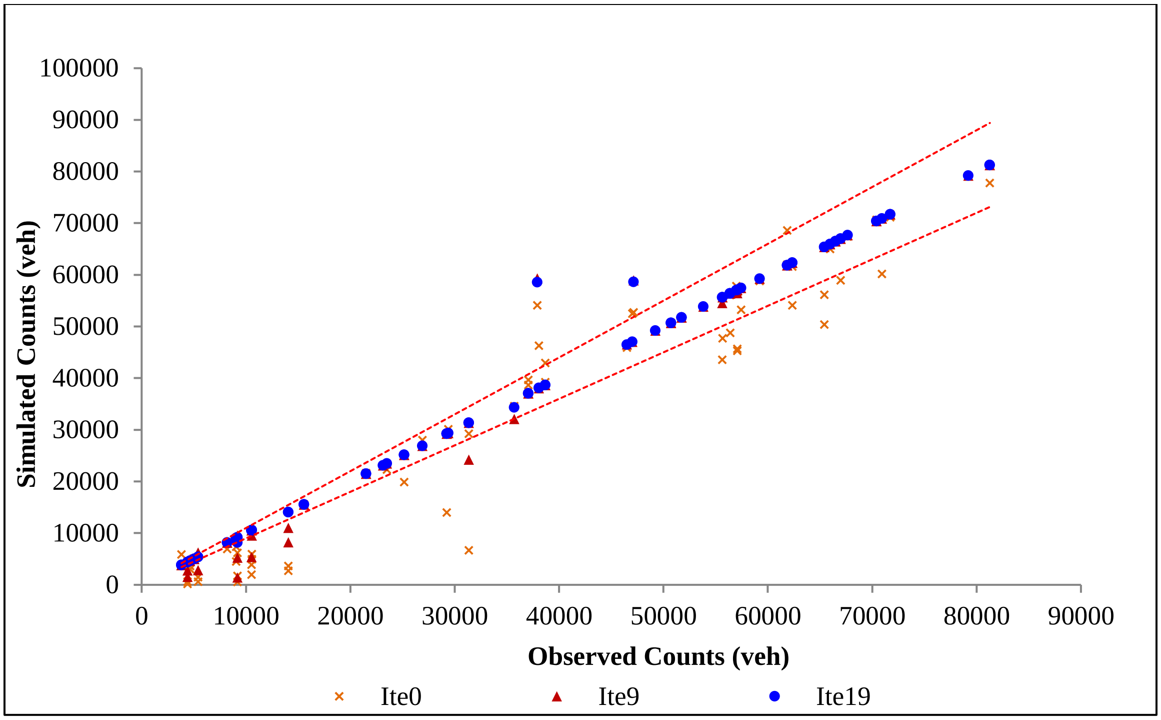


Figure 38. Austin—Auto OD Calibration Results.

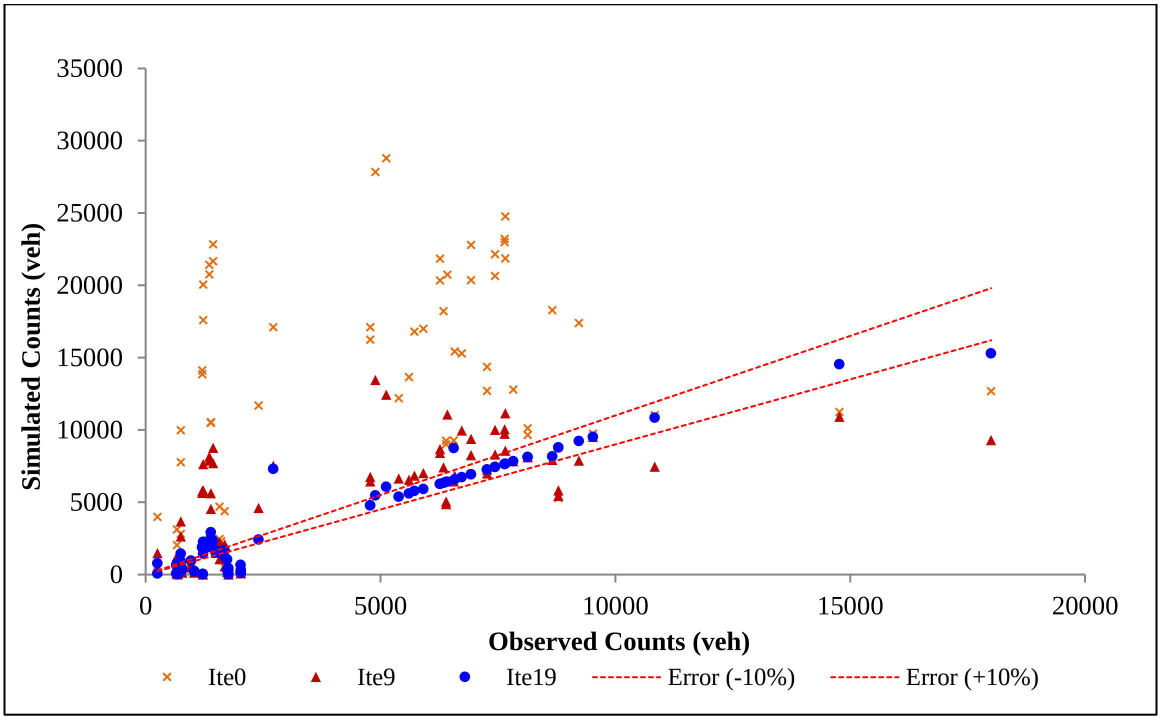


Figure 39. Austin—Truck OD Calibration Results.

El Paso/Juárez Binational Model Calibration

The development of the simulation-based binational DTA model (see Figure 40) was first derived from a static integrated land use and transport modeling system—TRANUS.[9] It combines state-of-the-art modeling of the activities, locations, and land uses and their interactions with a transportation system. In addition, TRANUS allows estimating OD matrices for several traveler categories, modes, and trip purposes.

Figure 40. El Paso/Juárez Binational DTA Model.

The binational model was derived from a 2009 base-year scenario. The entire roadway network was composed of 8645 links, including the ports of entry (POEs) and TAZ connectors. In addition, 20 individual link types were used to define the free-flow speed, penalizations, and tolls and to model each POE individually. Due to the complexity of the binational modeling area and the uniqueness of each POE (e.g., different capacities, volumes, delays), individual link types were used to model each POE using certain parameters to help with the OD matrix development. Researchers gathered data from Ciudad Juárez in terms of traffic counts and signal timings. In

[9] TRANUS is an integrated land use and transport modeling system developed by Modelistica.

addition, maquiladora[10] locations were obtained and were used to help identify OD travel patterns, as shown in Figure 41.

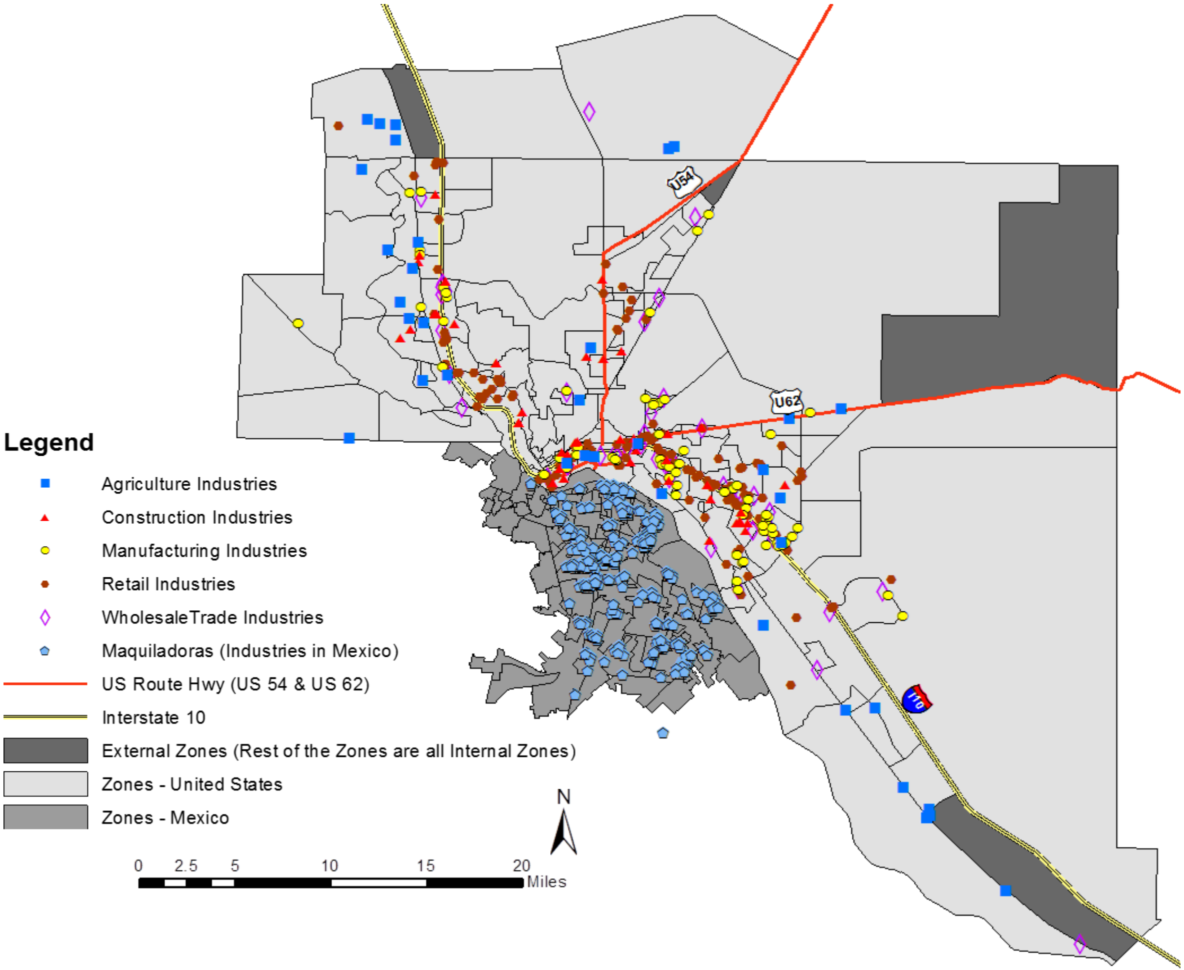


Figure 41. Input Data for Binational Model.

The seed OD matrix was developed from TRANUS and converted to DTA format. Researchers disaggregated the seed matrix into 24 one-hour matrices and used diurnal factors provided by the El Paso MPO to develop a profile of departure time distribution. The objective function was to minimize the absolute deviation between the simulated and actual link counts. The DTA model is run to a user-defined number of iterations. Upon completion of simulation and assignment, the OD calibration tool calls for the optimization solver to solve the minimization problem, adjusting all OD pairs of routes that traversed through all screen line count areas, resulting in new OD matrices.

[10] A Mexican assembly plant that imports raw materials and equipment from companies to assemble and then export back as a finished product.

The screen line counts used to calibrate the auto and truck matrices included locations at major arterials and freeways/highways for El Paso, Texas. However, for the city of Juárez, screen line data were limited to automobiles. As a consequence, internal truck traffic (e.g., suppliers to maquiladoras) was not considered for this study. Furthermore, data for all four POEs were collected to ensure that the binational model replicated existing conditions for both auto and truck traffic at the border. The auto and truck OD matrices were calibrated to 2013 conditions based on a total of 22 iterations until it reached satisfactory results within a ±10 percent absolute error range. Figure 42 and Figure 43 show the calibration results for 24 hours of demand.

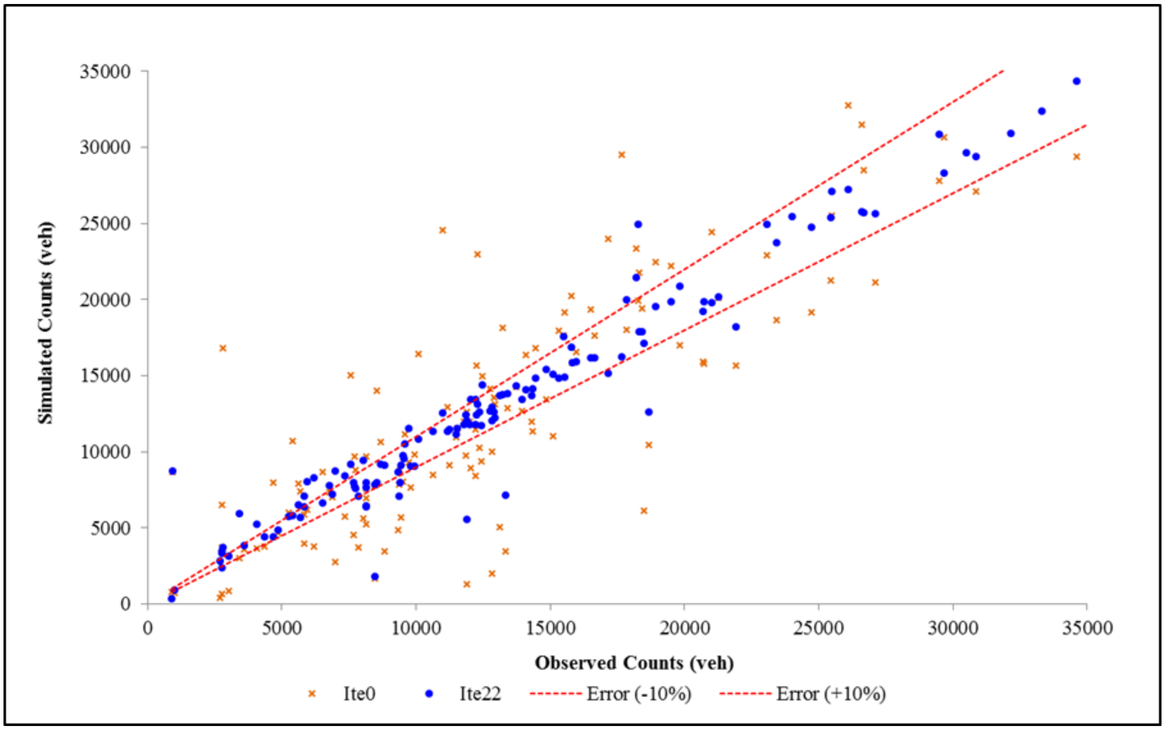


Figure 42. Binational—Auto OD Calibration Results.

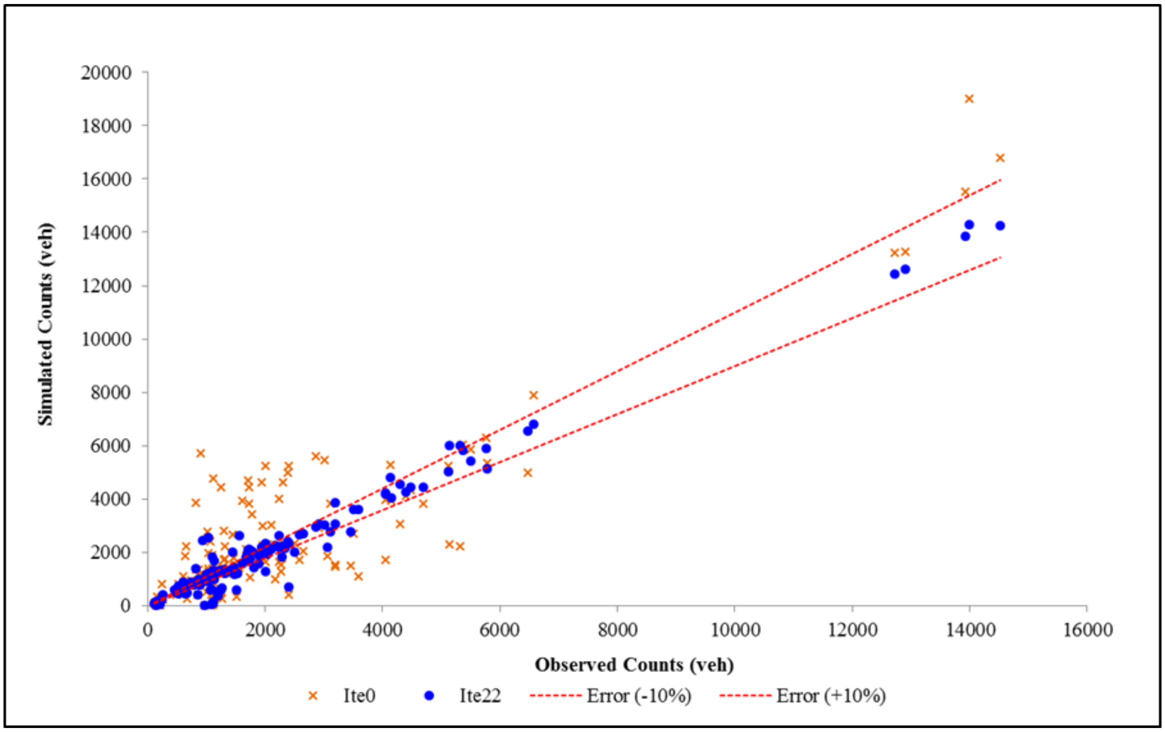


Figure 43. Binational—Truck OD Calibration Results.

DFW Model Calibration

The DFW auto and truck matrices were calibrated in two phases due to the dimensions of the travel demand model seed matrix and size of the DTA model. In order to do so, traffic counts were gathered from ATR stations throughout the DFW region. A total of 48 points was used to calibrate both AM (5:00 a.m. to 9:00 a.m.) and PM (2:00 p.m. to 7:00 p.m.) peak periods of the model. Figure 44 shows the traffic stations' locations for the calibration procedure. After the iterative process finished, results were obtained and processed. Figure Y and Figure Z show the calibration results for the AM peak period. In the same manner, Figure A and B show results for the afternoon peak period. Once calibration was performed on both peak periods, these matrices were merged with the off-peak periods to obtain a final 24-hour matrix for both auto and trucks. Figure 45 through Figure 48 outline the auto and truck calibration results for the AM and PM peak periods, respectively.

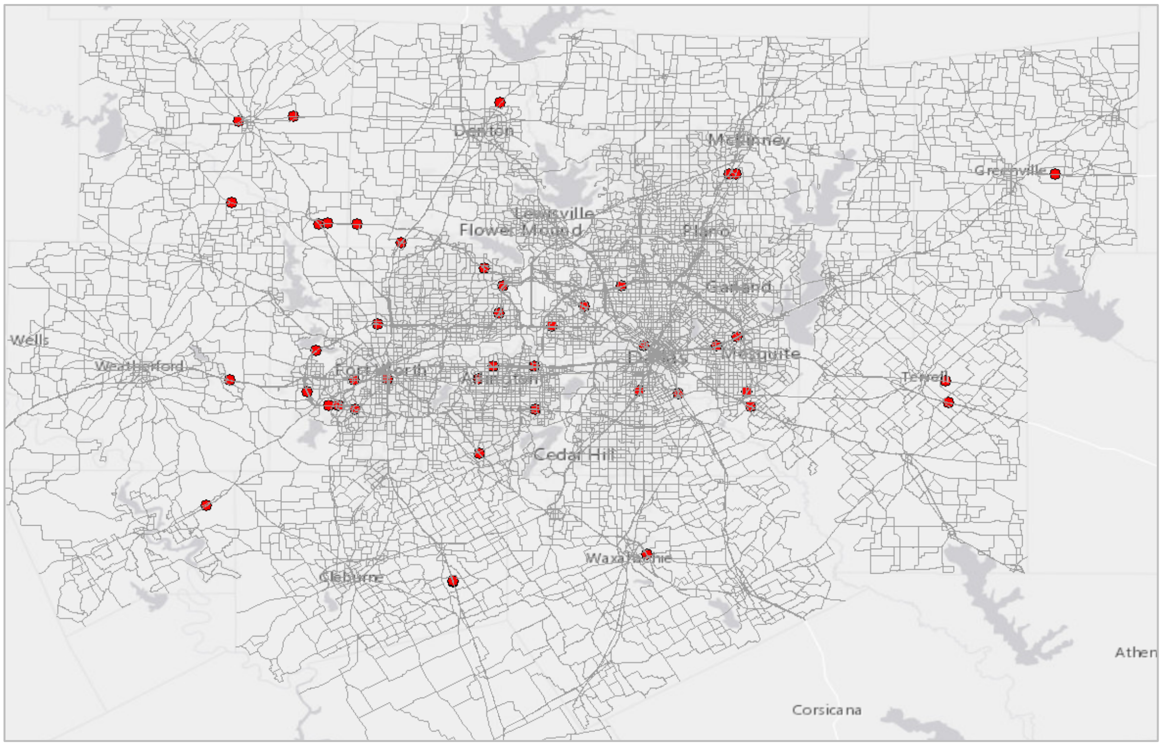


Figure 44. DFW Data Collection Points Used for OD Calibration.

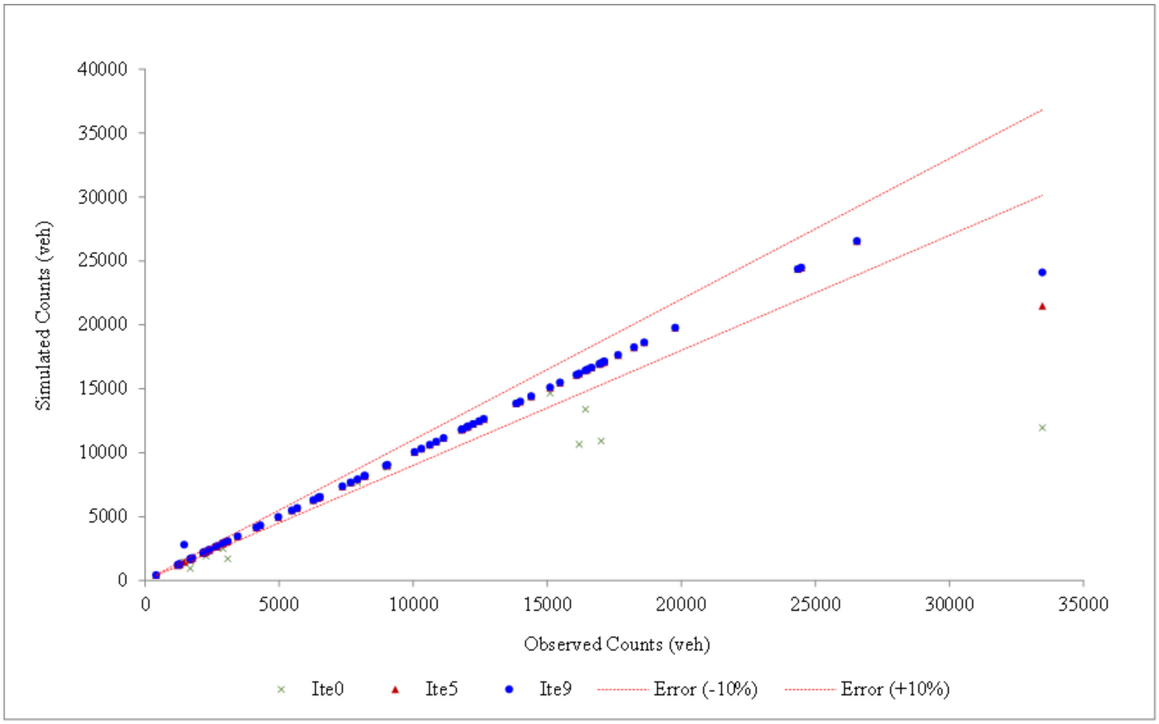


Figure 45. DFW AM Peak—Auto OD Calibration Results.

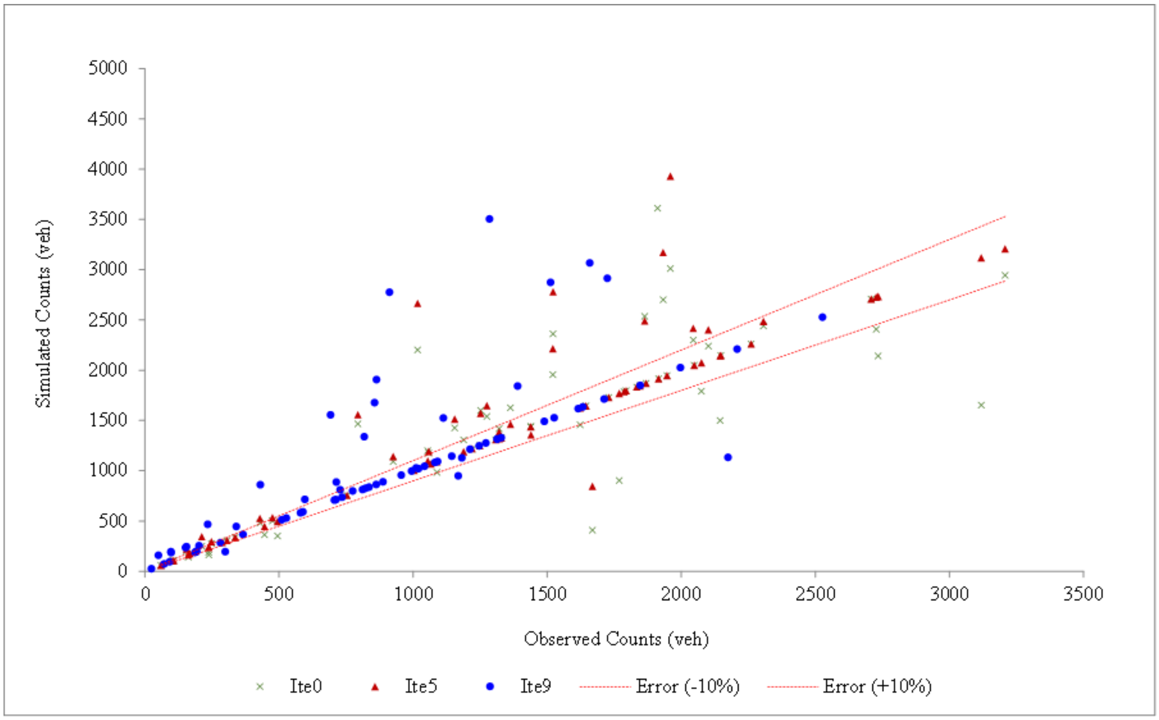


Figure 46. DFW AM Peak—Truck OD Calibration Results.

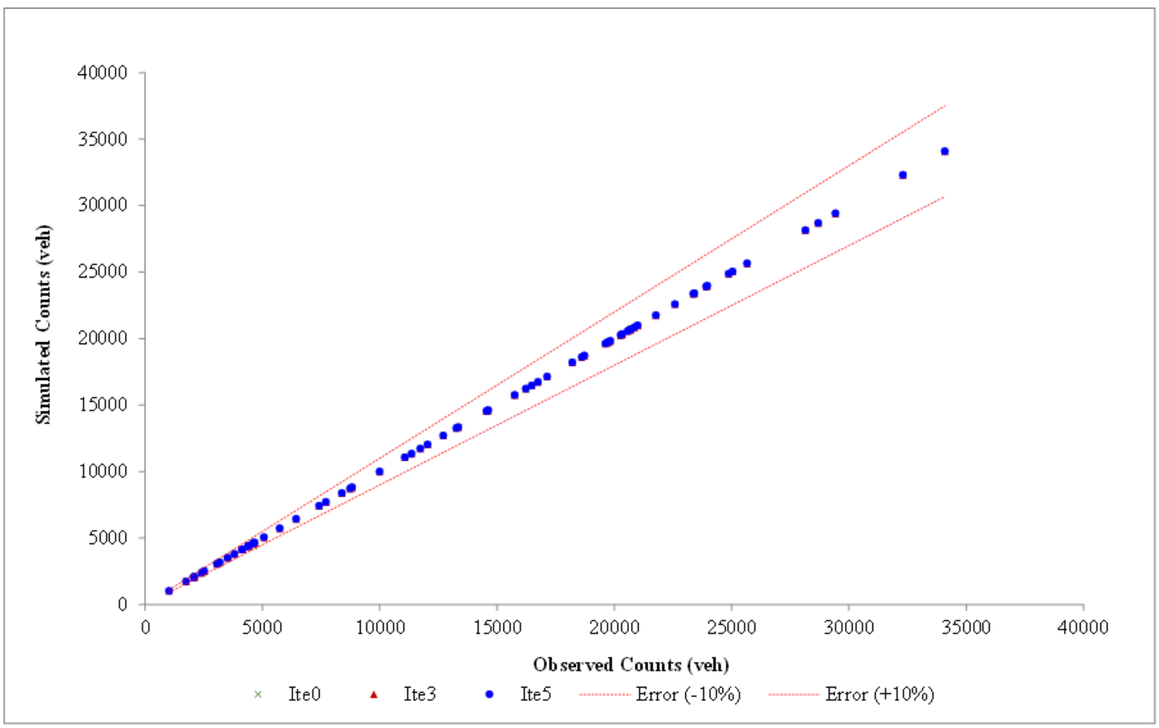


Figure 47. DFW PM Peak—Auto OD Calibration Results.

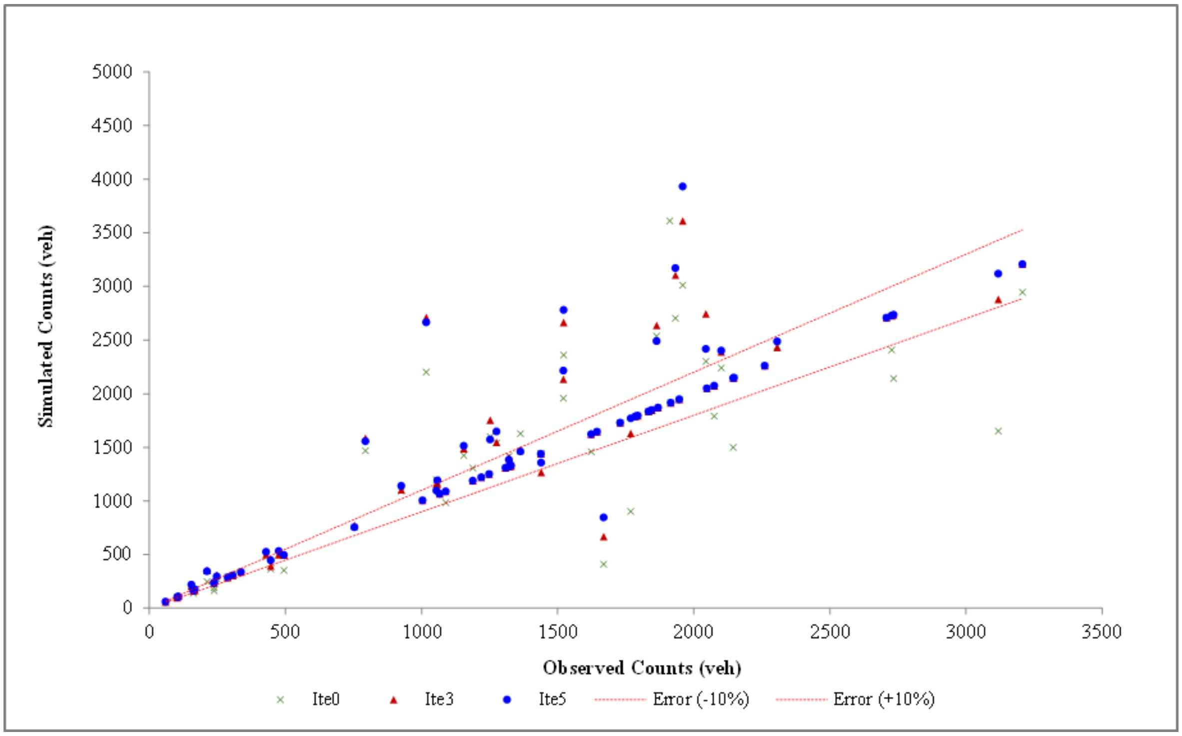


Figure 48. DFW PM Peak—Truck OD Calibration Results.

FREIGHT FLOW MANAGEMENT SCENARIO DEVELOPMENT

HOUSTON REGION

Researchers selected four short-listed freight management strategies that are feasible and can be implemented on specific corridors in Houston. The selected freight management strategies in Houston were (a) implementation of ATIS for truck route information when an incident occurs on a major freeway during peak hours, (b) off-peak use of HOT lanes, (c) bypass route designation/incentive for trucks, and (d) conversion of an at-grade rail/highway crossing near the port to a grade-separated facility.

The performance of these strategies was studied by using the Houston mesoscopic DTA model. Researchers updated and calibrated the Houston DTA model that consisted of 3531 zones, 46,212 links, and 17,740 nodes (see Figure 49). Prior to calibrating the regional model, all HOV/HOT lanes in the area were updated to represent current operating schedules and rates. The same process was applied to all the toll road system under the Harris County Toll Road Authority.

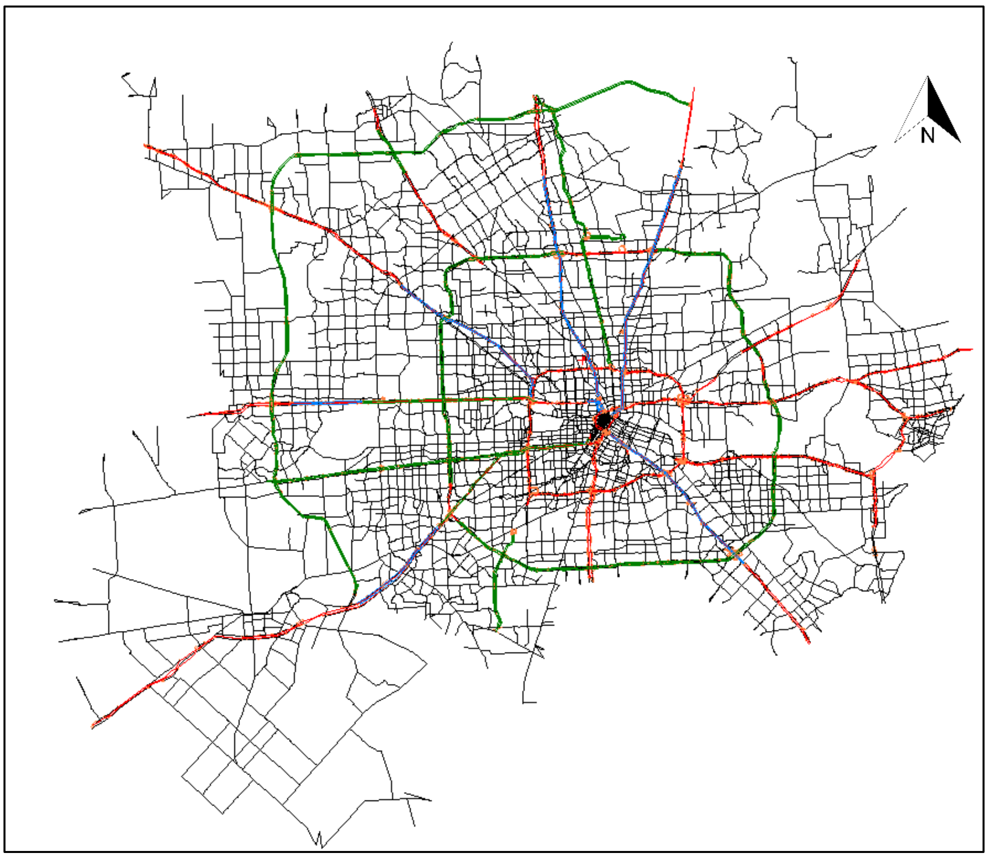
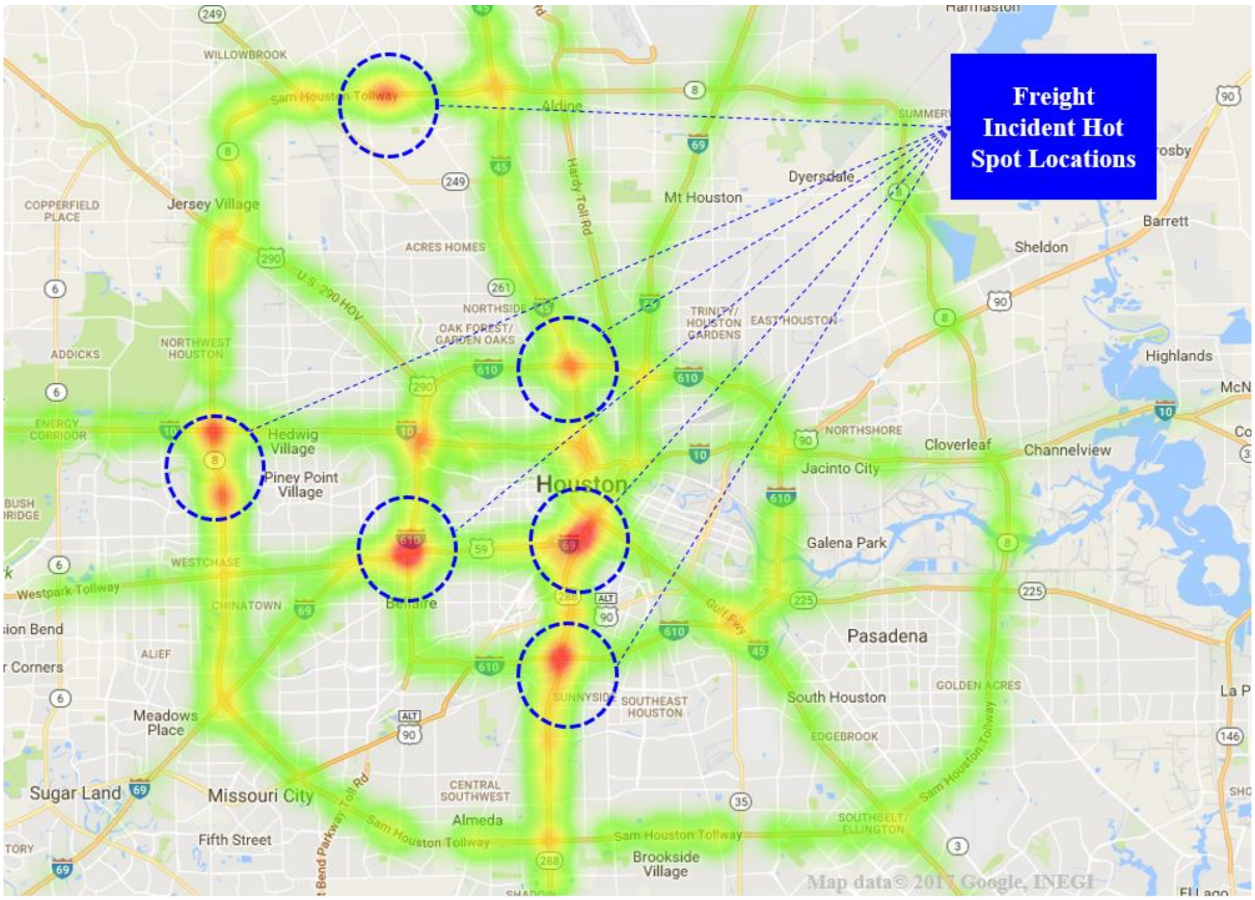


Figure 49. Houston Regional DTA Model.

Freight ATIS for Incident Management

The first strategy evaluated by researchers in the Houston area was freight-specific ATIS to provide detour information in case of an incident or heavy congestion on main corridors such as US 59, I-45, US 290, or I-10. In order to test this freight strategy, researchers examined the incident hot spots and freight bottlenecks with Houston's TranStar incident maps, as shown in Figure 50. The incident map highlights the highest heavy truck incident locations within the Houston area over a 3-month period.



Source: http://www.houstontranstar.org/rimsstats/incident_heat_map.aspx#

Figure 50. Houston TranStar Incident Map.

Using the data for 2016, researchers selected I-45 SB just north of I-610 (one of the major incident hot spots in Houston) for simulation of an incident. The incident was modeled with the following characteristics: (a) starting at 7:00 a.m. with a duration of 1 hour, and (b) a capacity reduction of 50 percent (i.e., two lanes open only in the SB direction). As shown in Figure 51, trucks were given an alternate path along N. Shepherd Dr., which runs parallel to I-45 near the incident location. From there, trucks could quickly incorporate onto I-610W or I-610E.

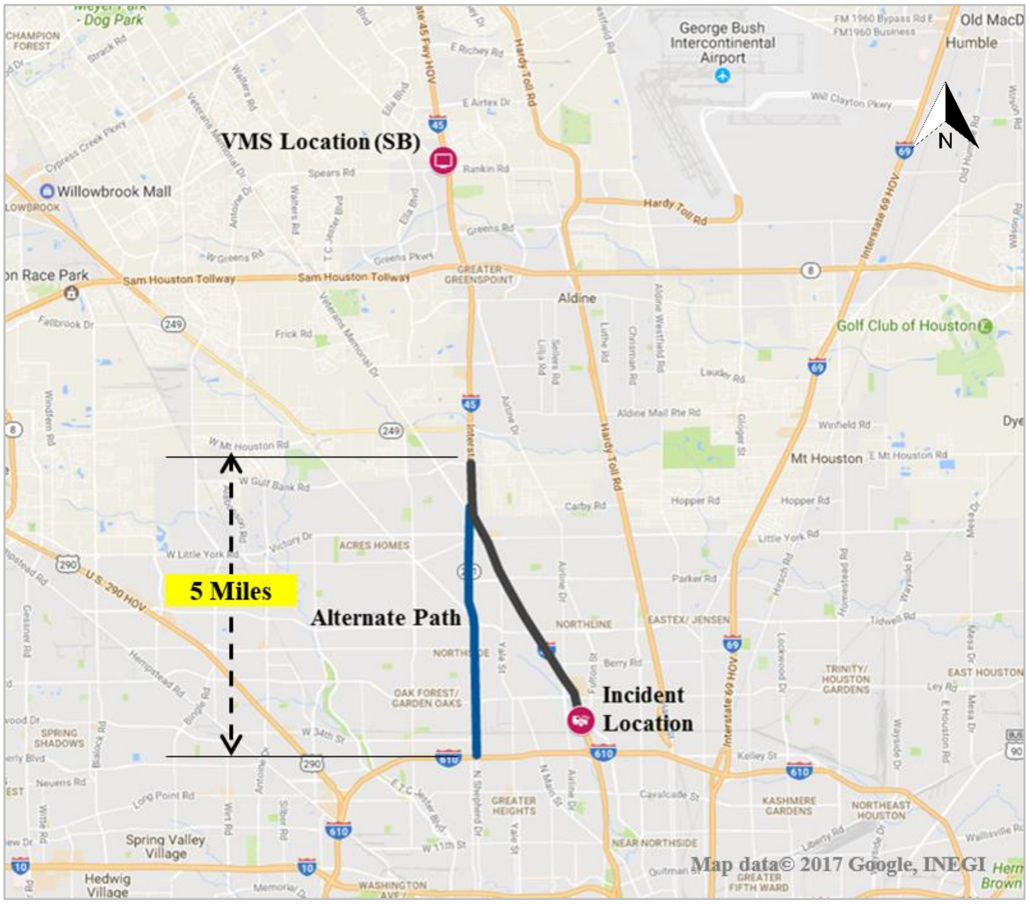


Figure 51. Freight ATIS—Incident Location and Detour Path.

In order to better quantify the advantages/disadvantages of freight-specific ATIS, several probe[11] vehicles were inserted into the network to capture the travel time differences on I-45 with and without ATIS implementation. These probes gathered data from 7:00 a.m. to 9:00 a.m. along I-45 SB, as seen in Figure 52.

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[11] A probe vehicle is defined as one vehicle that departs at a specific time interval and travels along a user-defined route.

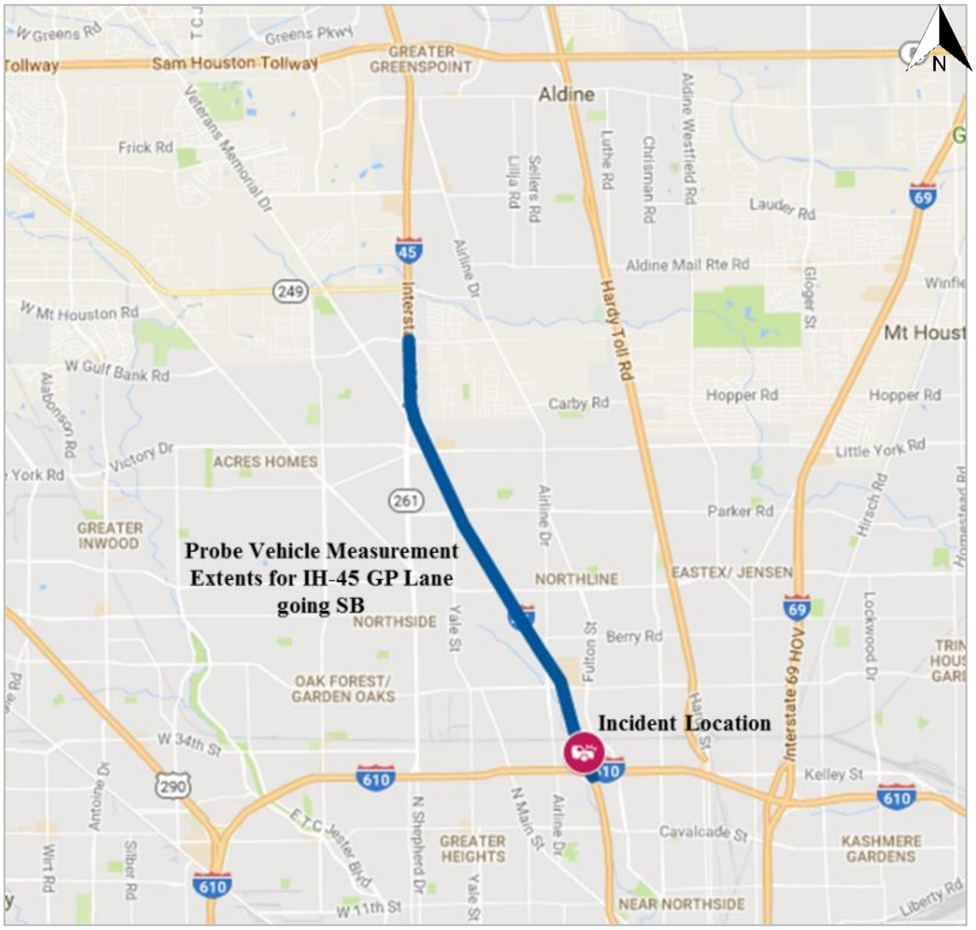

Figure 52. Probe Vehicle Travel Time Measurement Extents on I-45 SB.

Table 17 shows where travel time showed an average improvement of 38 percent for those vehicles traveling along I-45 SB between 7:00 a.m. and 9:00 a.m. when ATIS is active for freight.

Table 17. Travel Time Measurement Results along I-45.

Statistic	Route	Travel Time (min)		% Change
		Base (No ATIS)	Scenario (ATIS)	
Average	I-45 GP Lane	30.35	21.95	−38.30%
Max		37.99	30.71	−23.71%

Furthermore, heat maps along I-45 SB were developed to better depict the speed pattern changes throughout the day with and without ATIS implementation. The heat maps show that traffic congestion and queuing are mitigated as freight takes the alternate path throughout the duration of the incident. In other words, the shockwave impact on the freeway is diminished as freight receives information on an optimal alternate route to reach their destination (Figure 53).

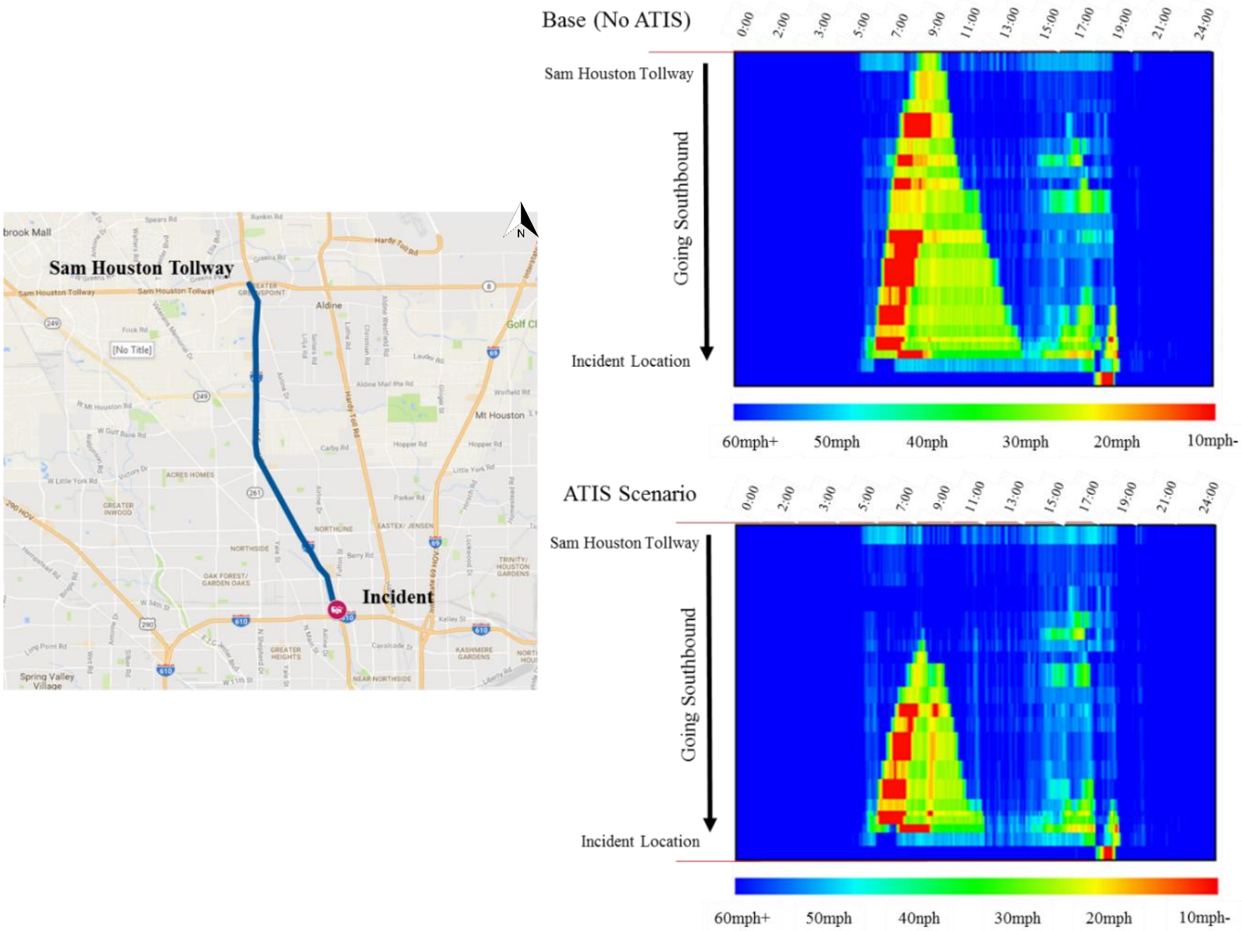

Figure 53. Heat Maps—I-45 SB for No ATIS and ATIS Implementation.

Off-Peak Freight Incentive on HOT Lanes

This strategy leverages the existing infrastructure of HOT/HOV lanes by allowing access to trucks during off-peak periods. This practice can be especially effective in providing access routes/corridors to ports and other urban freight generators. This strategy may improve the freight flow through urban areas and incentivize shippers and trucking companies to shift their operations to move freight during off-peak periods when they may use these facilities. Houston has an extensive network of HOV and HOT lanes, with heavy freight truck traffic on GP lanes even during off-peak hours making it an ideal candidate for implementation of off-peak freight incentive on HOT lanes.

However, most of the HOV/HOT lanes in Houston are reversible and have geometric constraints. Furthermore, access points along these managed lanes would make it difficult to accommodate trucks due to their turning radius and size. The only system where trucks are allowed is on the I-10 Katy Freeway HOV/HOT lanes since they are not reversible lanes. Trucks are tolled throughout the day for using HOV/HOT lanes. As a result, researchers selected this facility to test the off-peak use of HOT lanes for freight trucks during off-peak hours at this specific corridor. The incentive here will be no toll and faster speeds for using these lanes during off-peak hours. The Katy managed lanes' schedule is as follows (*46*):

- Morning peak hours—6:00 a.m.–10:00 a.m. (inbound).
- Afternoon peak hours—3:00 p.m.–7:00 p.m. (outbound).
- All other hours considered off-peak.
- HOV drivers ride free 5:00 a.m.–11:00 a.m. and 2:00 p.m.–8:00 p.m.

Figure 54 shows the location of the Katy managed lanes on I-10. Throughout this segment of I-10, trucks were given the option to travel along the Katy managed lanes with no toll during off-peak hours.

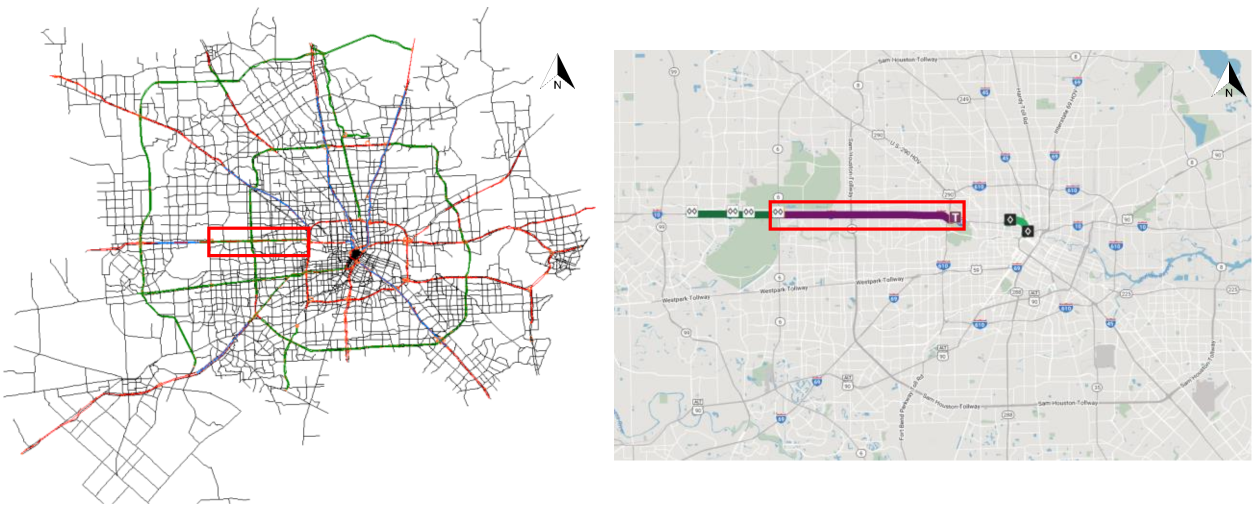

Figure 54. Location of Katy Freeway Managed Lanes on I-10.

The base case simulation results showed little to no truck flows on the Katy managed lanes; however, with the toll rates waived during off-peak hours, a significant jump was observed in both directions. Figure 55 shows the cumulative truck volume on the managed lanes near the Sam Houston Tollway. The blue line in the figure shows a cumulative increase in the truck traffic during the whole day, with the off-peak freight incentive strategy juxtaposed against the black lines that show conditions without this strategy in place (current scenario). Both directions experienced a significant freight flow spike.

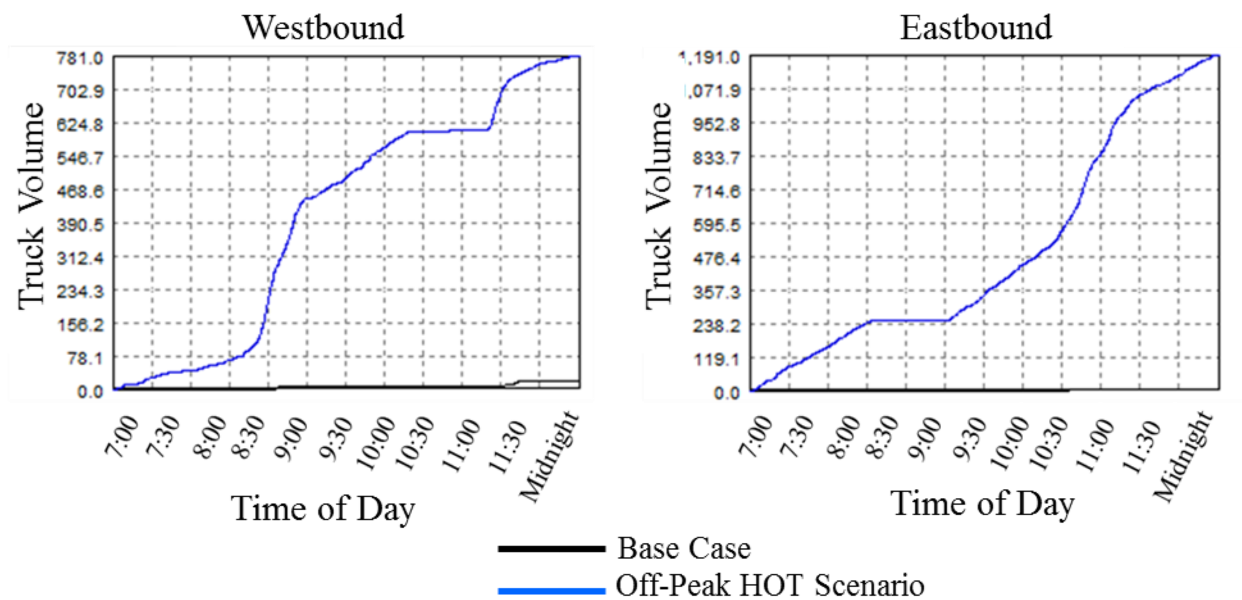

Figure 55. Cumulative Truck Volume near Sam Houston Tollway.

Travel time measurements were obtained with probe vehicles traveling along the I-10 corridor on both the GP and toll lanes. The evaluation limits go from the CBD in Houston to just east of SH 99 for a total travel time measurement of approximately 25 miles. As observed in Table 18, three out of the four routes evaluated showed some improvement in terms of maximum travel time savings. During the afternoon peak hours, the EB direction indicated the greatest benefit on both the GP and the Katy managed lanes (tolled lanes). On the other hand, Avg TTs throughout the day yield little to no improvement (e.g., less than 1 percent travel time savings).

Table 18. Travel Time Measurement Results on I-10—GP vs. Toll Lanes.

	Route	Travel Time (min)		% Change	Distance (mi)	Miles/Min Traveled	Departure Time
		Base Case	Off-Peak I-10 HOT Scenario				
Traveling WB	I-10 GP Lane	30.04	28.39	−5.49%	25.00	0.881	5:00 p.m.
	I-10 Toll Lane	25.01	25.04	0.12%	24.95	0.996	9:00 a.m.
Traveling EB	I-10 GP Lane	30.85	28.25	−8.43%	25.21	0.892	5:00 p.m.
	I-10 Toll Lane	30.55	28.12	−7.95%	25.20	0.896	5:00 p.m.

Freight Bypass Designation

The transportation network in the Houston area contains several major through corridors, along with three layers of loop routes. The Grand Parkway (SH 99) is the newest loop infrastructure to be constructed. It currently stretches between I-69/US 59 on the southwest and I-69/US 59 on the northeast part of the urban area. Other major through corridors with current connections to SH 99 include I-10 (west), US 290 (northwest), and I-45 (north). Since almost all of the major corridors through the urban core of Houston are identified on the TxDOT's Top 100 Congested Roadways, (see Figure 56) trucks using SH 99 could bypass the congested urban core roadways (*47*).

The freight bypass concept was discussed with the project oversight panel as part of scheduled project meetings. It was also discussed by Bruce Mann, Director of Freight Mobility with the Port of Houston Authority, as part of FHWA's "Talking Freight" webinar related to intermodal freight connectors on February 15, 2017. In the webinar, Mr. Mann indicated preliminary discussions have occurred between transportation planners in the region to investigate allowing trucks to use SH 99 and Beltway 8 toll-free to bypass the urban core congestion as a congestion-mitigation measure. This investigation looks to examine whether trucks using SH 99 as a freight bypass provide a benefit to those trucks and to the vehicles operating along the urban core corridors.

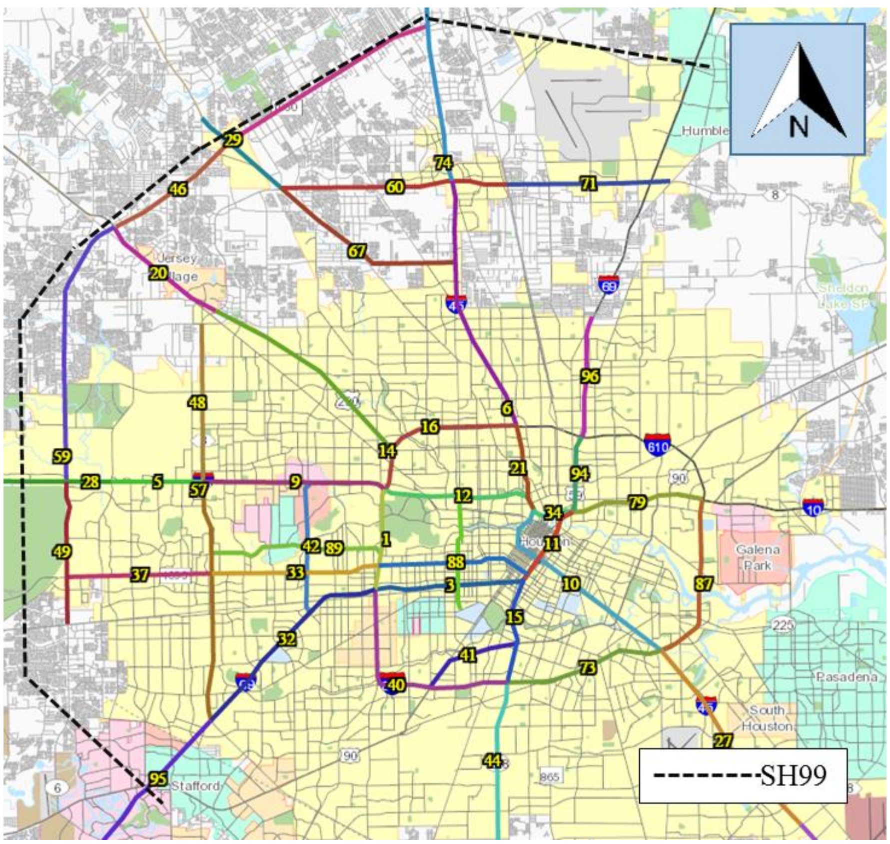

Figure 56. Houston Area Top 100 Congested Roadway (*47*).

To model the freight bypass strategy, the Grand Parkway (SH 99) loop circling the Houston metro region was coded into the regional DTA model, which includes five segments that stretch for approximately 70 miles (see Figure 57). In addition, all associated toll rates for plazas and ramps were included for all modeled SH 99 segments. Providing bypass is not enough to attract truck traffic onto SH 99 due to the longer length and perceived travel time on this bypass. Hence, truck traffic need to be incentivized to use this by waiving the toll (for through trucks) throughout the corridor. Therefore, to test this strategy, truck toll rates were removed/waived from all segments to incentivize freight traffic.

Figure 57. SH 99 Segments Added into the Regional DTA Model.

Model results showed very little freight traffic across all segments of the highway with tolls in place; however, with the removal of truck toll rates, a significant spike in flow was observed, as seen in Figure 58 (the broader the blue line, the larger the increase in truck traffic). Each picture shows the truck volume captured at different points along SH 99 in a particular direction. For example, the top left shows the freight flows taking the Grand Parkway (with no truck tolls active) going south to reach their destination. For comparison purposes, the truck flows captured on SH 99 with tolls active (i.e., base case scenario) are shown on the right.

Figure 58. SH 99 Truck Flow Comparison.

Average daily statistics were calculated for the whole network to quantify the impact in terms of trip time and stop time for both single occupancy vehicles (SOVs) and trucks. Table 19 shows the results. For both vehicle types, there was an improvement on the stop time of approximately 2 percent and 7 percent for SOVs and trucks, respectively.

Table 19. Freight Bypass Designation—Daily Network Statistics for SOVs and Trucks.

Vehicle Type	Measures of Effectiveness	Base Case (min)	SH 99 (No Truck Tolls)	% Change
SOV	Average Overall Trip Time	15.72	15.63	−0.60%
	Average Stop Time	0.97	0.95	−2.37%
Truck	Average Overall Trip Time	23.46	22.96	−2.15%
	Average Stop Time	1.18	1.09	−7.55%

In addition to the daily network statistics, individual probe vehicles were placed into the network to quantify travel time differences when commuting along SH 99 as opposed to entering the metropolitan area. A total of three paths (for both directions) were defined that start and end on US 69, as shown in Figure 59. All probe vehicles were assigned on the bypass scenario where all truck toll rates were removed from SH 99.

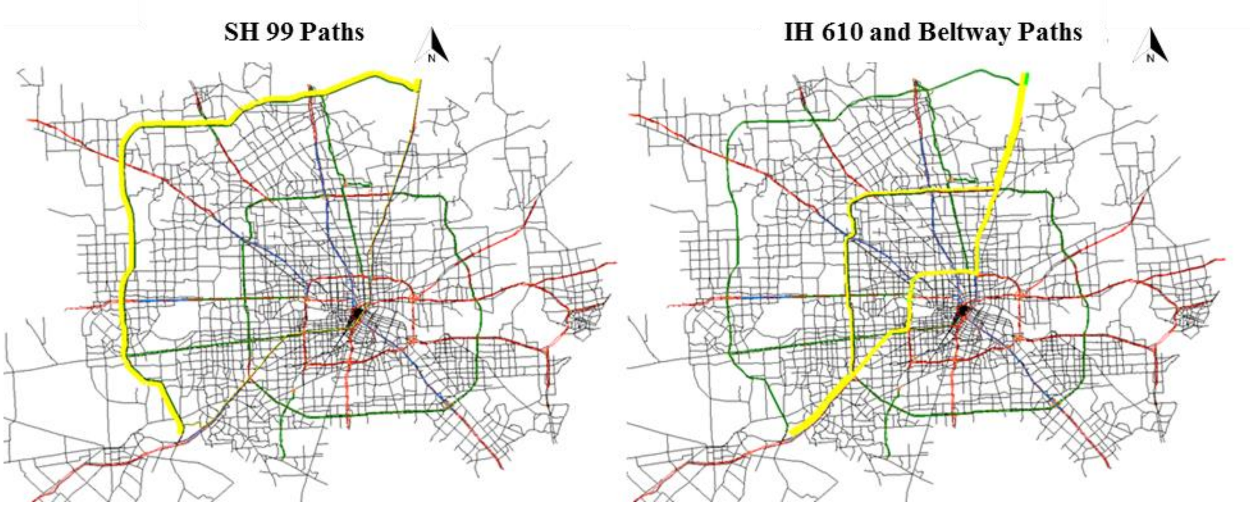

Figure 59. Probe Vehicle Paths for Freight Bypass Scenario.

Probe vehicle results showed travel time savings of up to 12 percent for the SB routes when departing during the afternoon peak hours, as shown in Table 20. On the other hand, the NB paths indicated a slight increase in travel time when compared to SH 99. However, the travel distance on SH 99 is significantly higher when compared to the I-610 or Beltway 8 route (i.e., 70 mi versus 50 mi on average). Furthermore, the miles per minute traveled along SH 99 are higher since traffic congestion is minimal along the whole corridor segments.

Table 20. Bypass Scenario Probe Vehicle Results on Three Different Routes.

Route - SB	SH 99 Travel Time (min)	% Change vs SH 99	Distance (mi)	Miles/min Traveled	Departure Time
SH 99	69.80	—	70.70	1.01	2:00 p.m.
Taking Beltway 8	70.58	1.12%	57.24	0.81	5:00 p.m.
Taking I-610	78.74	12.81%	52.26	0.66	5:00 p.m.
Route - NB					
SH 99	75.88	—	74.70	0.98	5:00 p.m.
Taking Beltway 8	73.93	−2.57%	51.80	0.70	6:00 p.m.
Taking I-610	73.36	−3.32%	46.89	0.64	6:00 p.m.

Grade Separation

Roadway geometry plays a big role in how freight moves on localized arterials, particularly in areas where freight interacts with rail. An area of concern is on E. Barbour's Cut Blvd. in Morgan's Point, Houston. Barbour's Cut Terminal is owned and operated by the Port of Houston Authority and has grown to be one of the premier container-handling facilities and is part of one of the world's busiest ports by cargo tonnage (*48*). However, stationed rail lines block the entrance into the port facility and cause substantial queuing of freight traffic waiting to enter the port facility, as shown in Figure 60 and Figure 61.

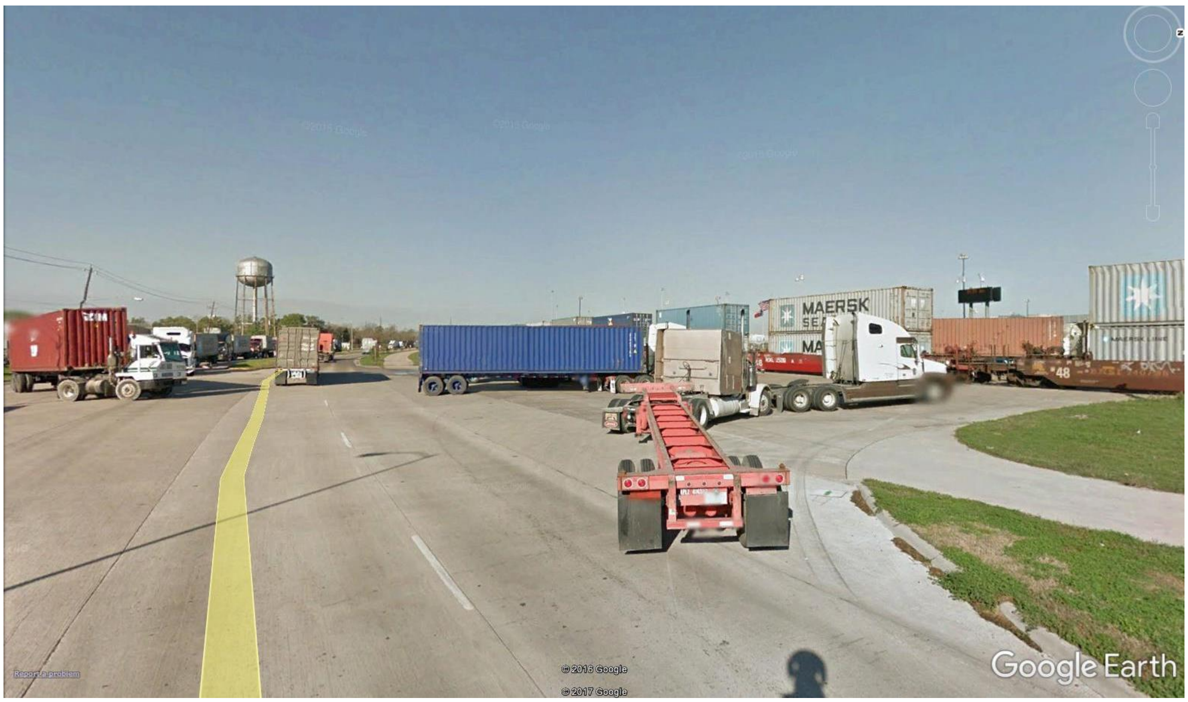

Figure 60. Barbour's Cut Terminal Freight Entrance.

Figure 61. E. Barbour's Cut Blvd. Freight Queuing.

A proposed rail grade separation will provide for a major unimpeded roadway crossing of the railroad line in a manner that also eliminates the potential for collisions and interference with railroad freight operations. Freight traffic routinely queues, and truck drivers sit idling until the rail has cleared the entrance.

A hypothetical microscopic simulation model was built of E. Barbour's Cut Blvd. (existing conditions) to simulate freight queuing, as shown in Figure 62. Several assumptions were made while developing the simulation model. First, the hourly flow rate of trucks was set to 100/trucks arriving per hour. The model was simulated for 6 hours with an hourly flow rate of 100 trucks arriving per hour. The speed of the trucks was set at a range of 30–35 mph. The rail line had an arrival every 2 hours, with a dwell time (stationary time) of 30 minutes to allow for loading/unloading, as shown in Table 21. During this dwell time, the rail line blocks the entrance and trucks queue back on E. Barbour's Cut Blvd. until the train departs and the entrance to the rail yard is open.

Figure 62. Simulation Model of Freight Queuing.

Table 21. Simulation Model Rail Arrival Schedule (Hypothetical).

Rail Line	8:00		8:30		9:00		9:30		10:00		10:30		11:00		11:30		12:00		12:30		1:00		1:30		2:00	
Train 1		▒	▒	▒																						
Train 2										▒	▒	▒														
Train 3																		▒	▒	▒						

A second simulation model was built to show how grade separation between freight traffic and rail could improve traffic and reduce queuing and greenhouse gas emissions. Grade separation substantially reduces queue lengths and wait times. In addition, it improves the air quality (greenhouse gas emissions) and fuel efficiency. The arrival rates of freight traffic varies throughout the day, so simulation results may vary. Figure 63 depicts a three-dimensional model with grade separation between freight and rail.

Figure 63. Simulation Model—Grade-Separated Crossing.

Various performance measures (PMs) were calculated between at-grade and grade-separation models. The average delay per vehicle for the at-grade was approximately 7 minutes, while grade separation was drastically reduced to approximately 17 seconds. The total stopped delay was 61 hours versus 22 hours, respectively, for at-grade and grade-separated. Table 22 shows the comparison between the two simulation model results.

Table 22. E. Barbour's Cut Simulation Model Comparison.

Parameter	At-Grade	Grade-Separated	(%) Change
Average delay time per vehicle (seconds)	415.7	16.6	185%
Average speed (mph)	5.7	23.0	121%
Average stopped delay per vehicle (seconds)	369.1	9.4	190%
Total delay time (hours)	68.8	2.8	184%
Number of stops	891	593	40%
Total stopped delay (hours)	61.1	1.6	190%
Total travel time (hours)	87.5	21.8	120%

Note: 6 hours of simulation.

EL PASO REGION

A comprehensive analysis of urban regions in Texas included the U.S.-Mexico border city of El Paso. Researchers selected dedicated truck lanes and ATIS because of the higher potential to reduce freight bottlenecks and the possibility of implementation in El Paso. Researchers studied two specific freight management strategies in El Paso: (a) conversion of underused toll lanes into dedicated truck lanes, and (b) implementation of ATIS for truck route information during an incident in peak directions.

Recently, there was a proposal by the Transportation Policy Board to eliminate the toll on César Chávez Border Highway in El Paso since the traffic using the toll lanes (6 percent) is significantly lower than that forecast in a 2010 study (*49*). Currently, most of the NB and SB truck traffic uses the I-10 corridor due to prohibited truck traffic on toll lanes of César Chávez Border Highway. Hence, researchers studied a hypothetical scenario of converting the underused 9-mile toll lanes on Border Highway (Loop 375) between the Zaragoza and Bridge of the Americas (BOTA) POEs to dedicated truck lanes, as illustrated in Figure 64. Only one lane (toll lane) of the highway in each direction was considered to be converted into a truck-only lane. The other lanes (two in each direction) were GP lanes.

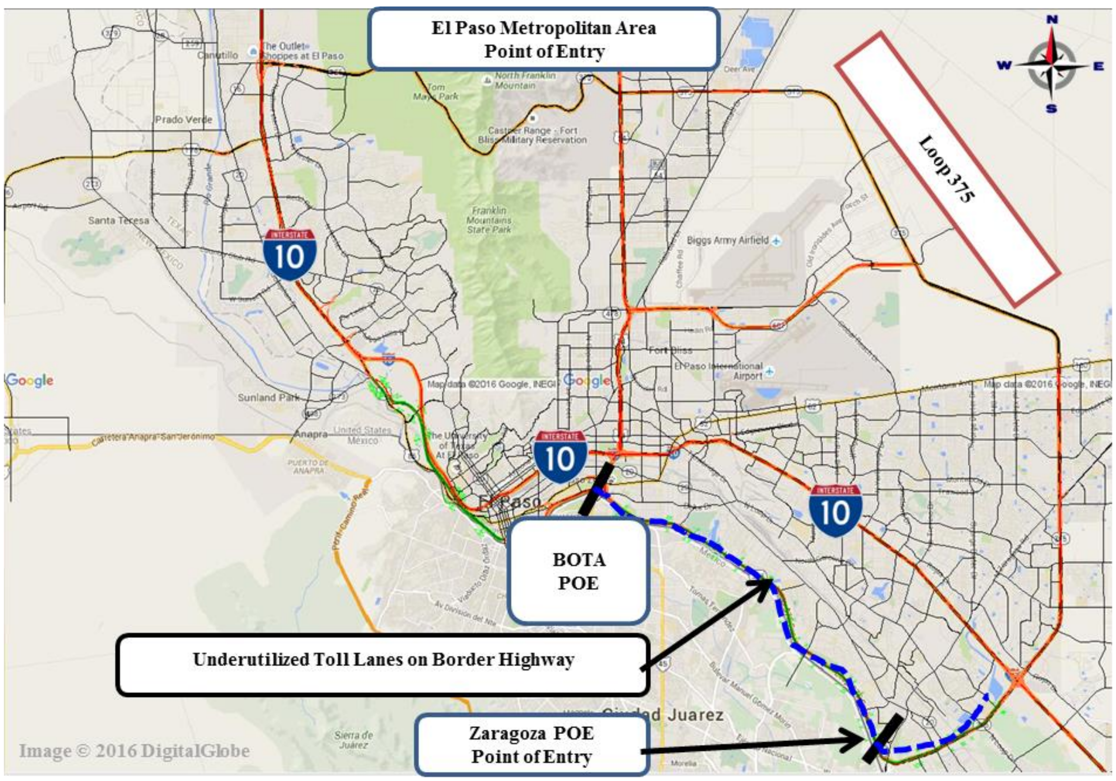

Figure 64. Underused Toll Lanes on Border Highway.

The second selected strategy for implementation was truck-traffic-specific ATIS for a freight bottleneck during peak hours. The idea is to divert the truck traffic to specific detours (non-residential streets, major highways) during a traffic incident. The selected corridor was I-10 near Executive Center Boulevard, identified as a top bottleneck for commuter traffic and prone to major delays due to incidents in the EB direction during the morning peak hours (see Figure 65).

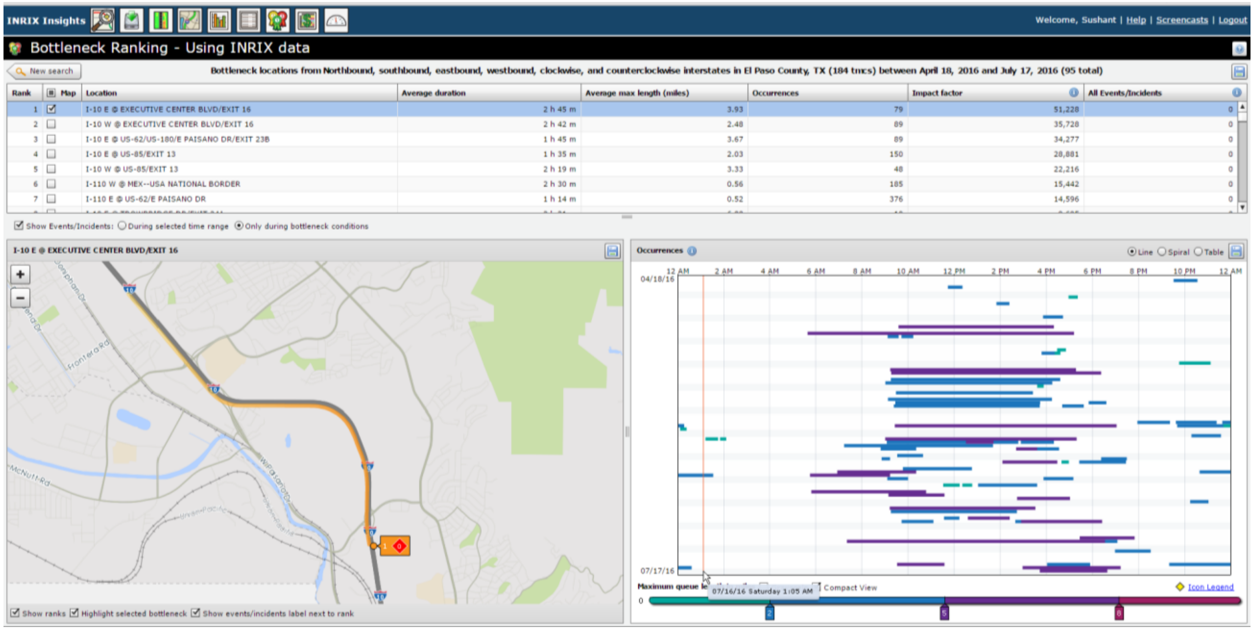

Figure 65. Top Traffic and Freight Bottleneck in El Paso Identified Using INRIX® Data.

Dedicated truck lanes can be modeled using DTA or MRM depending on the presence of a barrier. DTA is good for studying vehicle trajectories, route choices, and spatial-temporal patterns in a large network that requires multiple scenarios to be run. Both selected freight management strategies for El Paso (dedicated truck lanes and ATIS) are best studied using DTA models.

Researchers also used speed and travel time data for validation purposes. Specific corridor speeds during peak hours from the INRIX® data and field data were used to validate the model. This data may produce some minor adjustments to the traffic flow model to better represent realistic traffic conditions. Probe vehicles were also used as part of the validation process. Trying to match captured real-world travel times from the field with simulated travel times can be challenging. Departure times, exact route choice, and more all create challenges when trying to match simulated data with field data. To overcome this, researchers used the probe vehicle technique, where the model sends specific vehicles at predefined departure times and predefined routes. The travel times for each of the vehicles were matched with actual vehicles traveling the same routes and departing at the same departure time.

Dedicated/Exclusive Truck Lanes

For El Paso, the dedicated truck lanes strategy was modeled in two ways: first, by prohibiting cars from entering the truck-only lanes (basic definition of dedicated truck lanes), and second, by incentivizing trucks to use dedicated truck lanes by adding impedance (in the form of a minor penalty). The second strategy has higher potential to mitigate operational and safety impacts by reducing car-truck interactions in terms of weaving and passing maneuvers. Two scenarios were studied, one for dedicated truck lanes with current demand and the other for dedicated truck lanes with future demand (year 2020). The PMs were collected using probe vehicles in simulation that traveled through all the three routes (I-10 [marked in red], GP lanes on Border Highway [blue], and dedicated truck lanes on Border Highway [green]) (see Figure 66).

Table 23 shows the model results for the three PMs: Avg TT, standard deviation of travel time, and TTR. TTR is defined according to the recent requirements set forth in the Fixing America's Surface Transportation Act (*50*), (i.e., ratio of normal [50th percentile] and 95th percentile truck travel times for each reporting segment calculated to the nearest hundredth). The 95th percentile travel times estimate how bad delay will be on specific routes during the heaviest traffic days, whereas the 50th percentile shows normal travel time. The TTR ratio is how much total time a traveler should allow to ensure on-time arrival 95 percent of the time compared to Avg TT.

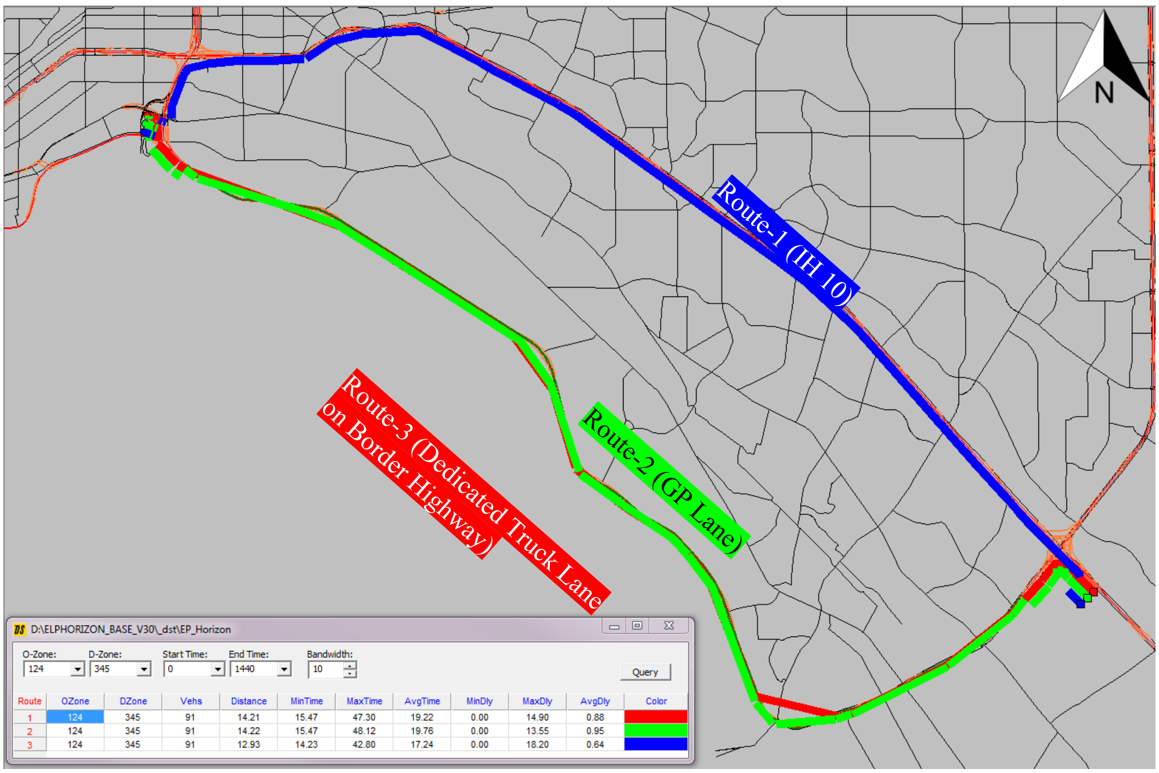

Figure 66. Border Highway Dedicated Truck Lane Results.

Table 23. Comparison of Toll Lanes to Dedicated Truck Lanes at Border Highway.

	Route 1 (I-10)			Route 2 (GP Lanes)			Route 3 (Toll Lanes/Truck Lanes)		
	EB								
	Avg TT (min)	Std Dev	TTR	Avg TT (min)	Std Dev	TTR	Avg TT (min)	Std Dev	TTR
Base Case	17	5.69	2.00	20	7.26	2.26	19	7.04	2.22
Dedicated Truck Lanes (2016)	18	5.68	2.05	22	10.65	2.45	16	2.74	1.40
Dedicated Truck Lanes (2020)	18	6.11	2.01	23	12.93	2.97	17	3.04	1.42
	WB								
Base Case	21	4.23	1.58	27	14.24	2.94	30	17.96	3.48
Dedicated Truck Lanes (2016)	20	4.34	1.61	30	17.75	3.22	19	1.04	1.10
Dedicated Truck Lanes (2020)	21	3.92	1.52	33	21.26	3.69	20	1.80	1.11

Three cases were compared: the base case, the dedicated truck lanes with current demand (2016), and the dedicated truck lanes with future demand scenario (the year 2020). The toll lanes in the base case were converted to dedicated truck lanes in the latter case. For the dedicated truck lanes strategy with 2016 demand, the conversion of toll lanes to dedicated truck lanes improved freight mobility (both travel time and reliability) on dedicated truck lanes (see Route 3 in Table 23) in both directions of the Border Highway. However, it increased Avg TT on the GP lanes (see Route 2) of the Border Highway and led to a marginal increase in travel time on I-10 (see Figure 66).

The shift of truck traffic from GP lanes to dedicated truck lanes increased truck freight mobility for the 2016 and 2020 demand, with travel time reducing around 15 percent (2–3 minutes) in the EB direction and 33 percent (9–10 minutes) in the WB direction compared to the base case. TTR also increased around 37 percent in the EB direction and 68 percent in the WB direction for all demands. However, the shifting of passenger traffic from underused toll lanes (now dedicated truck lanes) to GP lanes led to a travel time increase of 10 percent (2–3 minutes) in both directions for 2016 demand and around 18–21 percent (3–6 minutes) in both directions for 2020 demand. On I-10, travel time increased by 3 percent (1 minute) in the EB direction with no change in the WB direction.

Overall, the conversion of toll lanes to dedicated truck lanes appears to be an effective strategy from a truck freight mobility perspective, even in the future (2020 demand). The configuration of on-ramps and off-ramps on the proposed dedicated truck lanes may need to be revised. The induced truck trips from Zaragoza POE use these ramps to travel on the dedicated truck lanes.

Incident Management Using Truck-Freight-Specific ATIS

Another truck-freight-specific strategy that was considered was to provide detours and advance traveler information to truck traffic in case of an incident on a national freight corridor during peak congestion hours. This strategy was modeled using the option of traveler information that will only divert truck traffic and allow other passenger vehicles to plan their routes based on experienced travel time by employing TDUE.

Two scenarios were modeled: the first scenario was on the congested hotspot on EB I-10 in El Paso (the most congested national freight corridor in El Paso) during peak hours with 50 percent capacity reduction (only one lane available). The second scenario was truck-traffic-specific ATIS that provided a detour to truck traffic and discouraged them to be on the congested commuter route. The peak hours selected were between 7:00–9:00 a.m. To investigate the conditions with and without ATIS, probe vehicles were generated every 10 minutes for both scenarios to get an estimate of travel time and effectiveness of ATIS freight management strategy.

Table 24 presents the results of both cases. The results show a comparison of ATIS-based freight management strategy to no ATIS during an incident. Diverting truck traffic on other optimal corridors led to higher travel time savings and subsequently fuel savings. The travel time savings were 12–63 percent on the incident route and 37–71 percent on one of the non-mandatory (optional) detours, which is considerable given the truck traffic operating on this freight corridor.

Table 24. Travel Time with Truck-Centric ATIS Strategy during Incidence.

Start Time	Travel Time with No ATIS (minutes)	Travel Time with ATIS (minutes)		Percentage Travel Time Improvement with ATIS	
	Incident Route	Incident Route	Truck Detour (optional)	Incident Route	Truck Detour (optional)
6:40	9	10	12	−8%	−28%
6:50	9	9	13	1%	−47%
7:00	11	10	15	12%	−50%
7:10	36	23	15	35%	37%
7:20	45	38	19	15%	50%
7:30	54	44	21	19%	52%
7:40	64	48	25	24%	48%
7:50	75	52	28	31%	46%
8:00	75	57	29	23%	50%
8:10	74	60	28	19%	53%
8:20	75	59	30	22%	48%
8:30	73	57	26	22%	54%
8:40	71	54	23	24%	57%
8:50	67	52	21	22%	59%
9:00	63	48	17	24%	64%
9:10	59	43	12	27%	71%
9:20	53	36	14	32%	62%
9:30	47	30	13	36%	58%
9:40	42	25	13	41%	47%
9:50	39	20	13	49%	37%
10:00	33	15	13	54%	17%
10:10	29	11	13	60%	−12%
10:20	25	9	13	63%	−39%
10:30	20	10	13	49%	−28%
10:40	15	9	13	38%	−38%
10:50	11	9	13	14%	−41%
11:00	9	9	13	2%	−40%

AUSTIN REGION

Two freight management strategies that can be implemented in Austin are related to FRATIS and FSP. The FRATIS program was developed by U.S. DOT to promote improved urban freight mobility. It focuses on integrating regional ITS data, DOT commercial fleet data, third-party truck-specific movement data, and intermodal terminal data and using them for various FRATIS applications. Implementing these systems has the potential to greatly improve the decisions made by both fleet operations' planners and individual truck drivers and reduce congestion within urban areas. U.S. DOT has also contracted with TTI to expand FRATIS capabilities on I-35 between Austin and Dallas. This study assessed the expected effectiveness of FRATIS in managing freight flow under hypothetical incident scenarios on I-35 in Austin.

FSP is a potential ITS application that could help improve freight operations. FSP involves providing preferential treatment (e.g., traffic signal priority) for freight and commercial vehicles traveling within an urban area, particularly where there is a high volume of freight traffic, such as near ports (water and air), railyards, or other freight generators. FSP minimizes stops and delays to commercial vehicles at signalized intersections by extending the green signal when a truck is approaching the intersection. This practice can increase TTR for freight traffic, enhance safety at intersections, and provide environmental benefits by reducing acceleration and deceleration emissions for trucks. FSP strategy was considered on a 2.2 mi segment of Burnet Rd. from 183 to Gault Ln. for Austin because it serves major freight traffic generators and attractors.

Freight Advanced Traveler Information Systems

The location of the hypothetical incident was at mile marker 334 in the NB direction about 1 mile upstream of the point where the upper and lower decks of I-35 diverge, as shown in Figure 67. There is a DMS located at Mile Marker 220—14 miles upstream of the incident location—that can be used to divert trucks to SH 130 during the incident.

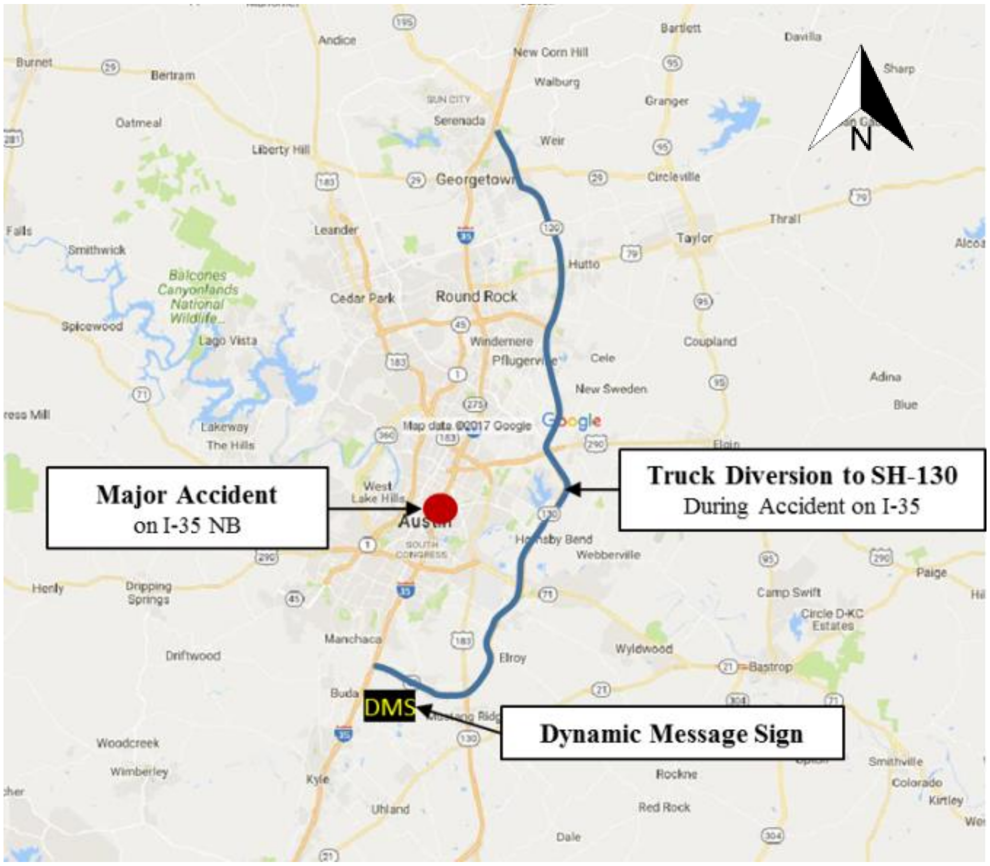

Figure 67. Major Incident on I-35 NB to Model FRATIS in Austin.

The FRATIS strategy was studied using the following three incident scenarios:

- Incident blocking one lane.
    - No diversion.
    - Diversion to SH 130.
- Incident blocking two lanes.
    - No diversion.
    - Diversion to SH 130.
- Incident blocking all three lanes.
    - No diversion.
    - Diversion to SH 130.

The FRATIS strategy encouraged truck drivers traveling through Austin on I-35 NB to take an alternate route during the major accident that blocked one, two, or three lanes of I-35. Other passenger vehicles were allowed to choose their routes determined by travel times they previously experienced based on TDUE. The dynamic message that can display advance travel information (e.g., incident location, expected delay, and available alternate route) is located about 14 miles upstream of the incident and 1 mile upstream of the I-35 junction with SH 130, a potential alternate route. During morning peak hours, under normal conditions without incidents, travel times on I-35 are typically 10 minutes longer than on SH 130, as shown in Figure 68. However, most drivers stay on I-35 to avoid paying tolls on SH 130. As part of the FRATIS strategy, it was assumed that the toll for trucks was eliminated for the duration of the incident and an additional half hour after that to encourage truck drivers to take SH 130.

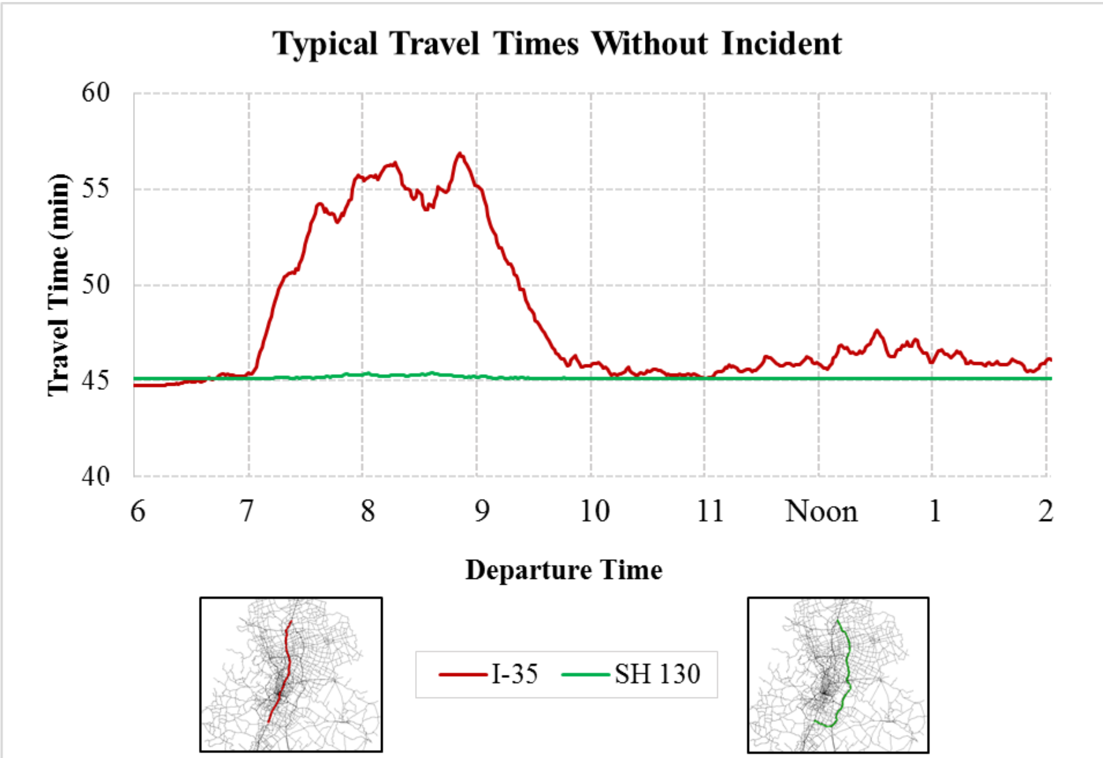

Figure 68. Typical Travel Times on I-35 and SH 130 without Incident.

Under the three incident scenarios, trucks traveling through Austin and taking SH 130 as an alternate route had to drive about 12 miles farther, but saved up to 18 minutes in travel time. The time-space diagrams in Figure 69 show that trucks diverting to SH 130 were able to drive at free-flow speeds with the exception of a 9-mile section of I-35 before they got to the SH 130 junction. Those vehicles that stayed on I-35 had to travel through a 15 to 20-mile long segment at significantly lower (0–45 mph) speeds.

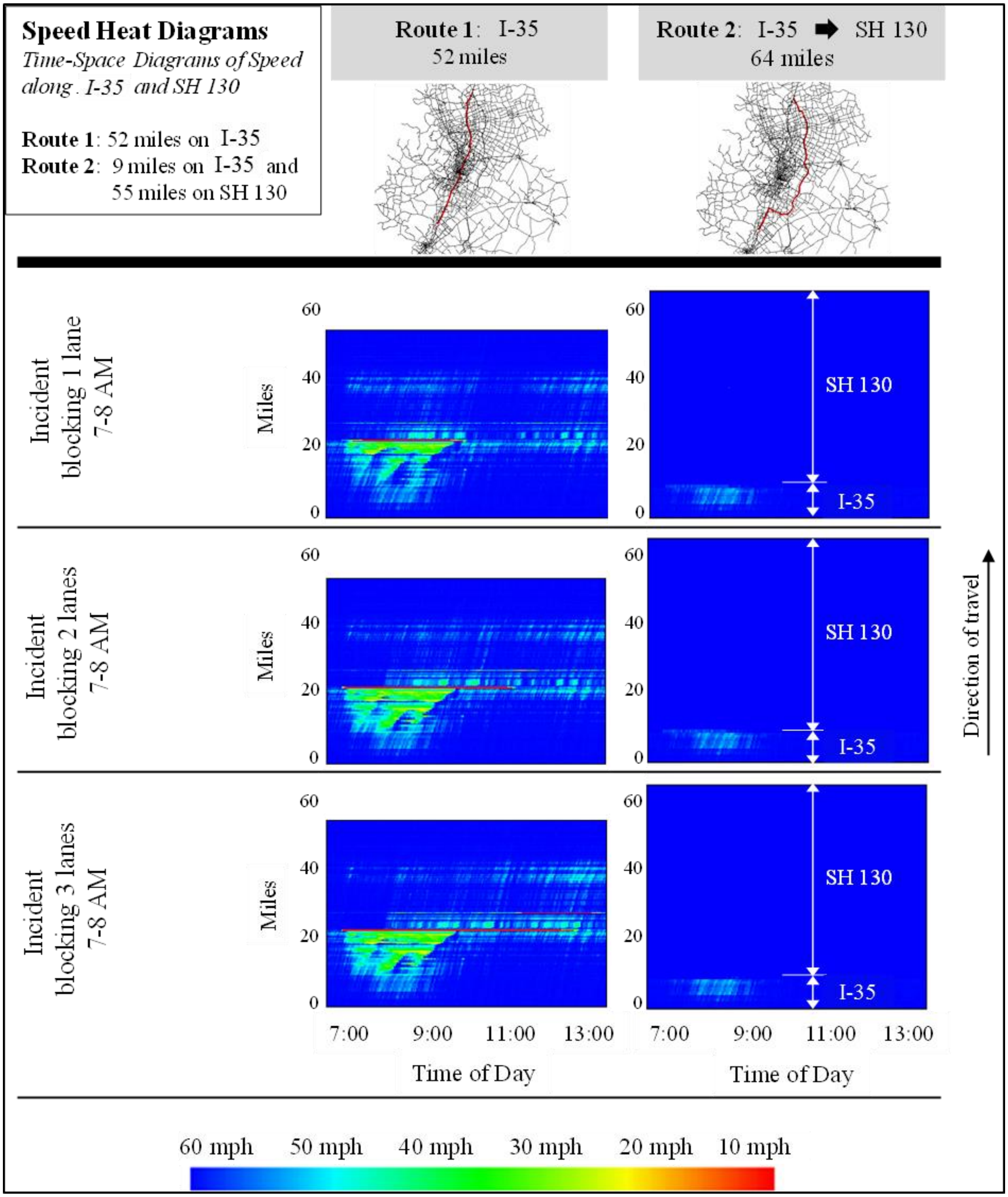

Figure 69. Time-Space Diagrams of Speed along I-35 and the Alternate Route.

Figure 70 shows the travel savings of trucks diverting to SH 130 instead of staying on I-35. The three time series plots correspond to the three incident scenarios with different capacity reductions (one, two, or three lanes blocked by the incident). The values on the horizontal axis show the times when trucks arrived at the DMS message sign location, and the values on the vertical axis indicate the travel times (in minutes) saved by those truck drivers who took the alternate route using SH 130. Table 25 gives the total vehicle-hours saved by all trucks using the alternate route to avoid the congestion on I-35.

Table 25. Vehicle-Hours Saved by All Trucks Diverting to SH 130.

	Incident Scenario		
	1 lane blocked	**2 lanes blocked**	**3 lanes blocked**
Vehicle-hours saved	224	303	399

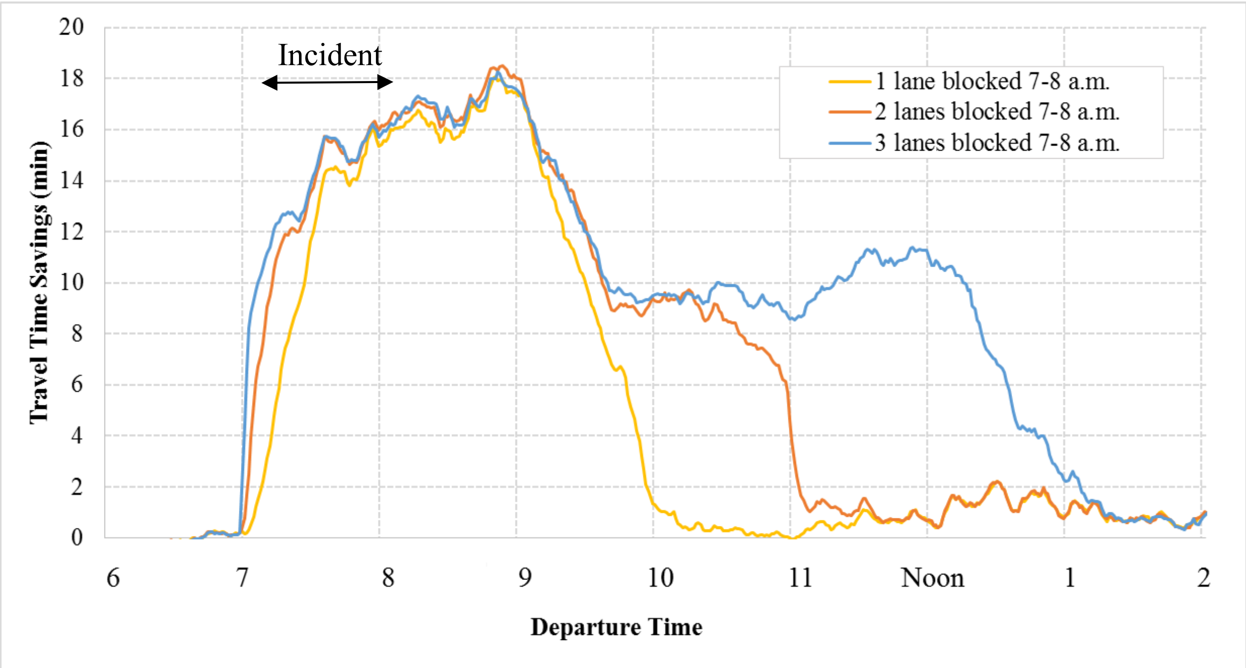

Figure 70. Travel Times Saved by Truck Diverting to SH 130.

Freight Signal Priority

In order to capture all traffic behavior patterns around the study area, researchers extracted a subarea from the Austin DTA regional model. This extraction was achieved by defining a boundary in the area of interest after running the DTA model to user equilibrium (UE) conditions. Once the subarea boundary was defined, all the paths, vehicle volumes, and the subarea network were imported into the microsimulation platform. Furthermore, the import process into the microscopic platform was done with a DTA-to-microsimulation converter developed by TTI.

The microsimulation model developed consists of a 2.2 mi segment of Burnet Rd. from US 183 to Gault Ln., which was selected as an FSP strategy case study for Austin, as shown in Figure 71. The 2.3-mile section is generally a four-lane arterial with a continuous two-way-left-turn lane and seven signalized intersections that currently run time-of-day coordinated timings.

Signal timing plans for all intersections were provided by the City of Austin's Transportation Department and coded accordingly into the model. The parameters of the base microsimulation model consisted of the following:

- Simulation period from 4:00 p.m. to 7:00 p.m. with 1 hour of warm-up.
- Afternoon schedule used for all signal timing plans.
- All signal controllers were coded as coordinated.

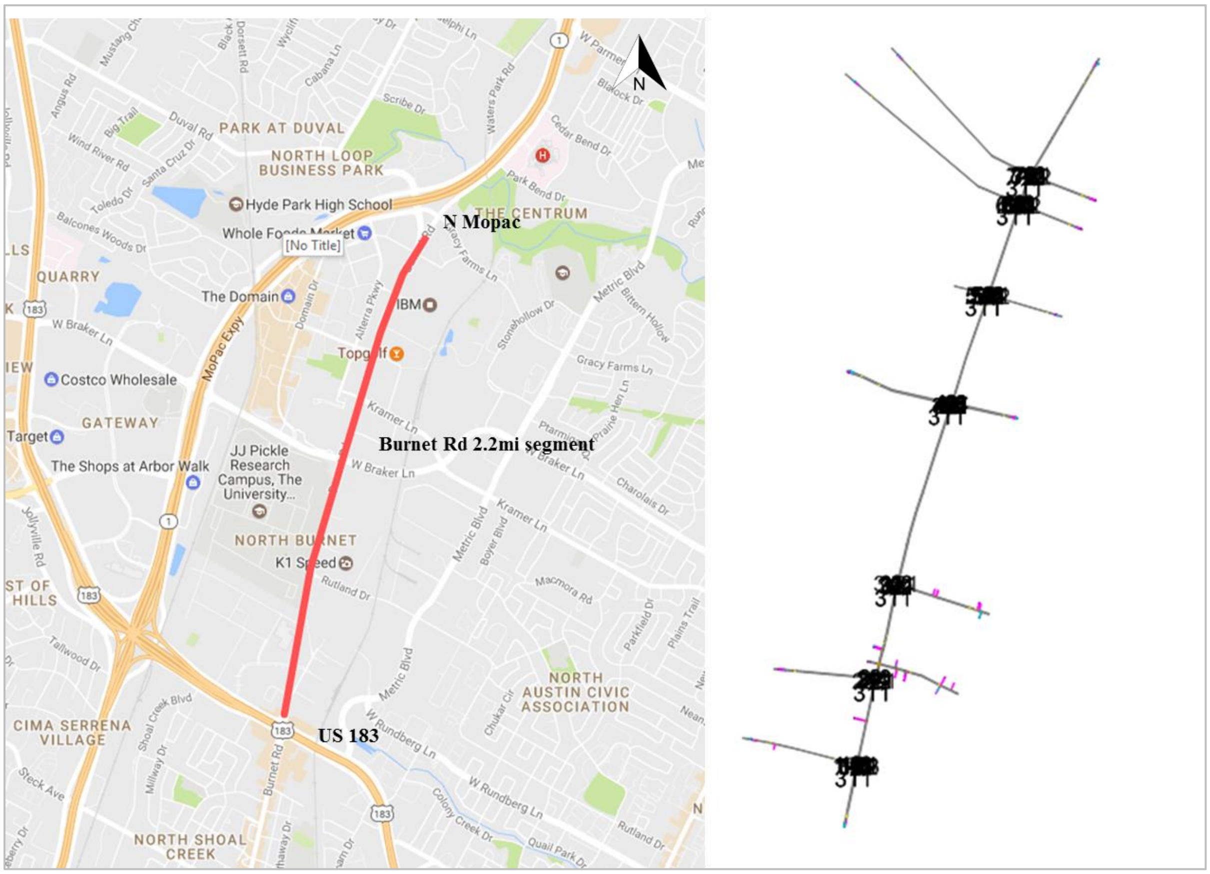

Figure 71. FSP Study Area and Microscopic Model.

The FSP scenario was developed on the base case model for the NB direction only. This approach is where the heaviest freight flow was observed throughout the afternoon peak period modeled. The parameters for the FSP model were coded as follows:

- A priority extension of 10 seconds was set for the NB approach.
- The priority mode was set to Early/Extend for all seven signal controllers.
- No signal omits (e.g., skipping phases) were considered for this scenario.
- The priority call was set to trigger only when the NB phase was active for that particular signal controller (i.e., call is sent to the controller on a NB Phase 2, but not on an EB Phase 8).

An evaluation of both scenarios was conducted to compare truck travel times and overall network statistics. Figure 72 shows the travel time segment examined going from Point A to Point B.

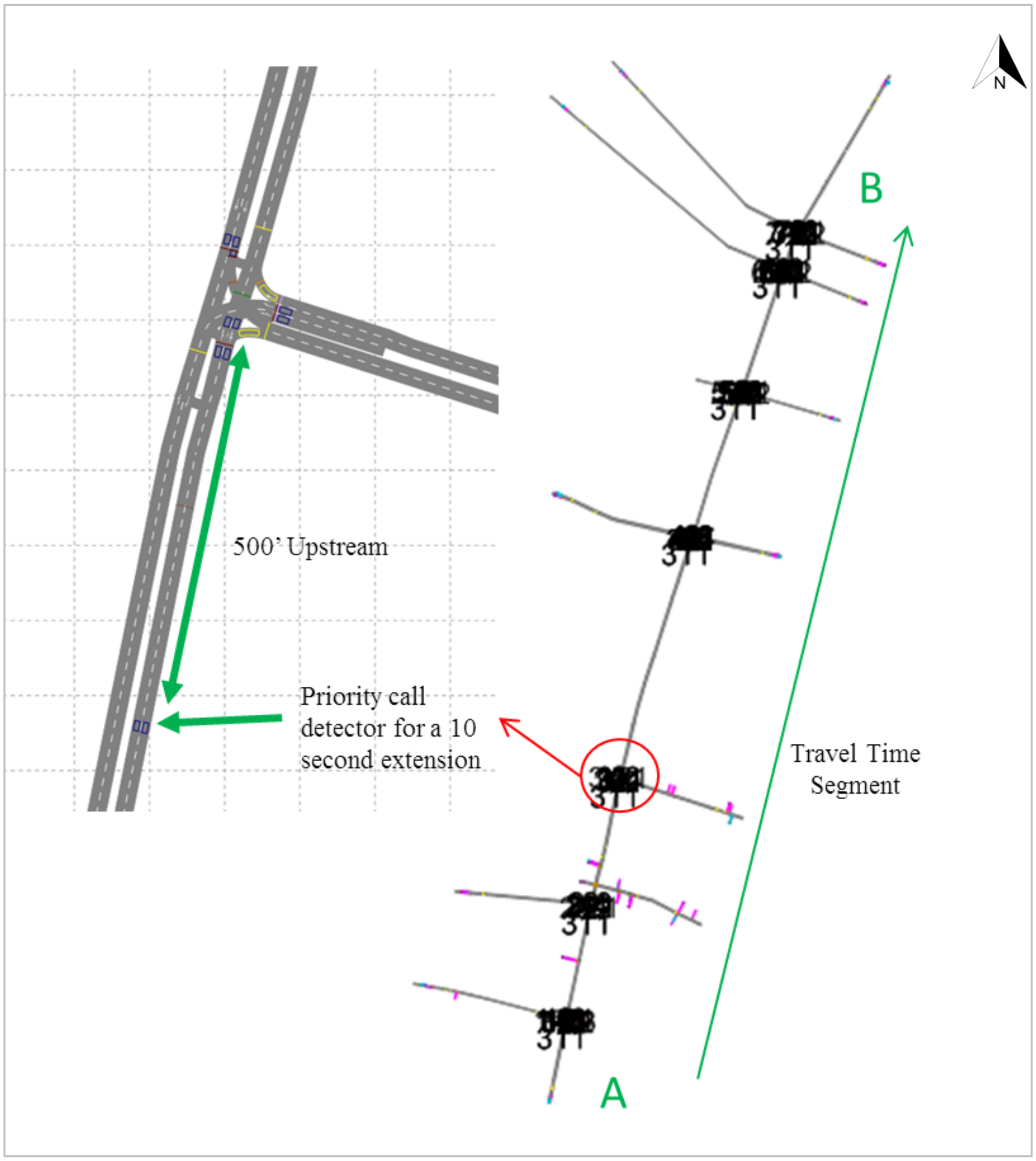

Figure 72. FSP Coding on Microsimulation.

The FSP simulation results showed no sign of improvement in terms of overall travel time for trucks traveling along the NB approach. This result is in part due to the NB approaches already using their maximum split during the heaviest peak traffic flow periods, making the minimum green extension have little to no impact on the overall throughput. Travel time on the NB approach showed a 1.90 percent and 0.87 percent increase for passenger cars and trucks, respectively. Furthermore, some of the cross streets experienced higher queue lengths (e.g., Palm Way) while others remained basically unchanged, as observed in Table 26.

Table 26. Burnet Rd. Cross Streets with Queue Length Percent Changes.

Cross-Street Approach	Queue Length Change vs Base (%)
Kramer Ln—WB	−3.92
Esperanza Crossing—EB	9.61
Esperanza Crossing—WB	−3.72
Palm Way—EB	30.87
Palm Way—WB	21.35

BINATIONAL REGION—EL PASO/JUÁREZ

The Texas economy relies heavily on freight mobility since 43 percent of industries and businesses are impacted directly and indirectly by freight transportation (*38*). In 2014, around 2.6 billion tons of freight were moved in Texas, and that number is anticipated to increase to nearly 3.8 billion tons by 2040, including 204 million tons that will cross the border. The U.S.-Mexico border city of El Paso, Texas, is served by three international commercial vehicle crossings: BOTA, Zaragoza–Ysleta, and Santa Teresa, New Mexico, all land POEs. Average U.S.-bound commercial movements through El Paso, Texas–Ciudad Juárez, Mexico border crossing are approximately 750,000 trucks every year, with BOTA experiencing an average of 330,000 U.S.-bound trucks every year. The average waiting time at BOTA is 37 minutes, and the 95th percentile waiting time is 90 minutes (*51*). The traffic steadily increases during the rush hour (6:00–9:00 a.m.) and peaks around 10 a.m. This truck traffic from POEs causes congestion on I-10 and various other major arterials in El Paso. Further, some of these POEs do not operate during off-peak hours and are closed for truck inspections. There is potential to reduce truck and commuter congestion by employing various freight management strategies (e.g., off-peak cross-border freight movement, OPD, off-peak usage of toll lanes) in the U.S.-Mexico bordering region. Thus, researchers studied different strategies that can be potentially implemented at these POEs.

BOTA Closure—Truck Route Diversion

Researchers simulated the closure of the BOTA POE to determine how freight would reroute to alternate border crossings. The scenario consisted of simulating and analyzing the first three defined scenarios. Traffic was assigned to all scenarios with 24 hours of demand, including both autos and trucks. A brief description of each scenario follows:

- **Base Case**: The do-nothing scenario ran for 15 iterations to reach UE conditions (i.e., satisfactory convergence criteria) in the network. The model aimed to represent 2015 traffic conditions in main arterials, freeways/highways, and the POEs.
- **Short Term**: To simulate the short-term impact of a critical failure infrastructure in the network, the model assignment method was changed from iterative (e.g., UE) to one-

shot. A one-shot method assigns vehicles with their habitual path previously obtained from the UE assignment. This allowed researchers to measure the immediate traffic impacts and related economic effects of shutting down a major interchange (US 54/I-10) and the BOTA POE.

- **Long Term**: The long-term model was run under an iterative UE assignment method to simulate the vehicles' change in routes because of the transportation infrastructure closure at the BOTA POE and the US 54/I-10 interchange. Under UE assignment, the vehicles adapted to the missing infrastructure by finding alternative paths (or a new POE if crossing the border) to arrive at their destination. In this scenario, the iterative UE process assumes that drivers have found new and generally cost-effective routes after several weeks of adjusting to the closed transportation infrastructure.

The diversion rates (defined as the ratio of the diverted truck volume due to the POE disruption) were assumed for the long-term equilibrium runs for the three previously discussed scenarios. For the SB truck trips from El Paso (United States) to Juárez (Mexico) via Ysleta and Santa Teresa, the average detour rates for the three time intervals was approximated as 42 percent, (long-term equilibrium run compared to baseline). This figure suggests that in the long-term run, approximately 42 percent of the baseline BOTA trips might divert to an alternate POE (e.g., Santa Teresa or Ysleta). For NB truck trips from Juárez (Mexico) to El Paso (United States) via Ysleta and Santa Teresa, the average detour rates for the three time intervals were estimated at 0.33 (long-term equilibrium run compared to baseline). This figure suggests that overall approximately 33 percent of the baseline BOTA trips might divert to an alternate POE (e.g., Santa Teresa or Ysleta). For the internal U.S.-U.S. trips, the detour rates were assumed at 100 percent.

These approximated diversion rates were derived based on behavioral assumptions of the only route rationalization as seen in the long-run and baseline equilibria. In other words, these rates will not reflect any other behavioral effects such as changes in departure time or trip reduction because of mode choice. Diversion rates were also approximated at the individual link level close to the POEs. This approach was used to account for trip reductions occurring in the long-term equilibrium and the impracticality of racking actual paths/route choices of individual vehicles. Hence, these will be likely biased. In this research, trips that crossed the border were considered as sensitivity parameters alone.

Figure 73 and Figure 74 show the potential simulated immediate network effects from a critical infrastructure disruption and in an adapted longer-term-run equilibrium in the context of DTA models (as distinctly different from economic notions of long-run equilibria). These figures include all trip types in the short term disrupted and long-term-run equilibrium scenarios (as trip origins). The figures show that all trips beginning from almost all zones (with the exception of trips starting farther south in Juárez) experienced a significant increase in travel time. The highest travel time increases were for trips starting along US 54, I-10, and zones in Juárez located near the U.S. border. The long-term-run equilibrium travel time changes were also very similar to the short-term disrupted scenario, both indicating a clear pattern of predominant hot spots in terms of the most affected zones along US 54 and I-10. One of the obvious values for this spatial exploration arises from the need to consider mitigation options starting at the northern perimeter of El Paso County along I-10 and US 54.

Figure 75 and Figure 76 showcase similar distributions of travel time for trip destinations. Not surprisingly, the destinations along I-10, US 54, and Central Juárez experienced the highest impedances in both scenarios. Since these scenarios include all trip types, travel time increases on the Juárez side are primarily driven by spillovers from congestion in internal movements. Interestingly, most external zones also showed a significant increase in travel times in both cases. This increase indicates that there is a significant potential for long-haul trips outbound from the binational region to experience significant delays. Figure 75 and Figure 76 show the corresponding thematic volume maps showing specific destinations for both short- and long-term disruptions.

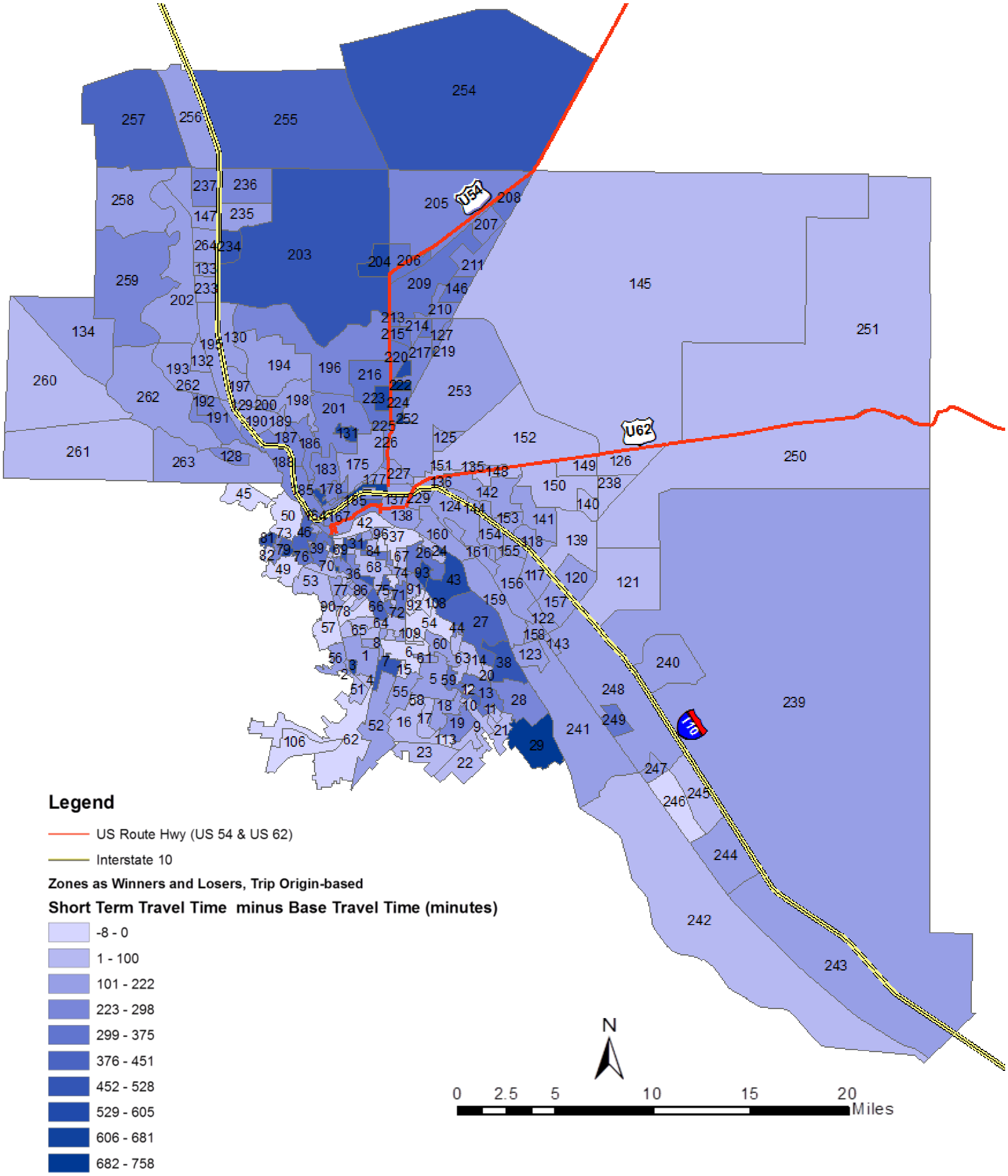

Figure 73. Change in Travel Times—Short Term vs. Base (Origins).

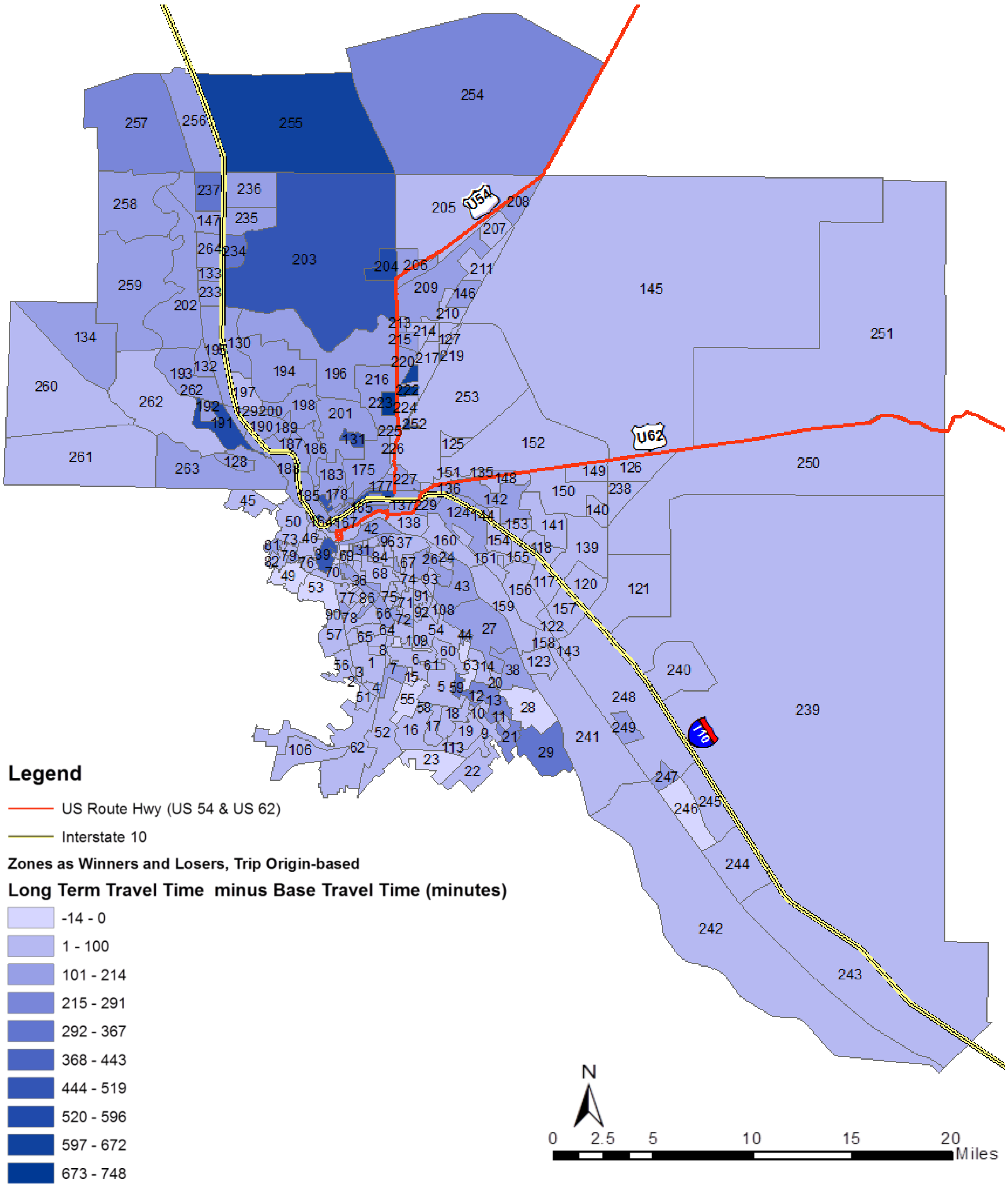

Figure 74. Change in Travel Times—Long Term vs. Base (Origins).

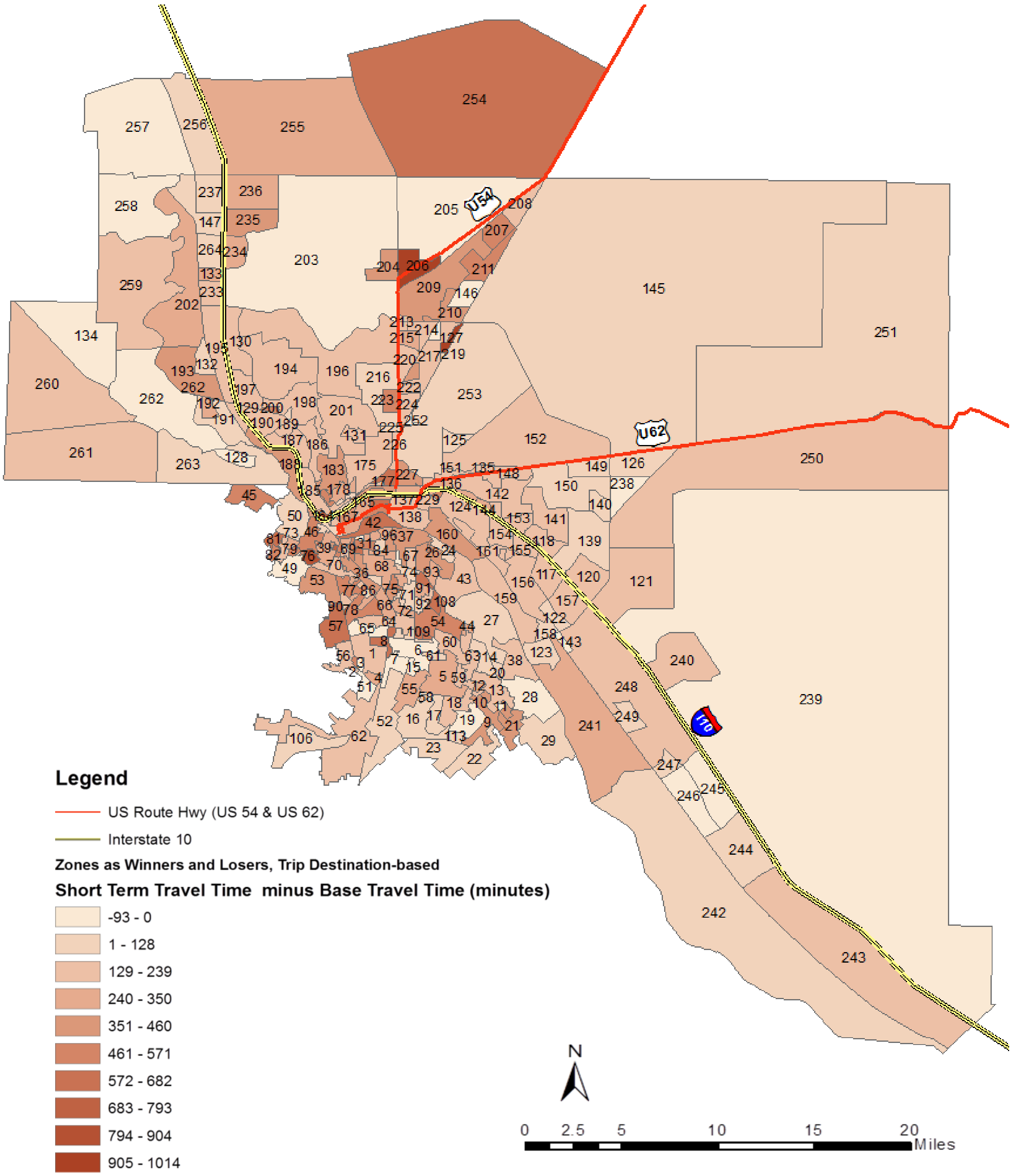

Figure 75. Change in Travel Times—Short Term vs. Base (Destinations).

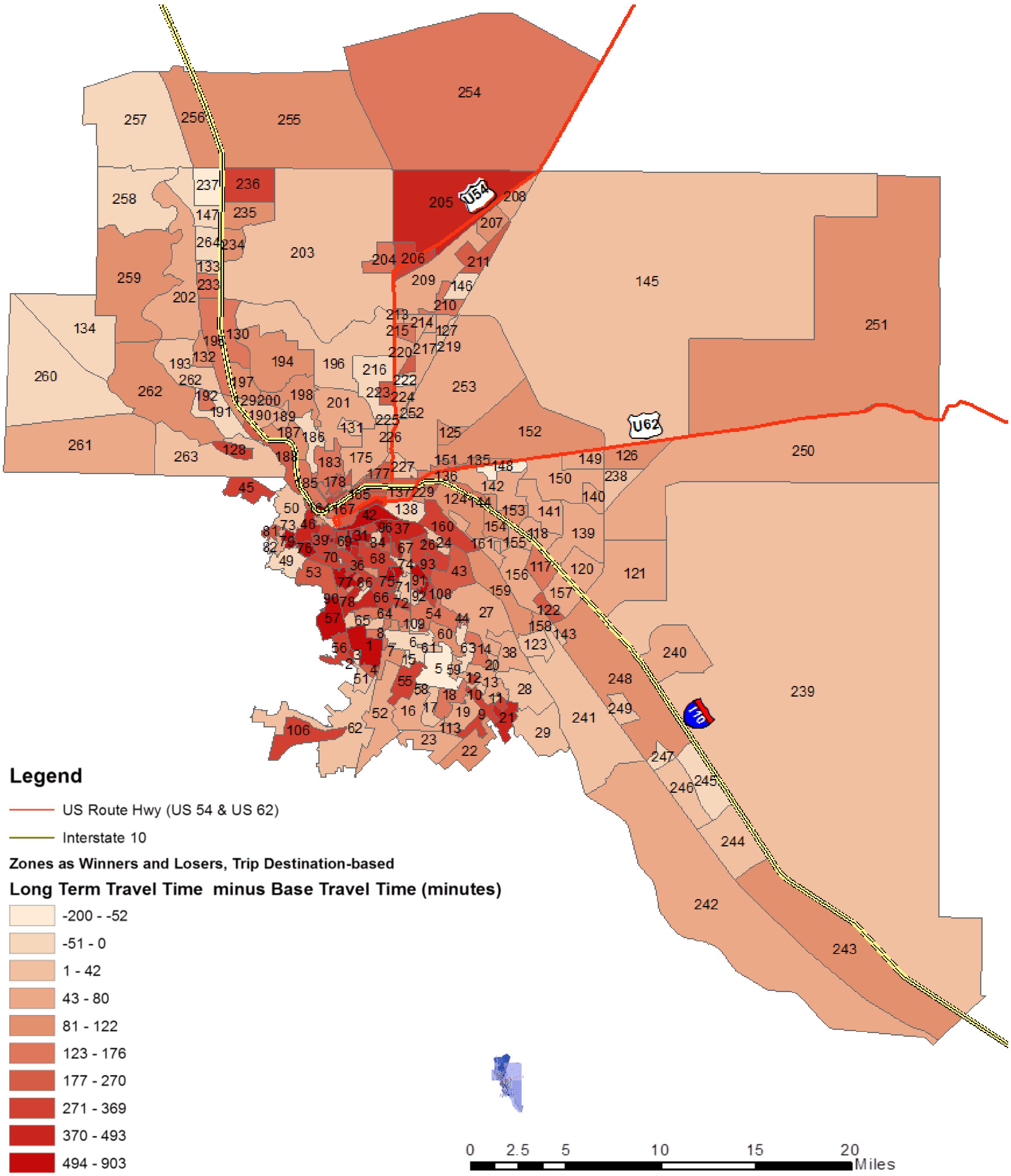

Figure 76. Change in Travel Times—Long Term vs. Base (Destinations).

Simulation results showed that Avg TTs for freight crossing the border NB experienced approximately a 30-minute travel time to internal destinations in El Paso. After a major incident that closed the BOTA POE, short-term travel times for freight crossing the border experienced over 2-hour travel times. After several weeks of driver adaptation to network conditions and vehicles learning new shortest paths to their respective destinations, the cross-border travel times were reduced to approximately 42 minutes (Figure 77). Travel times can vary significantly due to the number of inspection stations open at the bridge and inspection times at primary (U.S. Customs and Border Protection [CBP]) and secondary (Department of Public Safety) inspection stations.

Figure 77. Avg TT for Freight Crossing into the United States.

BOTA—Geometric Design Improvement Strategies

The BOTA POE in El Paso, Texas, experiences tremendous traffic congestion heading SB into Mexico during the afternoon peak hours. Three main approaches lead to the POE: (a) E. Paisano Dr. WB, (b) E. Paisano Dr. EB, and (c) the I-110 frontage road SB, as shown in Figure 78. While there are concrete barriers separating freight into a dedicated lane, passenger vehicles routinely enter and occupy any available lane.

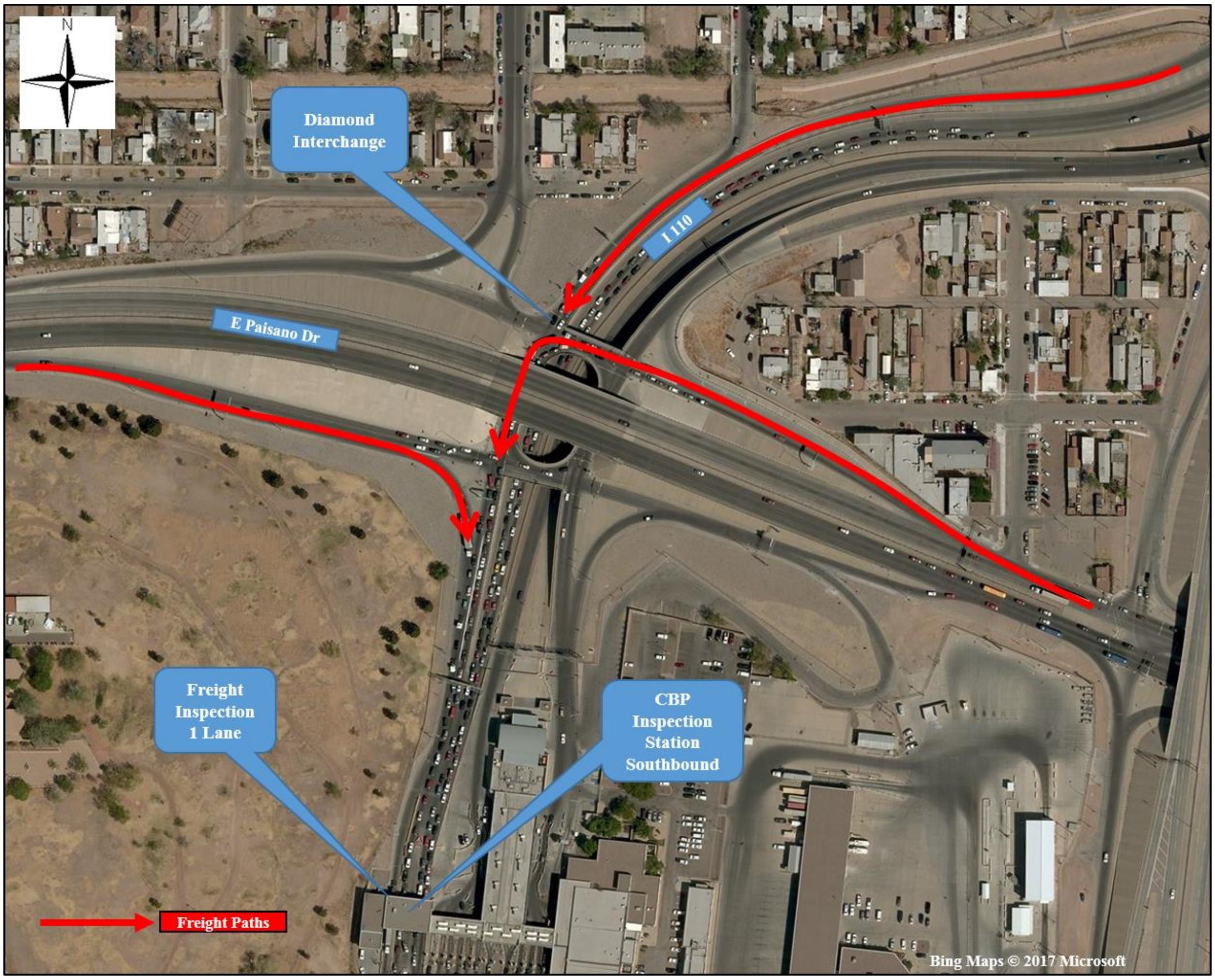

Figure 78. Freight Flows into BOTA POE.

Site investigation revealed that trucks traveling south toward the BOTA POE all exit from the I-110 main lanes to the parallel frontage road and travel through the signalized diamond interchange at E. Paisano Dr. while passenger vehicles are directed to stay on the I-110 main lanes and travel underneath the interchange. However, there are still passenger vehicles that travel through the interchange. Many of those vehicles do not obey traffic control and proceed into the intersection, even with a red signaled approach. This maneuver in turn blocks through movement for the next approach, as shown in Figure 79.

Figure 79. E. Paisano Dr. Congestion during Peak Period—SB.

The El Paso Police Department has officers directing traffic through the intersection on occasion, but police presence is needed Monday–Friday during the afternoon peak period (4:00–7:00 p.m.). This presence would provide better overall flow in and around the interchange—especially for through movement.

The BOTA SB inspection station into Mexico only has one lane dedicated for freight vehicle inspection. An additional inspection booth would increase the amount of freight that could cross and decrease the queuing caused by heavy vehicles. However, there is only one dedicated lane for freight approaching CBP inspections, and the bay dedicated for freight does not extend all the way to the frontage road. Extending the storage bay all the way back to E. Paisano Dr. and constructing an additional inspection station as shown in Figure 80 would improve freight throughput and reduce delay times and would be beneficial for passenger vehicles as well.

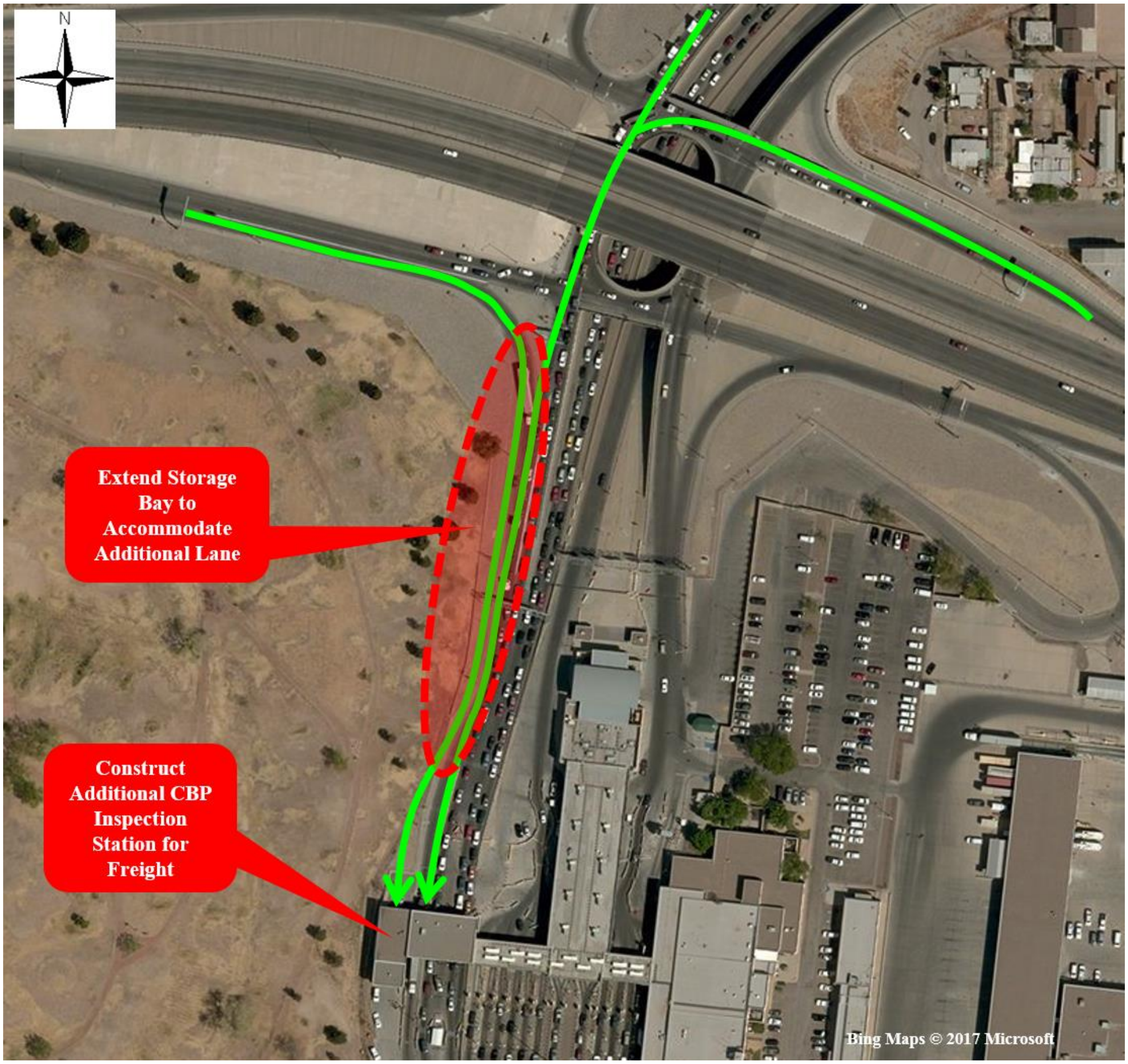

Figure 80. Improved Geometric Design and Inspection Capacity.

The site visit also revealed that the queuing from the POE was mainly due to the CBP booths. Random inspections in addition to the speed reductions on approach to the inspection stations are the main contributing cause of queue spillback. On occasion, the Juárez side has a reduced number of inspection booths open, which causes spillback to the CBP inspection station, which further contributes to the traffic congestion in and around the study area. Since the inspection times are random events, it is hard to predict the extent of the queuing on any given day.

Yselta/Zaragoza—Geometric and Operational Improvements

The Ysleta/Zaragoza POE handles approximately 260,000 commercial vehicles (based on 2015 counts) on an annual basis, as shown in Table 27. This POE has the fifth highest NB commercial crossings among all Texas-Mexico ports and is expected to more than double the number of trips by 2035 (*52*). However, the port is not open to commercial vehicles 24 hours a day. In order to understand the operational characteristics of the POE, it was necessary to collect temporal and spatial data of bridge operations. The data consisted of the average hourly crossing and the number of commercial lanes open (both FAST lanes[12] and non-FAST lanes). A database developed by TTI analyzed the NB commercial flow,. The database uses data from CBP's official website, which reports the number of inspection booths open and the corresponding average wait and crossing times (*53*). Figure 81 shows the average wait times during a typical weekday in March 2016.

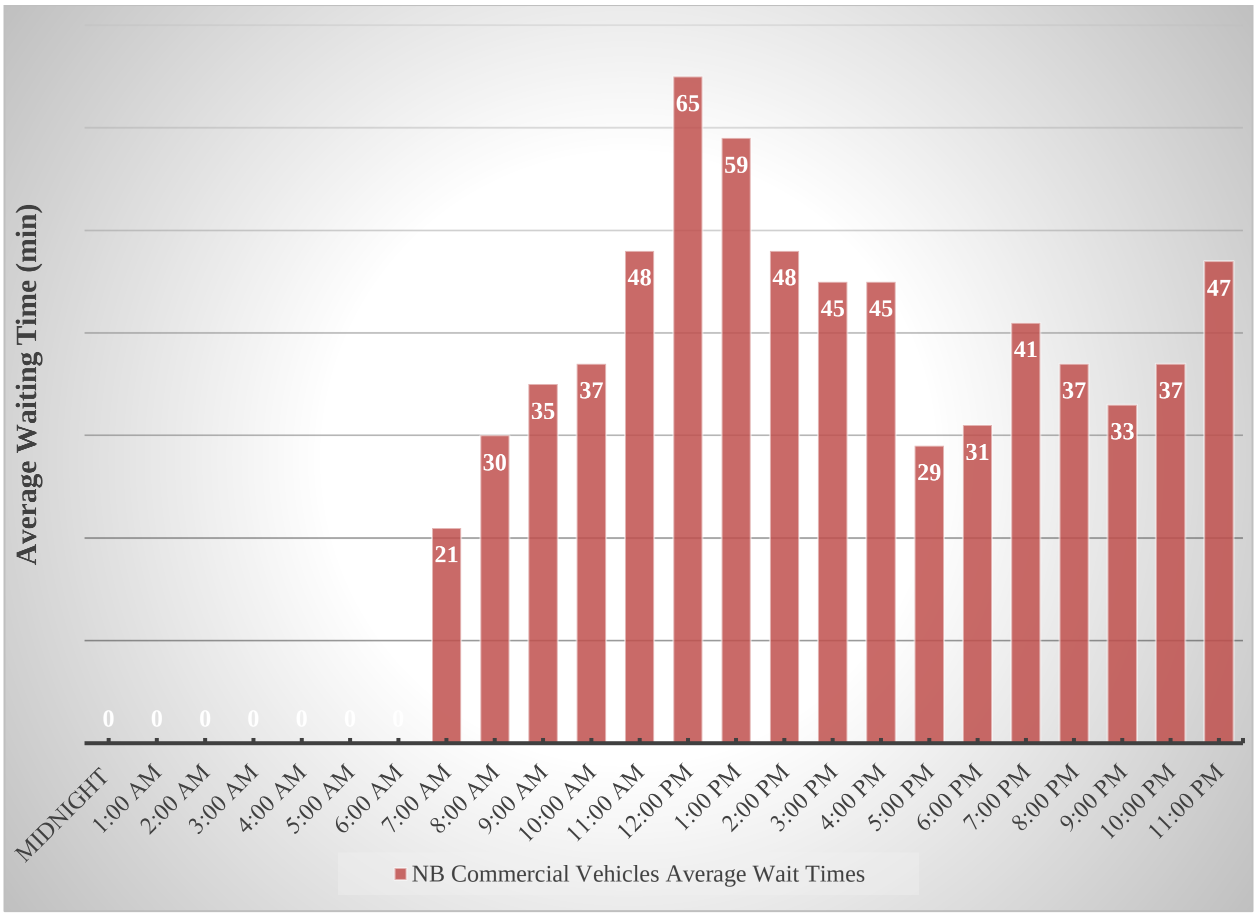

Figure 81. Ysleta/Zaragoza Commercial Vehicle Average Wait Times.

[12] FAST lanes: Free and Secure Trade for Commercial Vehicles is a clearance program for known low-risk shipments entering into the United States from Canada and Mexico that allows expedited processing for commercial carriers who have completed background checks and fulfill certain eligibility requirements.

Table 27. NB Commercial Vehicle Monthly Traffic—2015.

2015 - NORTHBOUND TRUCK MONTHLY TRAFFIC FIGURES													
POE	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Yearly Total**
Veterans International Bridge	14,675	14,287	16,043	15,484	14,645	15,940	15,634	14,272	15,100	16,140	14,716	13,728	**180,664**
Gateway International Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
B&M Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Free Trade Bridge	1,977	1,967	2,138	2,083	1,771	2,050	2,135	2,027	2,287	1,936	1,619	1,756	**23,746**
Progreso International Bridge	3,827	3,471	3,990	3,302	3,249	2,697	2,674	2,734	2,706	3,046	2,671	2,573	**36,940**
Donna International Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Pharr-Reynosa Intl. Bridge on the Rise	46,153	44,642	49,529	45,919	44,951	45,571	46,515	41,976	44,137	48,135	45,141	43,590	**546,259**
McAllen-Hidalgo-Reynosa Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Anzalduas International Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Los Ebanos Ferry	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Rio Grande City-Camargo Bridge	2,561	2,421	3,026	2,684	2,711	2,609	2,744	2,238	2,375	2,683	2,300	2,538	**30,890**
Roma-Ciudad Miguel Aleman Bridge	591	611	711	642	694	675	850	666	630	617	568	615	**7,870**
Lake Falcon Dam Crossing	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Juarez-Lincoln Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Gateway to the Americas Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
World Trade Bridge	130,417	128,192	144,513	138,288	137,509	145,929	144,820	135,949	140,409	146,277	135,166	131,480	**1,658,949**
Laredo-Colombia Solidarity Bridge	29,296	28,575	33,235	31,318	30,092	30,250	29,517	26,751	29,438	32,517	27,537	28,298	**356,824**
Camino Real International Bridge	11,325	10,844	12,081	11,965	11,925	13,031	12,230	11,397	12,064	12,246	11,188	11,296	**141,592**
Eagle Pass Bridge I	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Del Rio-Ciudad Acuna Intl. Bridge	5,529	5,445	6,181	5,984	5,564	6,110	6,165	5,579	6,117	6,556	5,670	5,109	**70,009**
Lake Amistad Dam Crossing	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Presidio Bridge	787	739	746	752	645	670	750	694	689	820	838	697	**8,827**
Fort Hancock-El Porvenir Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Tornillo-Guadalupe Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ysleta-Zaragoza Bridge	34,469	33,689	30,992	17,305	17,221	18,839	19,311	16,362	16,386	19,886	19,241	17,571	**261,272**
Ysleta-Zaragoza Bridge (DCL)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Bridge of the Americas	25,402	24,744	34,681	46,530	44,959	47,261	46,652	44,892	56,075	46,592	40,528	38,456	**496,772**
Good Neighbor Bridge (SB only, NB DCL)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Paso del Norte Bridge	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Monthly Total	**307,009**	**299,627**	**337,866**	**322,256**	**315,936**	**331,632**	**329,997**	**305,537**	**328,413**	**337,451**	**307,183**	**297,707**	**3,820,614**

DCL=Dedicated Commuter Lane

Allowing commercial vehicles to cross the POE 24 hours a day could alleviate some of the queuing and help reduce wait times in addition to reducing fuel consumption and greenhouse gases. However, there may be some caveats to having a 24-hour operational commercial inspection station. For instance, the Mexican side (Aduanas) of inspections only has two inspection lanes, whereas the Ysleta/Zaragoza port has eight lanes. If there is a bottleneck at Aduanas due to longer inspection times, then the flow rate across the bridge is constrained. In addition, not all maquiladoras are open 24 hours a day, so there may be some limitation in the number of commercial vehicles leaving those facilities during late night hours destined for the United States. Conversely, that could be offset by commercial vehicles traveling from the interior of Mexico to the United States.

The geometry of the Ysleta/Zaragoza POE has two lanes that cross over the bridge and then branch out at the primary inspection facility. Having all eight inspection booths open compared to only two increases capacity by approximately 33 trucks, depending on size and vehicle type, as shown in Figure 82. Not all inspection booths for FAST and non-FAST lanes are open continuously. This may be due to CBP staffing shortages and overtime pay required to have all inspection stations in operation.

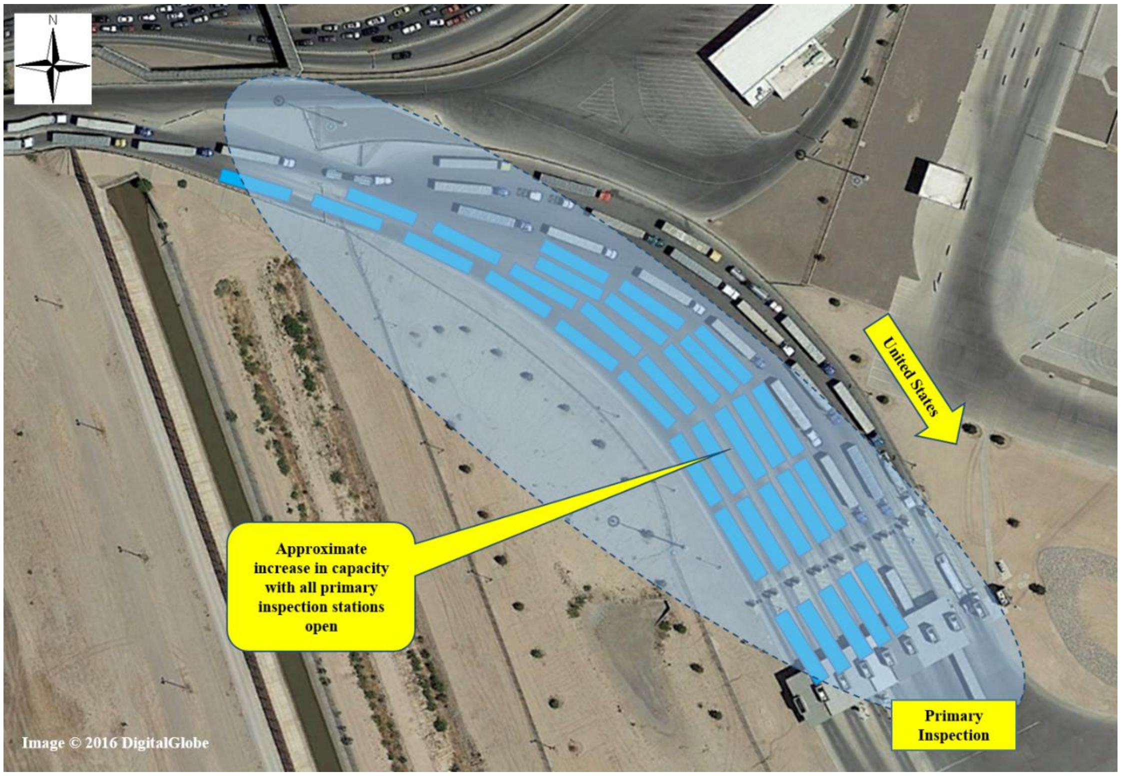

Figure 82. Capacity Comparison for Freight Primary Inspection.

The Santa Teresa POE is located 42 miles south of New Mexico's second largest city, Las Cruces, and just west of El Paso. Originally constructed in 1992, the port was reconstructed and completed in 1997 with state-of-the-art facilities. The port is open daily for commercial, non-commercial, and pedestrian traffic. It is the only port in the region that processes most types of exported used vehicles destined for resale in Mexico. In addition, hundreds of thousands of cattle cross each year, making the port host to the largest livestock import/export facility on the Mexican border (*54*). While the Santa Teresa POE is not located in Texas, it is part of the Paso del Norte[13] region, which includes cities in West Texas and Southern New Mexico (shown in Figure 83) and is the largest metropolitan area (2.7 million people) on the U.S.-Mexico border (*55*).

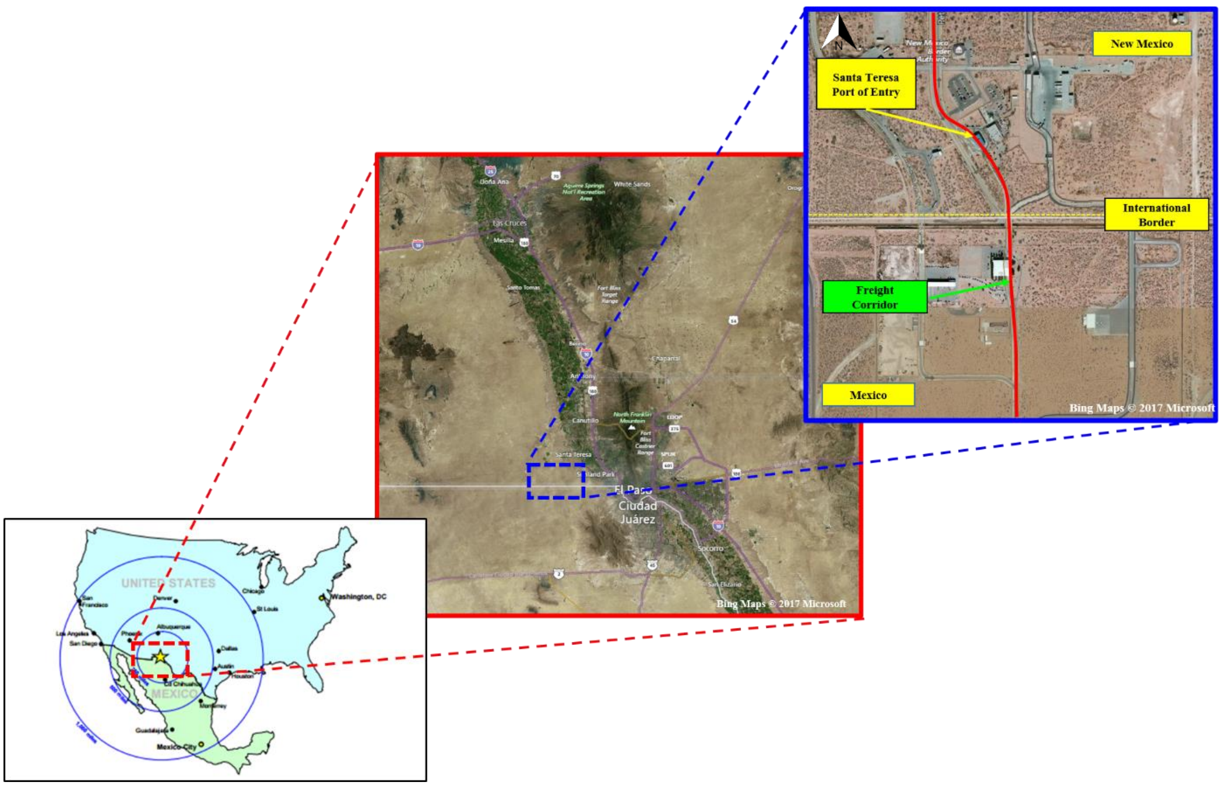

Figure 83. Santa Teresa POE.

The New Mexico Department of Transportation initiated the West Mesa Corridor Study to determine potential roadway corridors and improvements that would provide a direct connection between the Pete Domenici Highway (NM 136) near Santa Teresa and I-10 west of Las Cruces. The proposed corridor would run parallel to I-10 between Las Cruces and El Paso, providing a direct route for freight moving in and out of Mexico to the western portion of the United States. The route would not only provide commercial vehicles travel time savings but also, importantly, help direct some commercial vehicles away from the oversaturated ports heading into El Paso. More importantly, commercial vehicles crossing at Santa Teresa help alleviate congestion in the

[13] The Paso del Norte region is a binational metropolitan area centered around two large cities: Ciudad Juárez, Chihuahua, Mexico, and El Paso, Texas, and includes nearby Las Cruces, New Mexico.

urban area of El Paso, as shown in Figure 84. The West Mesa Corridor could serve as a designated truck route for the region.

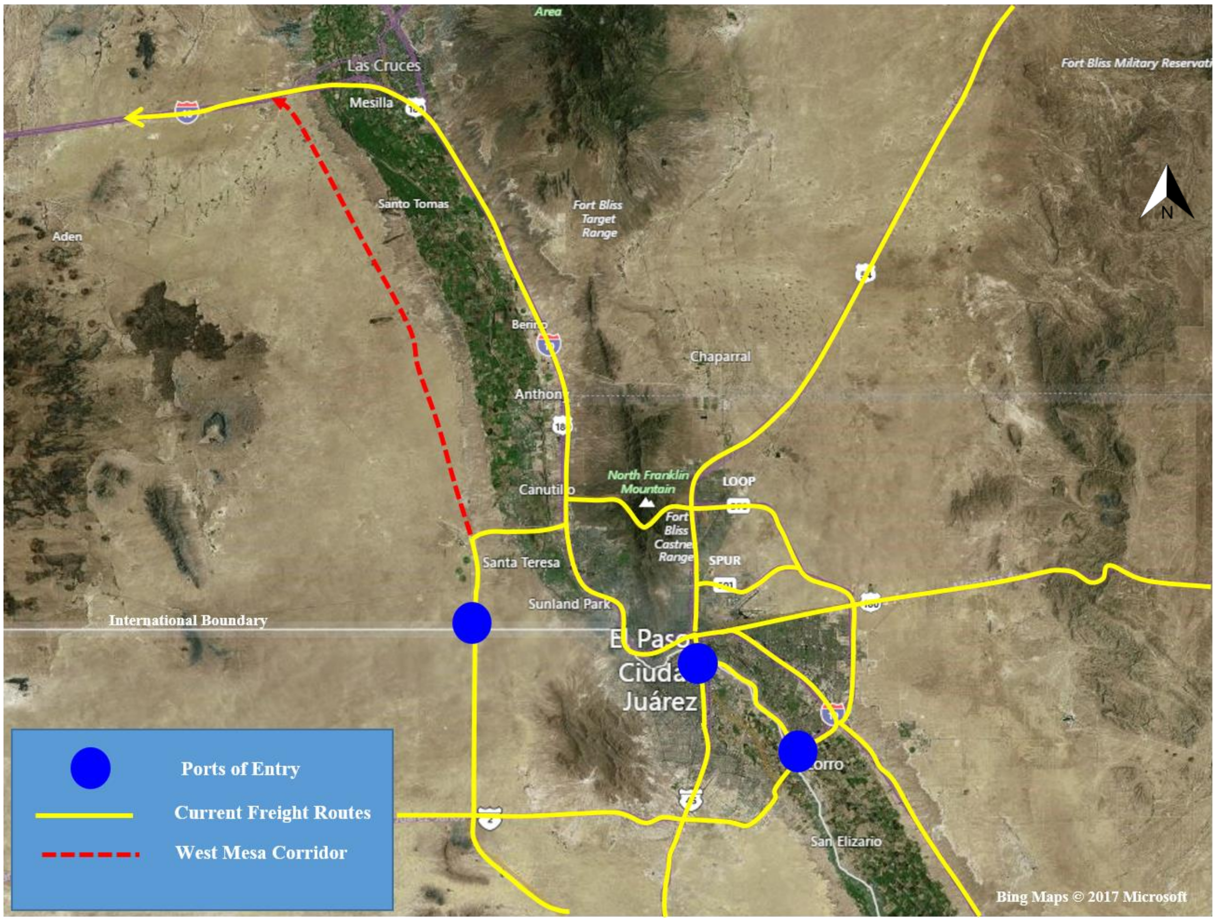

Figure 84. Proposed West Mesa Corridor.

DFW REGION

Researchers selected three different strategies from the short-listed freight management strategies that are feasible and can be implemented on specific corridors in DFW. The selected freight management strategies include (a) implementation of ATIS for truck route information when an incident occurs on a major freeway during peak hours, (b) off-peak use of HOT lanes, and (c) smart parking near freight-related facilities. The performance of these strategies was studied by using the DFW mesoscopic DTA model (Figure 85) and sketch planning tools. Due to extended runtimes, researchers were unable to simulate the DFW model for an entire day (24 hours). Therefore, researchers developed and calibrated the DTA model for the PM peak period (2–7 p.m.). The afternoon peak period was chosen because it has a higher number of generated trips (i.e., more congestion) than the morning peak periods. Prior to calibrating the regional model, all HOV/HOT lanes in the area were updated to represent current operating schedules and rates.

Figure 85. DFW Regional DTA Model.

Freight ATIS for Incident Management

The first strategy evaluated by researchers was FRATIS. It provides detour information during major traffic incidents (e.g., crashes) on freight corridors such as I-30, I-635, I-20, I-45, I-35E, or I-35W. To test this freight strategy, researchers examined 3 years of crash data from the TxDOT Crash Records Information System (CRIS) database. Figure 86 shows hot spots of the more severe crashes, including fatal, incapacitated, and non-incapacitated (also known as KAB) from the 2014–2016 CRIS data. These crashes typically have larger impacts (delays) to traffic, especially for truck traffic.

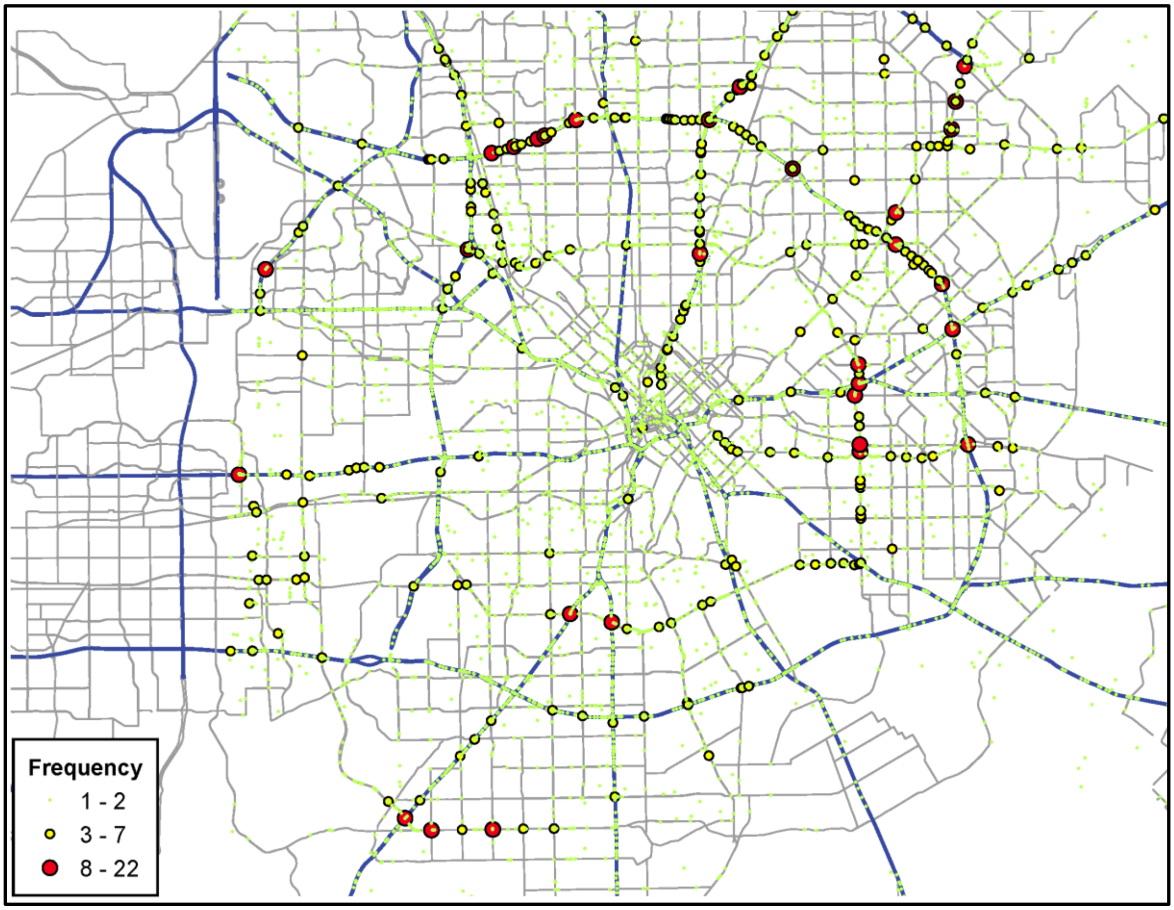

Figure 86. Dallas District 2014–2016 KAB Crash Map.

Researchers selected EB I-30 at the President George Bush Turnpike for simulation of the incident. The incident was modeled with the following characteristics: (a) from 4:00 p.m. to 5:00 p.m., and (b) with a capacity reduction of 67 percent (i.e., one of three lanes open). Two scenarios were modeled. First, trucks traveling on I-30 from the west to the east side of the metroplex were given two alternate parallel paths along I-20 to I-635/I-30 in Mesquite, as shown in Figure 87. The second scenario modeled truck routes with destinations in downtown Dallas. It compared staying on I-30 to diverting to a different alternate path, as shown in Figure 88. The location of the incident is indicated by a red dot, and the alternate routes are highlighted in blue. Note that Alternate 1 is simply staying on I-30 (baseline).

Figure 87. Freight ATIS—Incident Location and Detour Paths for Through Trucks.

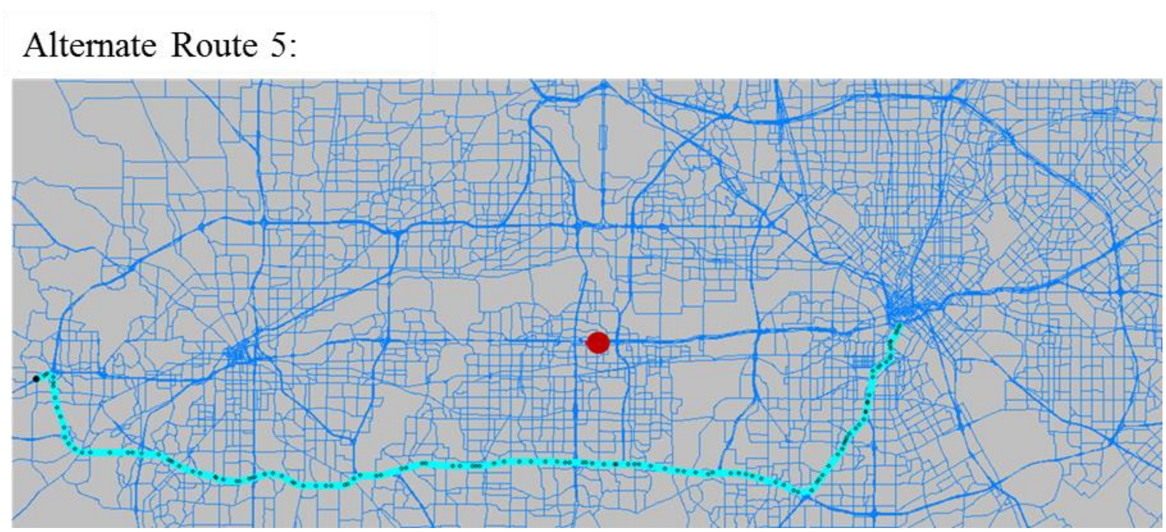

Figure 88. Freight ATIS—Detour Path for Trucks with Destination in Downtown Dallas.

Table 28 gives the sequence of roadway segments in each route and the length of the routes.

Table 28. I-30 and Parallel Alternate Routes Analyzed.

		Roadway Segments	Route Length (mile)
Through trucks from west side to east side of the metroplex	Route 1	I-30	52.68
	Route 2	I-30 > I-20 > I-30	64.94
	Route 3	I-30 > I-820 East > I-20 > I-30	69.77
Trucks with destination in downtown Dallas	Route 4	I-30	41.05
	Route 5	I-30 > I-20 > US 67 > I-35E > I-30	49.37

The Freight ATIS strategy encouraged truck drivers traveling on I-30 EB to take alternate routes during the incident and up to 1 hour after it cleared. Other vehicles were allowed to choose their routes based on time-dependent user-equilibrium travel times (best travel times found from previous trips under typical traffic conditions without incident).

Impact of Incident

To estimate the impact of the incident and the effectiveness of FRATIS strategies, first a baseline scenario with typical traffic demands and normal conditions (i.e., no incident) during the PM peak period (2–7 p.m.) was modeled using the DFW mesoscopic DTA model. Results from the simulation of the baseline scenario provided the TDUE travel times and related DTA under normal conditions during PM peak. Then the incident scenario and the different diversion strategies were coded and modeled.

The impact of the incident was evaluated based on the extra delays caused by the incident. This extra delay was calculated as the difference between travel times from the incident scenario and travel times from the baseline scenario. Figure 89 shows the impact of the incident on travel times along I-30 (Route 1). Figure 90 shows the incident-related delay on I-30. Note that this is the extra delay that drivers experience in addition to the typical delay during peak hours on a normal day without the incident (baseline).

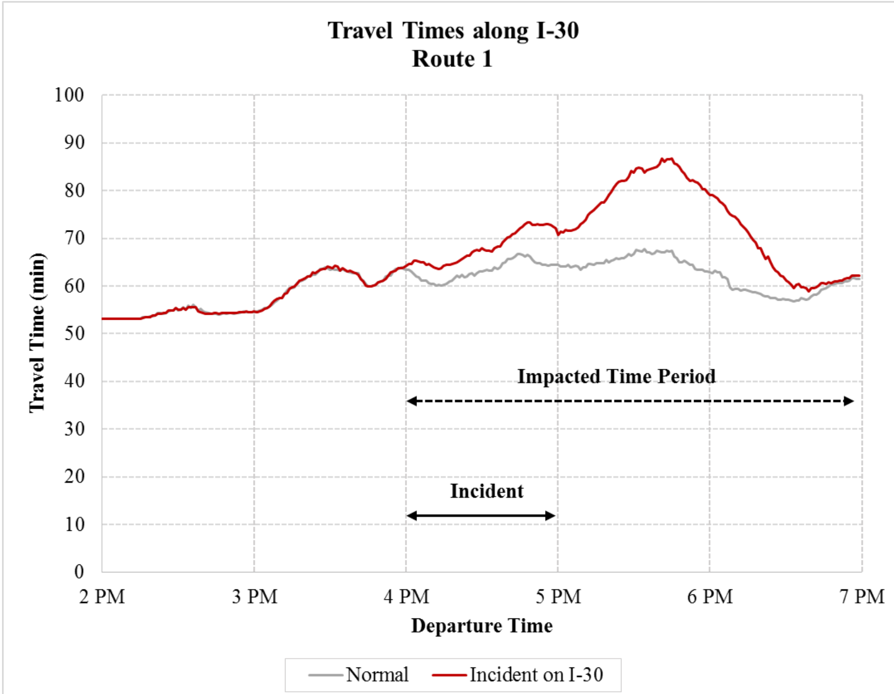

Figure 89. I-30 Travel Times with and without Incident.

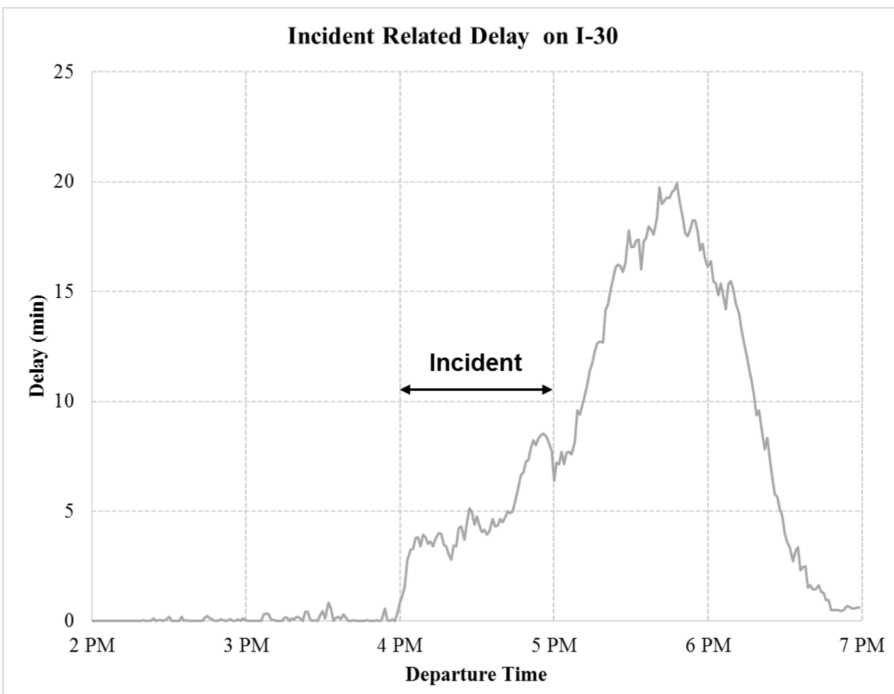

Figure 90. Extra Delay Caused by the Incident on I-30.

Although the incident was cleared after 1 hour, its impact lasted for almost 3 hours, as shown in Figure 90. The largest extra delay occurred around 5:45 p.m., 45 minutes after the incident was cleared. This was the time required for the dissipation of queues that formed upstream of the incident location.

The time-space diagrams for speed in Figure 91 and for density in Figure 92 clearly show the negative impact of the incident on traffic along the I-30 corridor (Route 1). As expected, the bottleneck created by the incident caused a significant reduction in traffic speeds and significant increase in density during the simulation time period of 120 to almost 300 minutes (4 p.m. to 7 p.m.). The relatively large red area in the middle of the lower time-space diagrams indicate near-zero speeds and stop-and-go conditions for an extended period of time over a 2–3 mile segment just upstream of the incident location.

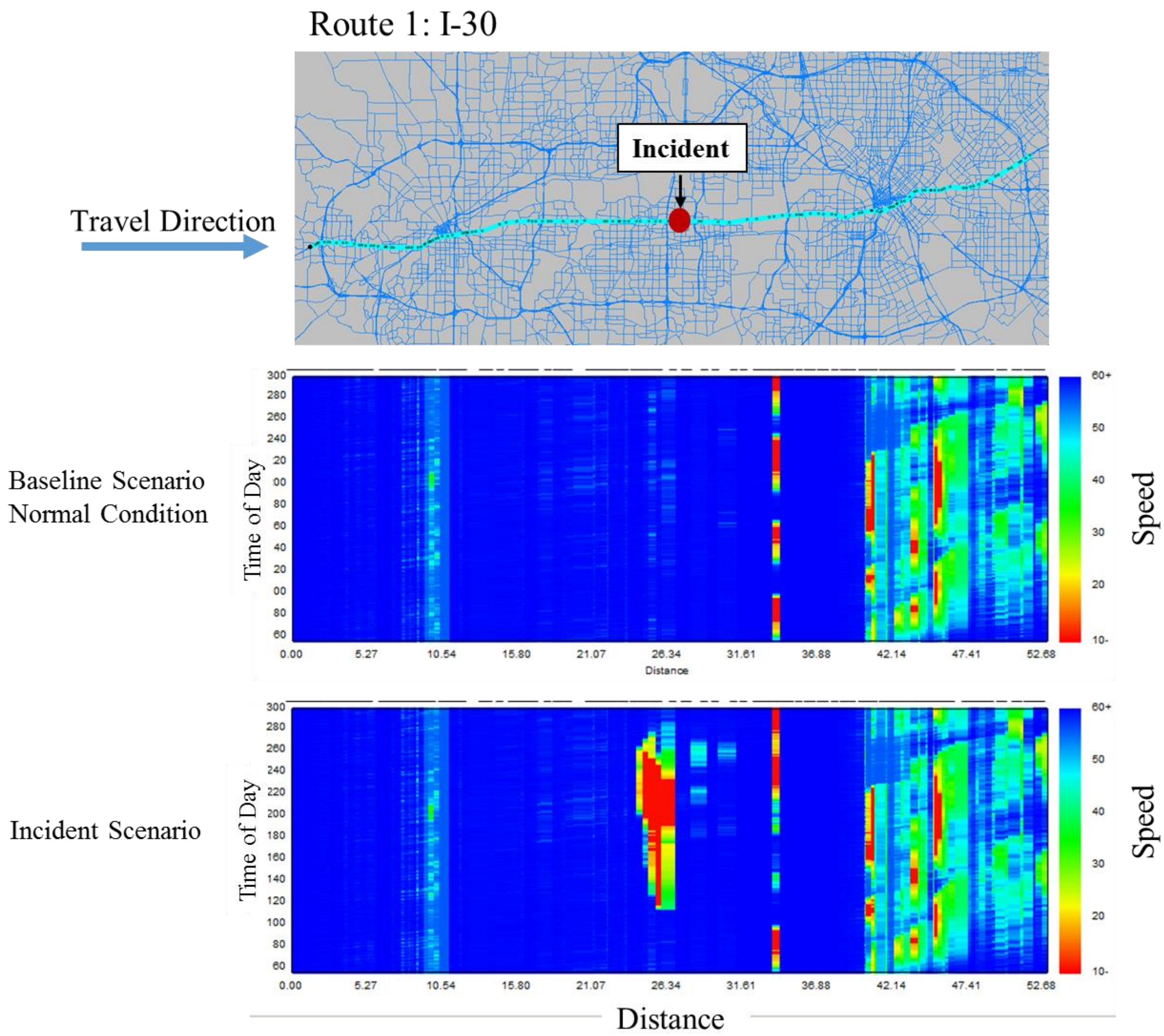

Figure 91. Speed Time-Space Diagrams for Baseline and Incident Scenarios along I-30.

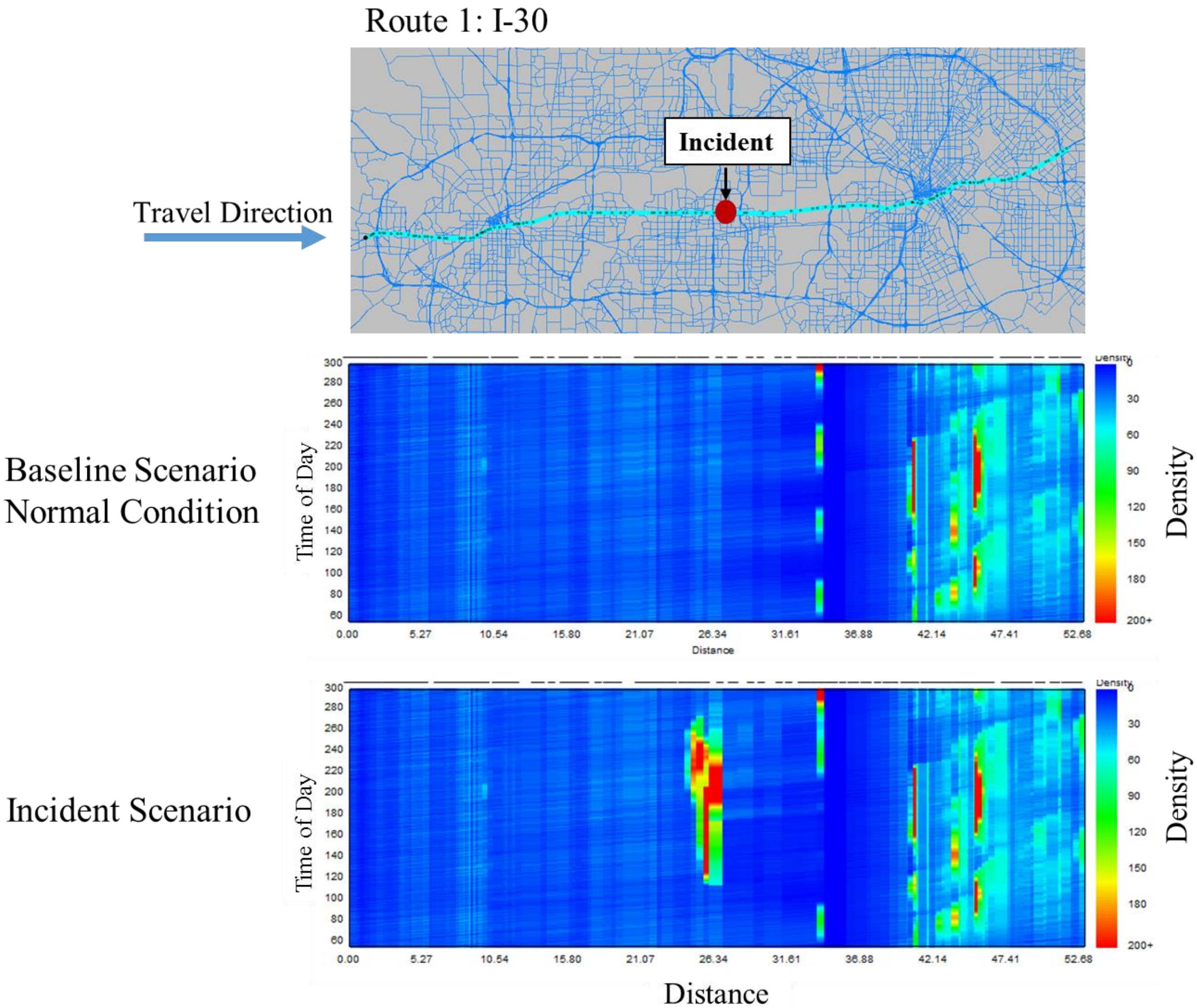

Figure 92. Density Time-Space Diagrams for Baseline and Incident Scenarios along I-30.

Effectiveness of FRATIS Strategies

The effectiveness of FRATIS strategies were evaluated based on travel time savings that truck drivers could experience by diverting to a recommended alternate route instead of staying on I-30. First, it was determined what time periods may be effective to divert trucks to alternate routes by analyzing time-space diagrams of speed and density, as illustrated in Figure 93, which shows time-space diagrams for Route 1 (I-30) and Alternate Route 2 (I-30 > I-20 > I-30).

Based on the temporal extent of high-density and low speed traffic states upstream of the incident location, diversion of trucks from I-30 to Alternate Route 2 is expected to be effective between 4 p.m. and about 6:45 p.m. (simulation times of 120–285 minutes). However, the distance of 64.9 miles that vehicles have to travel on Alternate Route 2 is more than 12 miles longer than the distance of 52.7 miles along the route on I-30. The actual benefits of truck diversion can only be confirmed by comparing travel times on the two routes.

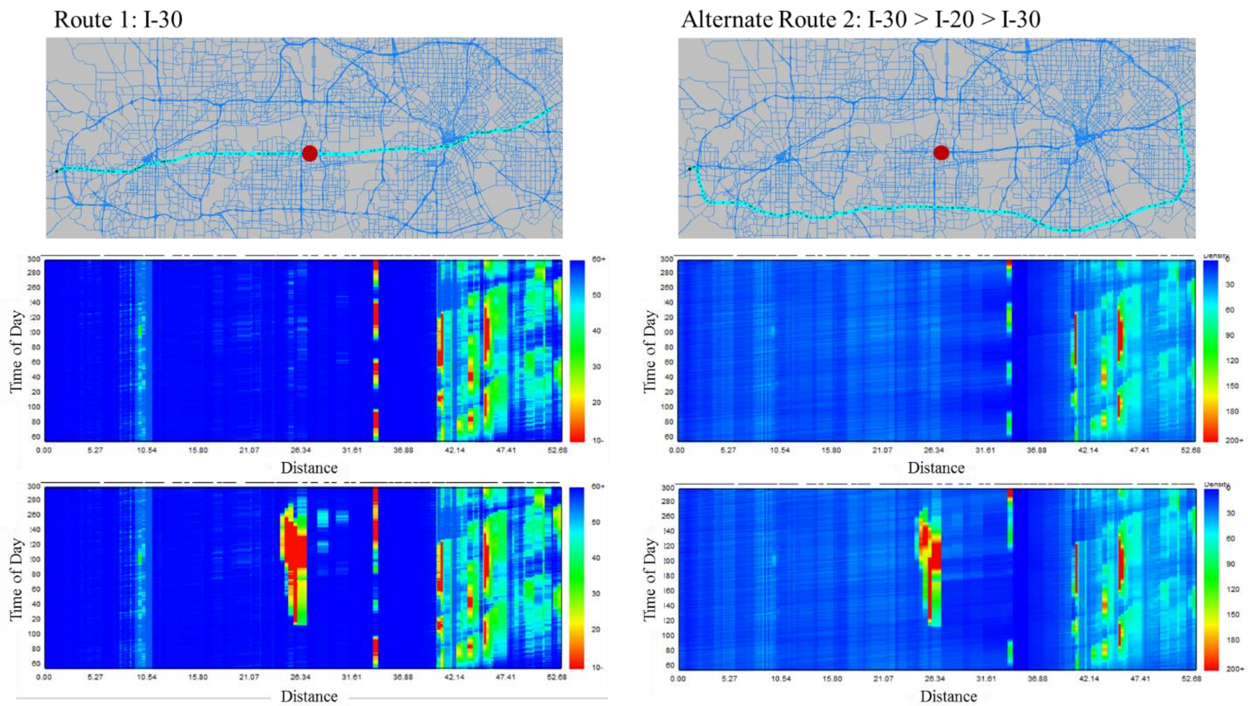

Figure 93. Density and Speed Heat Diagrams To Determine Effective Diversion Time Periods.

For through trucks traveling from the west side to the east side of the metroplex, the travel times were determined for the I-30 corridor and the two alternate routes (Routes 2 and 3) described previously in Table 28. In Figure 94, route travel times are plotted as functions of vehicle departure times from the beginning of the routes. Vehicles departing within the time interval of 4:42 p.m.–6:10 p.m., indicated by the line with bi-directional arrows, will experience shorter travel times if they divert from I-30 to Alternate Route 2. Vehicles departing in the time interval of 5:15–5:53 p.m. will experience shorter travel times on both alternate routes. Trucks departing outside of these intervals should stay on I-30 because they will experience shorter travel times without diversion.

Figure 95 plots travel times saved by through trucks that divert to Alternate Routes 2 or 3. Figure 96 plots travel times saved by trucks that have destinations in downtown Dallas and divert to Alternate Route 5. The maximum travel time saved is about 14 minutes per truck, which may not appear significant for some truck drivers. However, in addition to saving some time and money, they also avoid frequent stopping and accelerating maneuvers in the stop-and-go traffic and at the lane drops approaching the incident location, which minimizes regional emissions and the risk of being involved in a secondary incident (and causing more traffic delays).

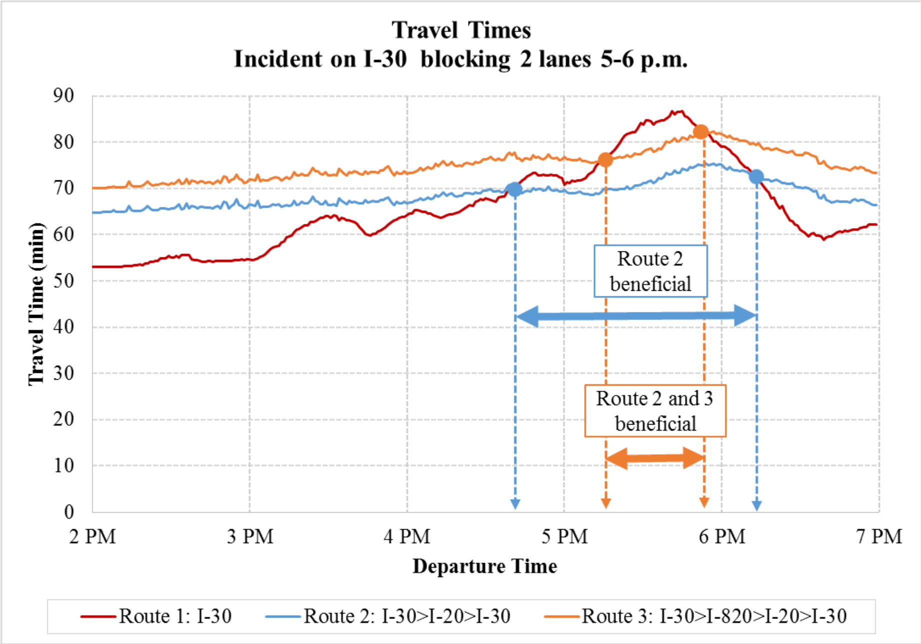

Figure 94. Time Periods when Diversion to Alternate Routes Is Beneficial.

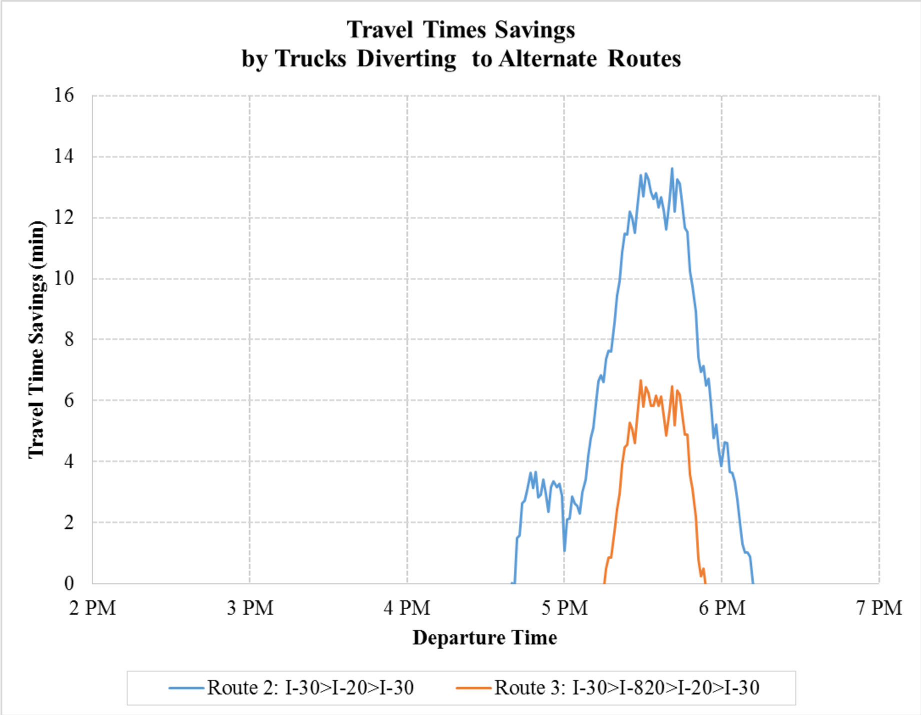

Figure 95. Travel Times Saved by Through Trucks Diverting to Routes 2 or 3.

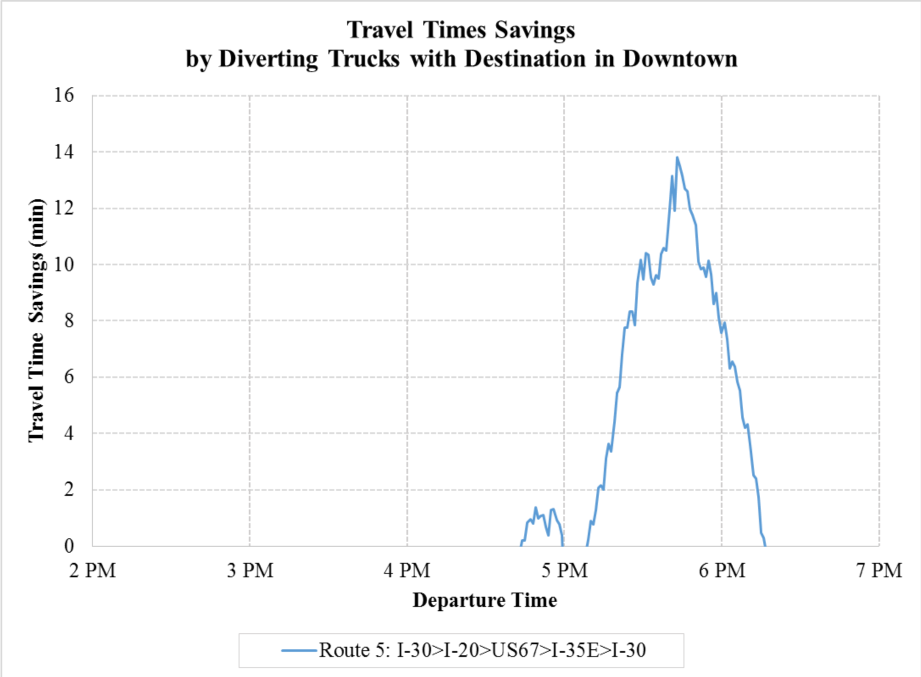

Figure 96. Travel Times Saved by Diverting Trucks with Destination in Downtown.

Off-Peak Freight Incentive on Managed Lanes (TEXpress)

This strategy leverages the existing infrastructure of managed lanes by allowing free access to trucks during off-peak periods. This practice can be especially effective in providing access routes/corridors to ports and other urban freight generators. This strategy may improve the freight flow through urban areas and incentivize shippers and trucking companies to shift their operations to move freight during off-peak periods when they may use these facilities. DFW has an extensive network of tolled managed lanes (TEXpress), making it an ideal candidate for implementation of off-peak freight incentives on express/HOV lanes (see Figure 97).

TEXpress lanes are tolled express lanes located in the medians of several major highways throughout North Texas. These managed lanes provide much-needed congestion relief on the roadway and offer drivers more choices in their daily commutes. Drivers can choose to use the adjacent GP lanes for free or pay for predictable travel speeds on the TEXpress lanes. TEXpress lanes include:

- Lyndon B. Johnson (LBJ) Express—I-635/LBJ Freeway and I-35E.
- NTE—Northeast Loop 820 and SH 121/183 Airport Freeway.
- NTE 35W—I-35W North Freeway.
- DFW Connector—SH 114.
- I-30—Tom Landry Freeway.

- I-35E—I-635/LBJ Freeway to US 380.
- Midtown Express—SH 183 Airport Freeway, SH 114, and Loop 12/Walton Walker Freeway.

The I-635 East HOV/Express lanes (US 75 to I-30) allow both HOVs and SOVs to use this corridor.

Figure 97. DFW TEXpress Managed Lanes.

Currently, TxDOT restricts trucks over 1 ton or vehicles with trailers on I-30 managed lanes and the I-635 East Express/HOV lane. However, trucks are allowed on all other TEXpress managed lanes but have to pay a higher base toll rate. The LBJ TEXpress lanes opened in 2015 and have two dynamically priced managed lanes in each direction. TEXpress lanes use variable congestion management pricing to help manage traffic flow and provide faster, more predictable travel. Roadside equipment recalculates real-time prices every 5 minutes, 24 hours a day, aiming to ensure the lanes are moving at 50 mph or faster. Unlike other North Texas toll roads, toll prices on the LBJ TEXpress lanes and the NTE TEXpress lanes vary by the shape and size of the vehicle driven, not the number of axles. These two roadways are the only managed lanes in the system that do not use axle-based vehicle classifications. For example, motorcycles, cars, sport utility vehicles, most vans, and pickup trucks pay the same price. But large and extra-large trucks can pay three to four times the toll prices of cars (see http://www.texpresslanes.com/pricing/vehicle-classification-shapes). Researchers selected the

LBJ Express (I-635) managed lanes section from I-35 to US 75 (see Figure 98) to test the impact of freight trucks on this facility during off-peak hours. The incentive consisted of no base toll rate for trucks during the selected off-peak period from 7:00 p.m. to 12:00 a.m.

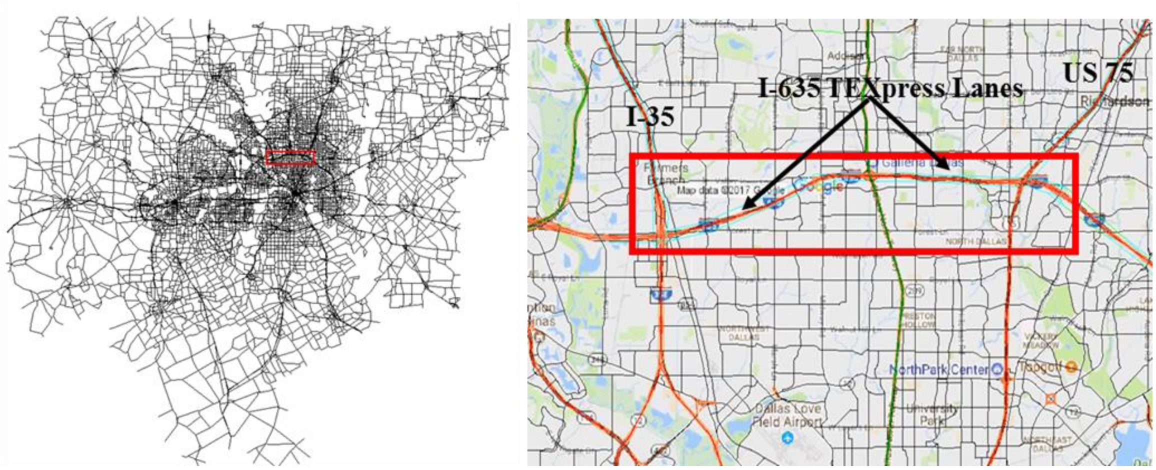

Figure 98. Location of I-635 TEXpress Lanes.

The DTA model was set for 5 hours of runtime to quantify the impact of trucks traveling for free through the TEXpress lanes after the afternoon rush hour (3:00 p.m. to 6:30 p.m.). The simulation results showed a significant change in both directions along the TEXpress lanes, as shown in Figure 99. The cumulative truck volume increased when the off-peak freight incentive strategy was implemented in comparison to the base case scenario.

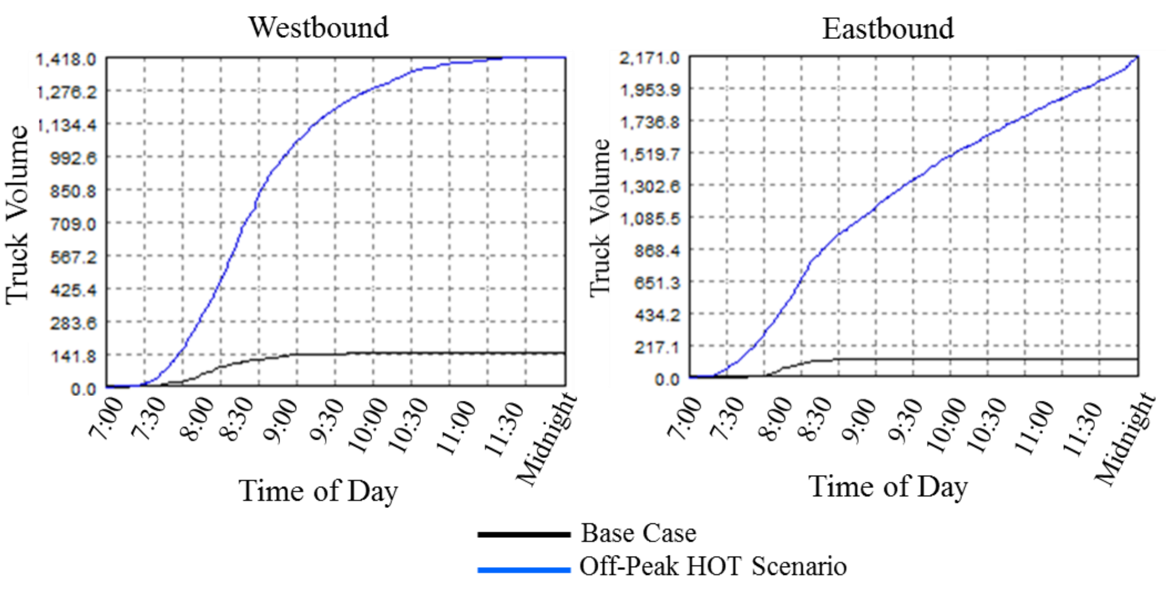

Figure 99. Cumulative Truck Volume Comparison on LBJ TEXpress Lanes.

The Heat diagrams were plotted to illustrate the vehicle speed variations along the I-635 main lanes from I-35 to US 75 (see Figure 100) with and without active incentives for trucks. Results show a slight improvement in the EB direction. The WB direction reflected similar speed behavior when compared to the base scenario. The observed small speed improvements on I-635 main lanes caused no disruption on the TEXpress lanes because they maintained speeds higher than 50 mph.

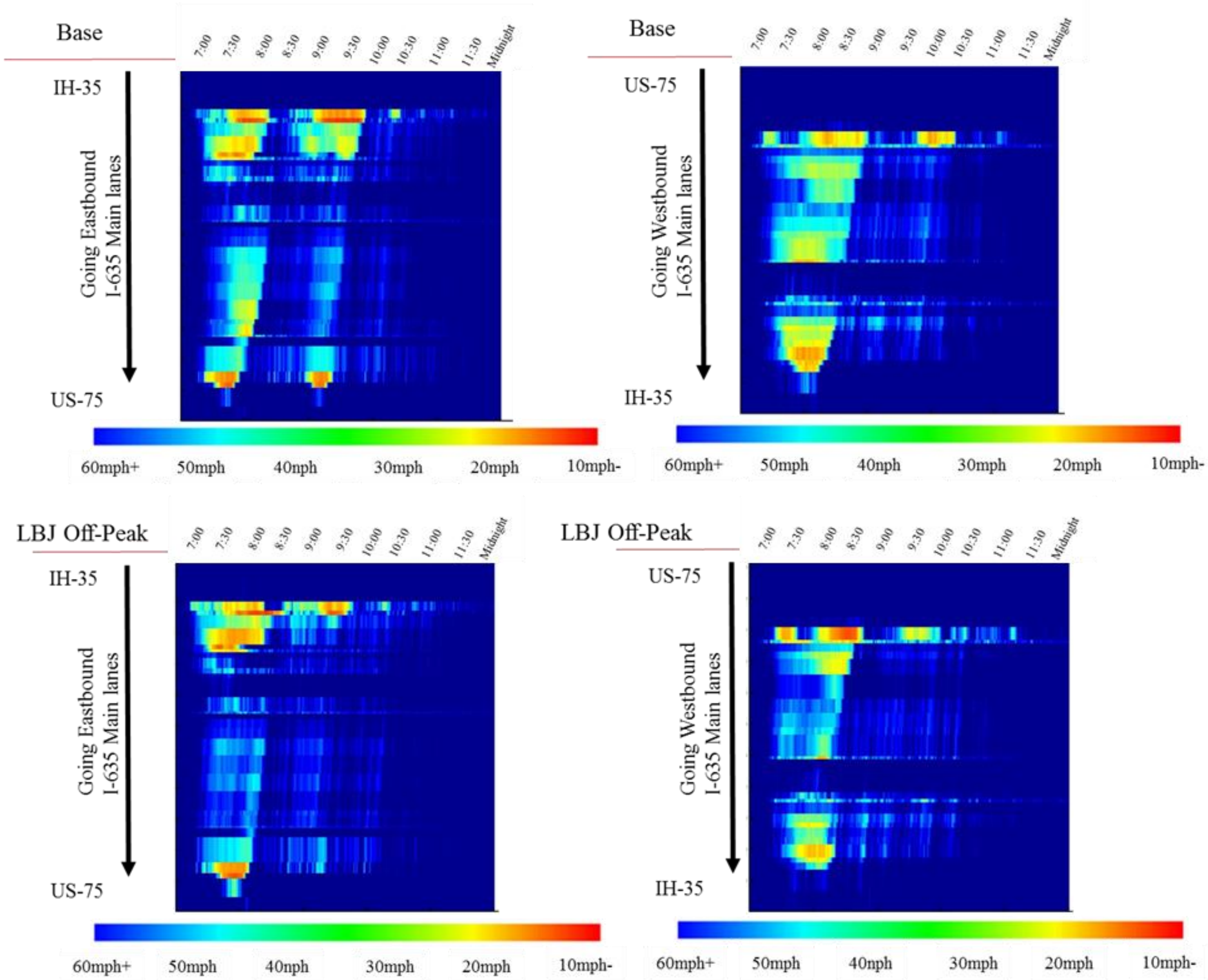

Figure 100. Heat Diagrams—I-635 Main Lanes between US 75 and I-35

Avg TTs along the main and TEXpress lanes study section were obtained (see Table 29). The simulated measurements indicated a small Avg TT improvement on both directions throughout the I-635 main lanes. The TEXpress lanes displayed a minor increase on Avg TT of 1.73 percent and 1.34 percent on the EB and WB direction, respectively.

Table 29. Travel Time Measurements

Travel Time Measurement Location	Avg. Travel Time (min)—Base	Avg. Travel Time (min)—Strategy	Avg. Travel Time % Change vs. Base Case
I-635 EB Main lanes	12.64	12.07	−4.51%
I-635 EB TEXpress	9.27	9.43	1.73%
I-635 WB Main lanes	12.22	11.78	−3.60%
I-635 WB TEXpress	8.20	9.20	1.34%

Smart Parking

Truck drivers face a critical shortage in truck parking due to a dramatic growth in commercial vehicle truck travel on the nation's roads. Fatigued drivers who must drive to search for parking can become not only a roadway hazard but an environmental hazard because they generate unnecessary diesel emissions (*32*). Commercial truck drivers typically spend 30 minutes or more searching for a place to park their rigs. The Michigan Department of Transportation leveraged $4.48 million in funding from FHWA to develop and install TPIMS. TPIMS is a smart truck parking network: a virtual environment where information about safe, secure, and convenient truck parking is available in real time to truck drivers. TPIMS is installed along a 129-mile stretch of I-94 in southwest Michigan (*33*). Detection cameras and other sensors were deployed at rest areas and private facilities to collect accurate parking data.

TSRC is another FHWA-sponsored project that explores possible roles for smart truck parking. TSRC partnered with Caltrans to analyze the truck parking problem and used the I-5 corridor as a test bed. This project used intelligent transportation system technologies to transmit parking availability data to commercial truck drivers. The technology also provides the opportunity to make reservations at participating truck stops. This suite of information allows truckers to plan and operate more efficiently when they can bypass a full truck stop and go directly to one with space available. ParkingCarma and NAVTEQ are assisting TSRC with the parking availability, reservations, truck stop amenities, and routing. The information may be collected and disseminated through various means, including sensors, the Internet, mobile phones, changeable message signs, and radio.

Recently, TTI also conducted a detailed literature review on the need of smart truck parking or TPIMS in Texas and on available technologies (*56*). The study found that Texas currently ranks 15th on the list of the top 20 states with limited truck parking. This is particularly concerning given the leadership role Texas has in economic competitiveness. It ranks second in the United States behind only California in terms of gross state product (*10, 56*). A 2015 study performed for FHWA found 1,150 public truck parking spaces in Texas, which equates to a rate of 3.4 spaces per 100,000 daily truck volumes. This rate is the second worst in the nation behind Oklahoma, which has a rate of 2.6 (*56*). Additional concern related to the availability of truck parking is that the truck freight volume is expected to increase from 1 billion tons in 2014 to more than 2 billion tons in 2040 (*38*). The same study ranked truck safety, which includes parking, as one of the eight major freight transportation challenges facing the state.

One freight management strategy through urban areas can be the deployment of smart truck parking, which has real potential in the DFW metro region. TTI researchers identified at least one specific location where truck parking has been an issue, and smart parking strategy may assist. Discussions with the North Central Council of Government's Regional Freight Advisory Committee and the Traffic Dallas County Sheriff's Department disclosed that trucks are observed to routinely park overnight along I-20 exit ramps between I-35E and I-45. There is a high concentration of park stops and freight-related facilities in the area, as shown in Figure 101. Figure 102 shows the locations of truck parking and available parking spots in this area, along with the average daily truck traffic on the major road segments near these areas. For this 6-mile I-20 section (between I-35E and I-45), there are 556 parking spots, and the average daily truck traffic is approximately 14,350 vehicles.

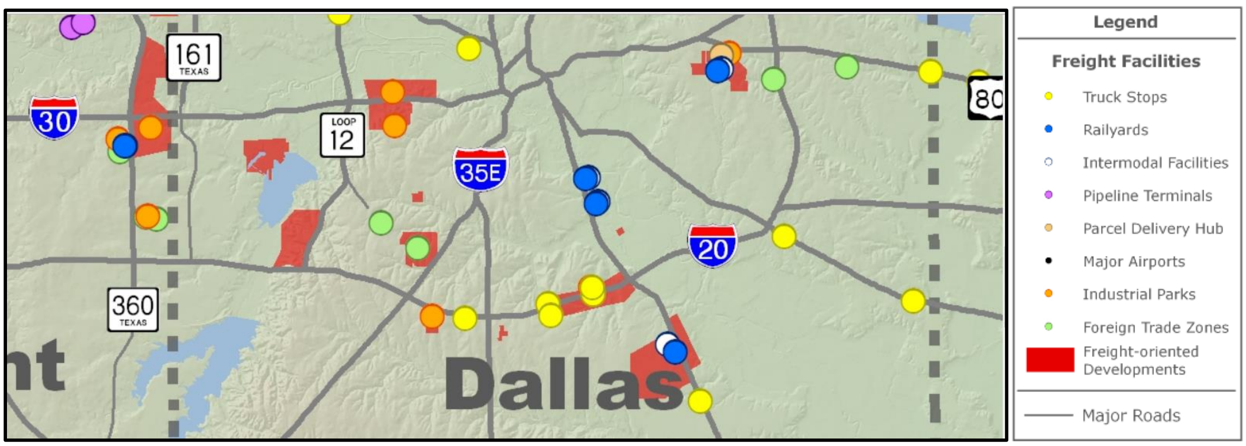

Figure 101. DFW Freight Transportation Facilities (*57*).

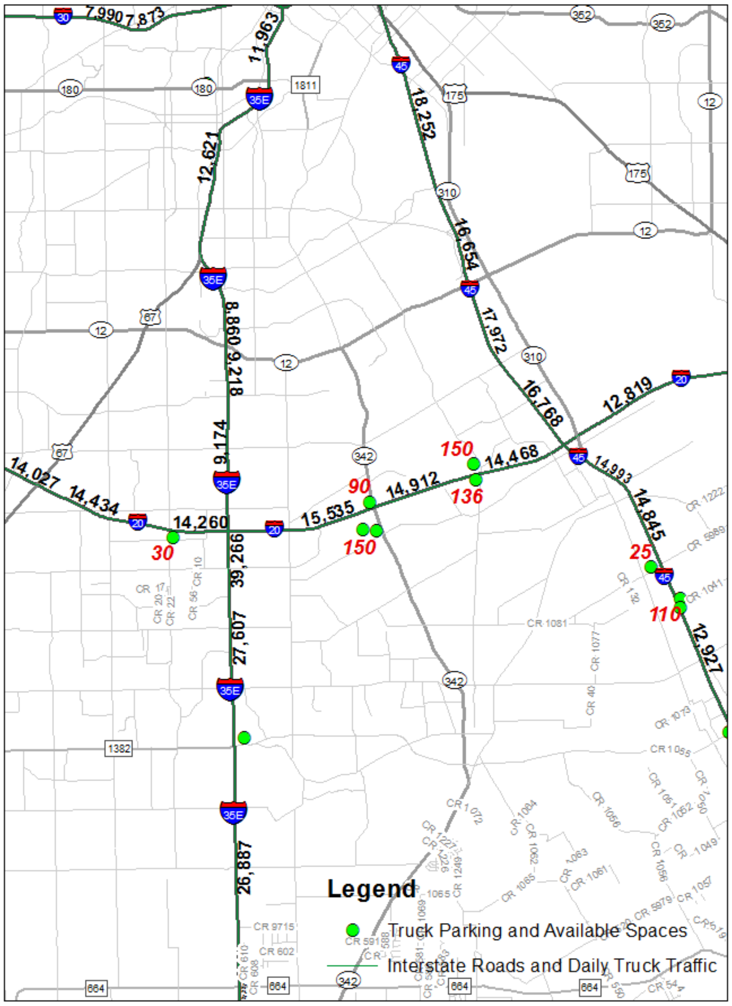

Figure 102. Truck Parking Availability—Truck Traffic along I-20 Corridor.

Figure 103 highlights some of the major freight facilities along I-20, which include the Amazon Fulfillment Center, Flying J Travel Center, Blue Beacon Truck Wash, and a TA Dallas Travel Center. Another TA Travel Center is farther east in Terrell, Texas. Truckers who know they cannot make it to the TA Terrell Travel Center will often default to parking overnight along this section of I-20 in Dallas.

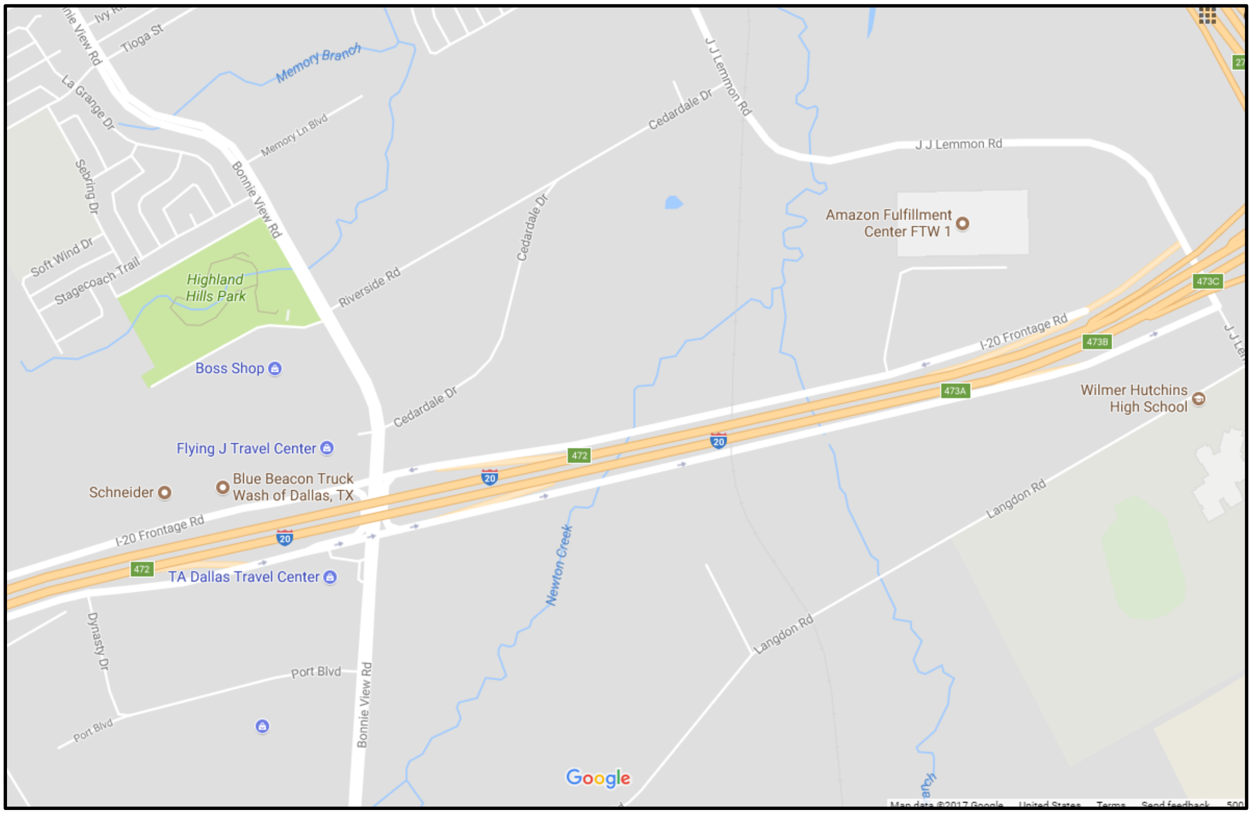

Figure 103. Examples of I-20 Freight Transportation Facilities.

Figure 104 provides generic information about truck parking types and the parking space availability in the DFW region. Major truck parking stops are near Weatherford, Terrell, Denton, Alliance Airport, and Hutchins. Similarly, as shown in Figure 105, the daily truck traffic through urban areas in the DFW region is heavy, whereas the major parking stops are mostly on the outskirts. The orange dots in Figure 105 further classify the number of available parking spaces by each location (more classes/bins of parking spaces than in Figure 104). Truckers typically park overnight on the ramps because there is a general shortage of free truck parking, especially in urban areas. Some truckers are not willing to pay the parking costs or want to avoid being propositioned when parking at these stops. This dilemma may have been exacerbated when TxDOT began its statewide rest area beautification program that renovated/modernized older rest areas but resulted in the closure of some rest areas due to limited funding and maintenance resources. Recently, some research and news articles have focused on the lack of truck parking stops and their impact on safety (*58*) and on disappearing old-fashioned highway rest stops (*59*). Although in the DFW region it is impossible to narrow down the exact reasons truckers choose to park on ramps, if the problem is parking availability at the truck stops or the cost of parking, it can be solved by providing smart truck parking solutions or TPIMS, as demonstrated in various research studies (*33*, *55*).

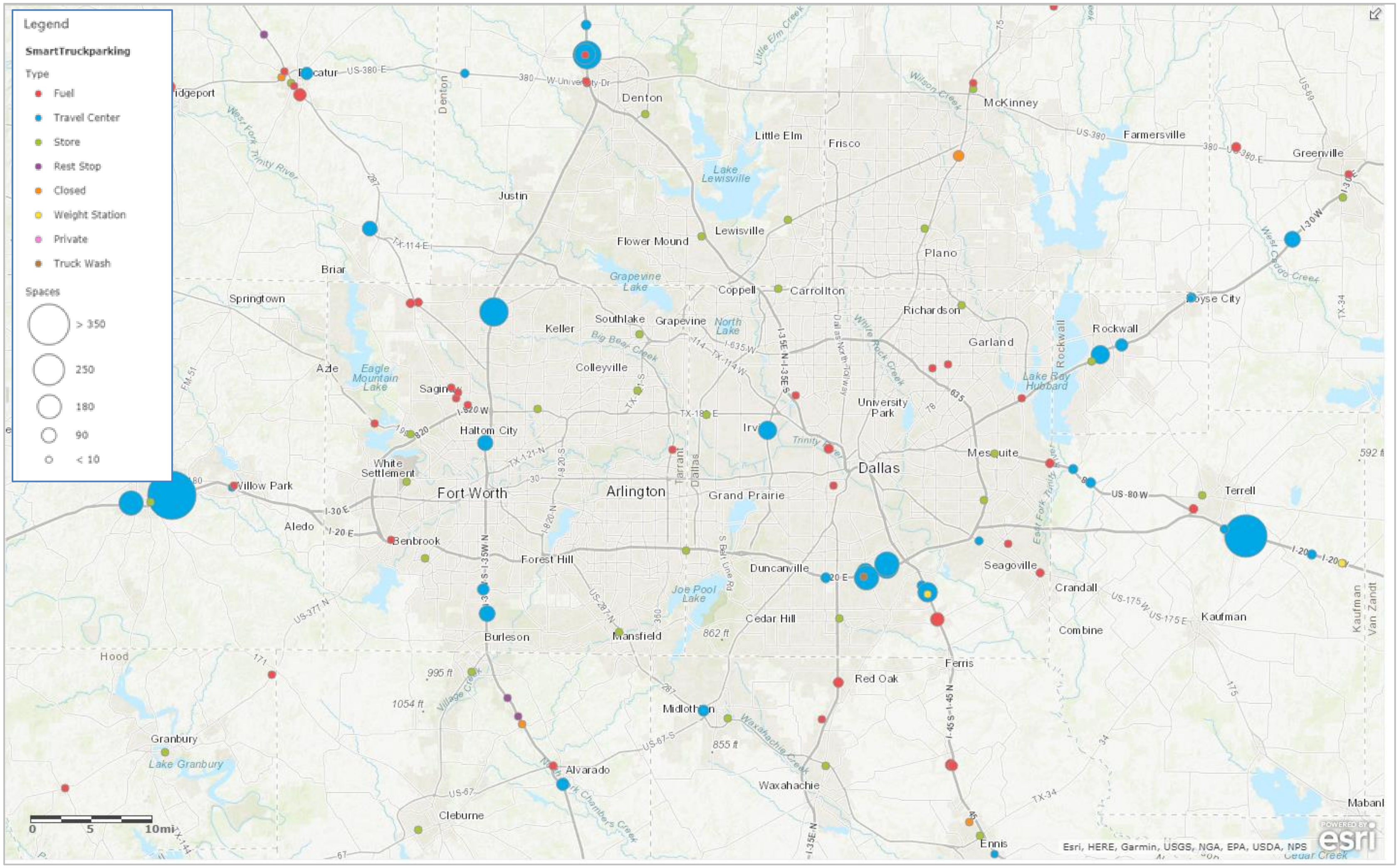

Figure 104. Types of Truck Parking and Available Spaces—DFW Region.

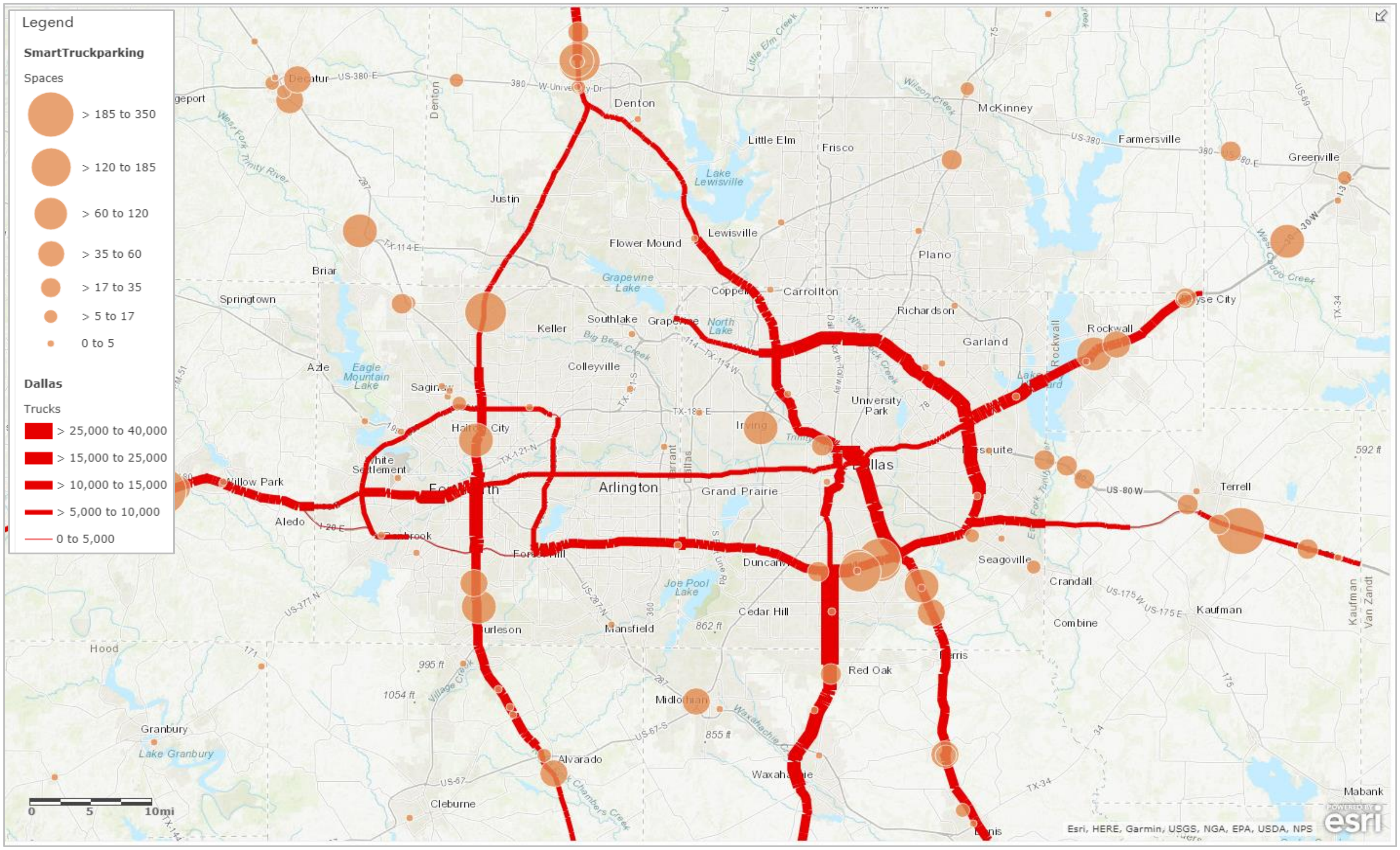

Figure 105. Truck Traffic and Available Truck Parking Spaces—DFW Region (*57*, *60*).

GUIDELINES

INTRODUCTION AND BACKGROUND

Strategies to manage freight in urban areas can be analyzed in several different ways, including the locations where they are most applicable and how they are deployed, what tools are needed to make sound judgment on various strategies and alternatives, and the policy implications for those strategies. This section outlines three specific sets of guidelines related to freight management strategies in Texas urban areas: modeling guidelines, selection and deployment, and policy, as shown in Figure 106.

Figure 106. Freight Management Guidelines.

MODELING

This section outlines the general guidelines used when modeling freight management strategies using a state-of-the-art modeling methodology. These guidelines highlight the most applicable tools and techniques needed when managing urban freight movement. The guidelines were developed to help TxDOT understand the analytics behind the modeling approach of various defined scenarios and the type of model resolution most applicable. This guidance will provide the foundation for future analyses on additional corridors in Texas. The following section includes:

- Lane- and Route-Based Strategies.
  - Truck Lane Restriction.
  - Dedicated Truck Lane.
  - Designated Truck Route.
  - Truck Route Diversion.
  - Grade Separation.
- Time-of-Day-Based Strategies.
  - Off-Peak Use of Managed Lane.
  - Change in Departure Time.
- ITS/ATM-Related Strategies.
  - ATIS.
  - FSP.
- Land-Use Practices Promoting/Facilitating Freight Movement
  - Smart Parking.

Lane- and Route-Based Strategies

Truck Lane Restriction

Restricting trucks from a specific lane on a freeway corridor in Texas has certain deployment requirements. The length of freeway to be restricted should be a minimum of 6 continuous miles, the section of freeway should be approximately one mile beyond any entry and/or exit ramps in the restricted lane to allow sufficient distance for traffic to access or vacate the lane as needed, there should be a minimum of 4 percent total trucks in the traffic stream over a consecutive 24-hour period, and approximately 10 percent of total truck traffic should be observed using the lane (typically the left lane) to be restricted. Trucks are allowed to enter the restricted lane for passing purposes.

To accommodate these requirements, certain parameters must be accounted for in a simulated environment. The simulation platform must be able to account for individual vehicles and trajectories within different lanes on a corridor while simultaneously retaining OD patterns. Mesoscopic models are link-based, meaning they cannot distinguish individual lanes or the types of vehicles that are traveling within lanes on a corridor. Microscopic models are capable of identifying different vehicle types on individual lanes. However, as the length of the corridor expands beyond several miles, with multiple on/off-ramps, it becomes increasingly difficult to determine OD patterns (i.e., where vehicles enter and exit ramps on the corridor). Therefore, a multiresolution modeling approach is best suited for this type of freight management strategy. A mesoscopic DTA model simulates the entire region to UE conditions using separate trip tables for trucks and cars. Once the model has converged to a stable UE condition,[14] a subarea of the DTA model is extracted and converted to a microscopic counterpart. The microscopic model retains all the paths and flows that are truncated within the subarea bounded area. The microscopic model is then calibrated to existing conditions using various field data. Speed can be calibrated using radar guns for instantaneous speed profiles or Bluetooth sensors for longer speed segments (e.g., freeway corridors). Global positioning systems (GPSs) can be used to determine elevation profiles to calculate grade sections in areas where mountainous terrain plays a factor in speed profiles and acceleration/deceleration patterns.

Due to the wide range of speed distributions along the freeway corridor, it is often necessary to create multiple vehicle classifications for large commercial trucks. **Error! Reference source not found.** shows the FHWA 13-Category Scheme (*61*). Previous research (*62*) was the guide in determining what types of trucks were typically found in Texas and what percentages of the truck traffic stream each comprised. Truck traffic stream includes smaller heavy vehicles with three axles all the way to large commercial vehicles that have six to seven axles.

[14] A stable UE condition indicates that the simulation model has reached an acceptable approximation where there is no substantial incentive for vehicles to shift routes to improve travel time.

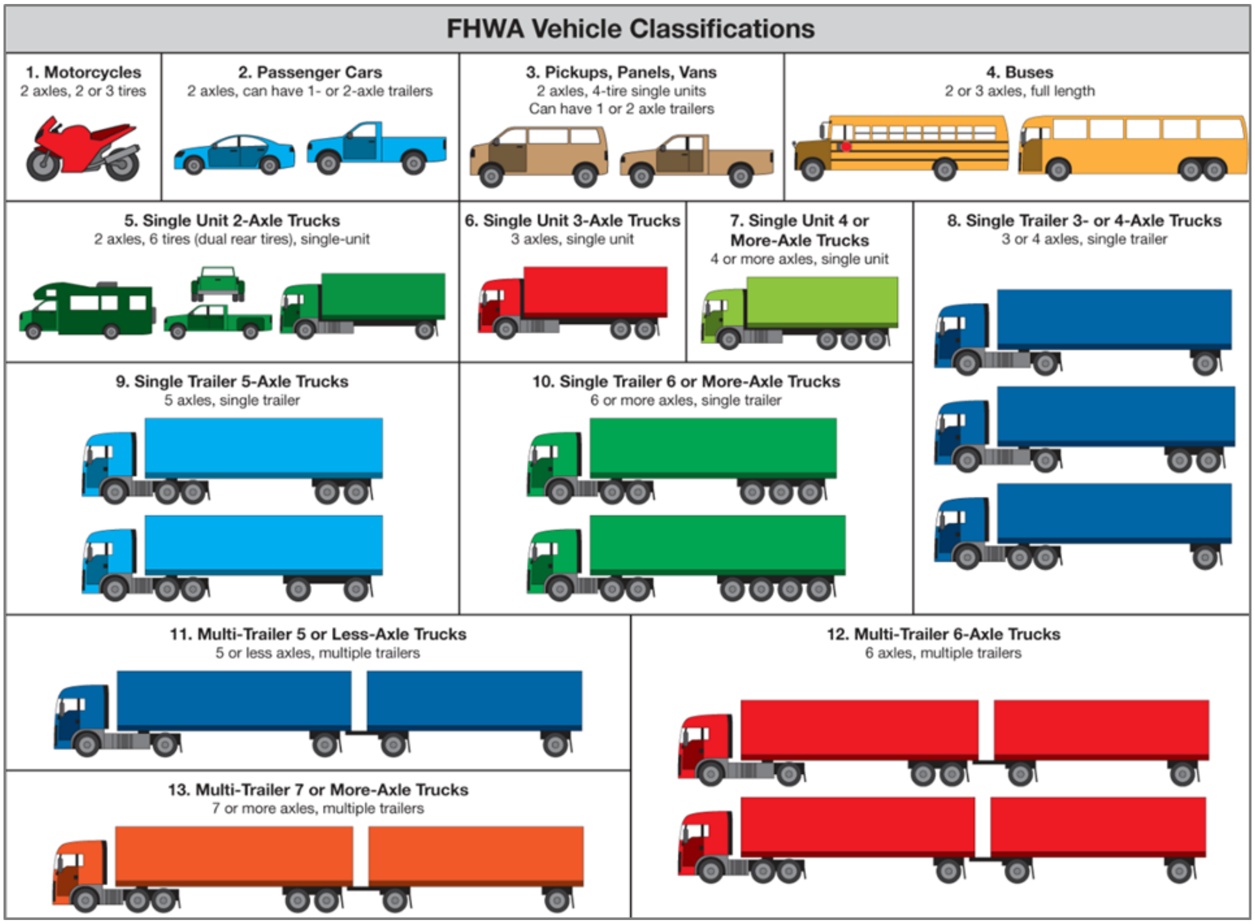

Figure 107. Vehicle Classification—FHWA 13-Category Scheme (*61*).

An adaptation of each of these truck types into a microscopic model employing its modified truck and trailer features is shown in Table 30. Information contained in Table 30 is ultimately coded into a microscopic model to create a representative Texas truck fleet. In any simulation model where trucks are a part of the vehicle stream, those trucks are distributed according to the percentages shown and have the characteristics noted (*63*). A vehicle composition is ultimately created to complete the coding necessary for the microscopic model. The distribution of vehicles for the traffic composition varies depending on the time period of simulation. These general parameters can be used for other freight strategies (modeled in microsimulation) where ATR data are not available.

Table 30. Truck Characteristics Applied to Texas Truck Fleet.

Truck Class	Relative Flow	Length (ft)	Width (ft)	Weight (lb)		Power (hp)	
				Minimum	Maximum	Minimum	Maximum
5	0.004	27.89	8	15,000	46,000	220	260
6	0.001	27.89	8	20,000	53,000	220	300
7	0.000	30.94	8	25,000	52,000	250	300
8	0.001	36.13	8	28,000	66,000	315	380
9	0.042	60.22	8	30,000	80,000	380	480
10	0.000	55.39	8	32,000	87,000	415	490
11	0.002	70.69	8	35,000	92,000	440	500
12	0.040	67.24	8	35,000	106,000	505	525
13	0.000	92.35	8	35,000	120,000	570	580

Once the microscopic model has been calibrated to existing conditions, a base model is developed wherein trucks and cars interact freely on all lanes. A subsequent scenario model is developed wherein trucks are restricted from a specific lane (e.g., left lane) and PMs are compared. For a truck lane restriction strategy, speed comparison is the most widely used PM. Speed comparison can show if lane restrictions help improve speeds on the corridor and identify locations where these restrictions have an adverse effect on traffic flow.

The microscopic models developed should be simulated for both morning and afternoon peak periods in addition to off-peak hours. Modeling both peak periods will highlight the directional volume (e.g., heavy flow inbound during the morning and heavy flow outbound during the afternoon) and give a better picture of the overall dynamics of traffic flow on the freeway system.

Preferred Modeling Tool: Multiresolution Modeling (Mesoscopic/Microscopic)

Dedicated Truck Lanes

There is no specific guidance or published deployment requirements for dedicated truck lanes, most likely because they are uncommon in the United States. However, the guidelines for restricting trucks from a specific lane on a freeway corridor in Texas can also be used for restricting cars on dedicated truck lanes. The system-level benefits of dedicated truck lanes can be best understood using mesoscopic simulation, such as DTA, and operational level and safety benefits can be understood using microscopic simulation. To model the system-level benefits, the dedicated truck lanes need to be coded as separate lanes since DTA is typically link-based and cannot distinguish individual lanes. Further, other vehicles (not trucks) need to be restricted on the dedicated truck lanes. If the DTA tool does not have vehicle restriction features, it is recommended that an impedance factor be used to disincentivize other vehicles to use truck lanes. However, the impedance factor should be very high to restrict the vehicles other than trucks, and sensitivity analysis should be performed to understand if the addition of an impedance factor is not adversely impacting route choice behavior. Separate OD trip tables should be obtained for different vehicle classes, especially for passenger vehicles and trucks. If possible, commodity-based truck trip tables can be used to completely understand the economic benefits of the dedicated truck lanes.

The PMs such as Avg TT, standard deviation of travel time, and TTR can be used for comparison between existing and future conditions. TTR is defined according to the recent requirements set forth in the FAST Act (*50*), (i.e., ratio of normal [50th percentile] and 95th percentile truck travel times for each reporting segment calculated to the nearest hundredth). The 95th percentile travel times estimate how bad delay will be on specific routes during the heaviest traffic days, whereas the 50th percentile shows normal travel time. The TTR ratio is how much total time a traveler should allow to ensure on-time arrival 95 percent of the time compared to the Avg TT.

Microscopic simulation should be used to understand the safety and operational benefits of the dedicated truck lanes. The selection of corridor/network is critical before performing microscopic simulation. The corridor/network selected for simulating dedicated truck lanes should be comprehensive and should consider nearby arterials/freeways. There is no golden rule for boundary selection for a corridor/network, and modelers should use their engineering judgment and familiarity with the network before selecting. Once the modeling area has been selected, the network coding (including ramps) should be done to capture the realistic field conditions. The field data should be obtained for determining vehicle composition and traffic for inputting in the model.

Most of the microscopic simulation tools have lane restriction capabilities by vehicle class. The operational benefits can be studied and understood by comparing typical PMs (delay, travel time) for existing and future conditions. The safety benefits can be understood by studying the vehicle trajectories and capturing space and time headways between trucks and vehicles, as well as the acceleration/deceleration patterns that occur.

Preferred Modeling Approach: Mesoscopic or Microscopic Modeling

Designated Truck Routes

In urban areas, truck traffic often shares the roads with other modes (i.e., passenger vehicles, bicycles, and pedestrians) and creates some negative impacts, including congestion, emissions, noise, and safety concerns, for other road users and nearby communities. Designating certain roadways for truck traffic is the most common strategy employed by cities to manage freight transportation demand (*18*). Directing truck traffic on specific routes allows local governments to:

- Target infrastructure improvements to primary users by providing more generous turning radii and greater overhead clearance on truck routes.
- Reduce exposure of residents to noise, emissions, and vibration by identifying truck routes that avoid residential areas.
- Separate truck traffic from bicycles and pedestrians by reducing truck traffic on key pedestrian and bicycle thoroughfares.

Before truck route designations, it is critical to study current trends in truck movement and identify the routes with appropriate road geometries within the city to ensure efficient connectivity to downtown areas. All planning authorities with responsibilities for roads in the urban area and the freight transport industry should be involved in identifying truck routes to ensure that they link key destinations, avoid sensitive populations, and are coordinated across jurisdictional boundaries. Additionally, truck routes should be clearly mapped and identified with road signs, and cities should consider adjusting the signal timing on truck routes (increasing the yellow and green signal phases to meet increased acceleration/deceleration requirements) to improve the flow of truck traffic (*19*).

The performance of designated truck routes can be studied using macroscopic and mesoscopic simulation. The modeling guidelines for designated truck routes and freight bypass are similar due to similarities in both these strategies. Macroscopic/sketch planning models are based on the deterministic UE principle known as the static traffic assignment. This principle is based on individuals choosing a route to minimize their travel time or travel cost, and such a behavior on the individual level creates equilibrium at the system (or network) level over a long period of time. Since macroscopic/sketch planning models are deterministic, they do not account for uncertainty or spatial-temporal patterns in traffic conditions; however, they are good for quick, large-scale analysis. More than 90 percent of the large MPOs and planners apply the macroscopic planning models to model the road user behavior and assign highway traffic or road network traffic (*64*). Mesoscopic simulation (simulation-based DTA model) suits best the time-of-day-based designated truck routes that require changes in departure time, so adjustments can be made to time-dependent demand matrices at the macroscopic level. DTA is also good for studying vehicle trajectories, route choices, and spatial-temporal patterns in a large network that requires multiple scenarios to be run.

After selection of potential designated truck routes, the modeler needs to code the network with the restrictions and possible tolls, if required. If the restrictions and tolls are time-based, then they need to be to be coded at the link level. If the restrictions are lane-based, then the link needs to be separately coded. For the macroscopic/sketch planning models, the daily/peak-period demand matrices for truck and car trips can be obtained from MPOs. For mesoscopic models, MPOs' official travel demand model can be used as a basis for conversion to a simulation-based DTA model. Demand matrices for passenger cars and trucks should be disaggregated based on trip purpose and then converted to a time-dependent mesoscopic format (typically in 15-minute to 1-hour intervals). If sufficient data are available and the DTA platform supports multiclass assignment, it is recommended to further divide the truck trip tables based on specific user classes (e.g., commodity).

Next, the demand matrices need to be calibrated using an OD matrix estimation tool. Researchers used the matrix estimation tool that employs linearized quadratic optimization algorithm with the objective function to minimize the absolute deviation between simulated and actual screen line counts (i.e., field data are used to adjust counts on specific links by adjusting the OD pairs that travel through those links). Figure 108 and Figure 109 show calibration was reasonable, with very few outlier OD trips (error more than 10 percent). Calibrated trips can be further refined by increasing the number of iterations in the algorithm; however, the computational time can vary (hours to days) with no guarantee of an optimal solution.

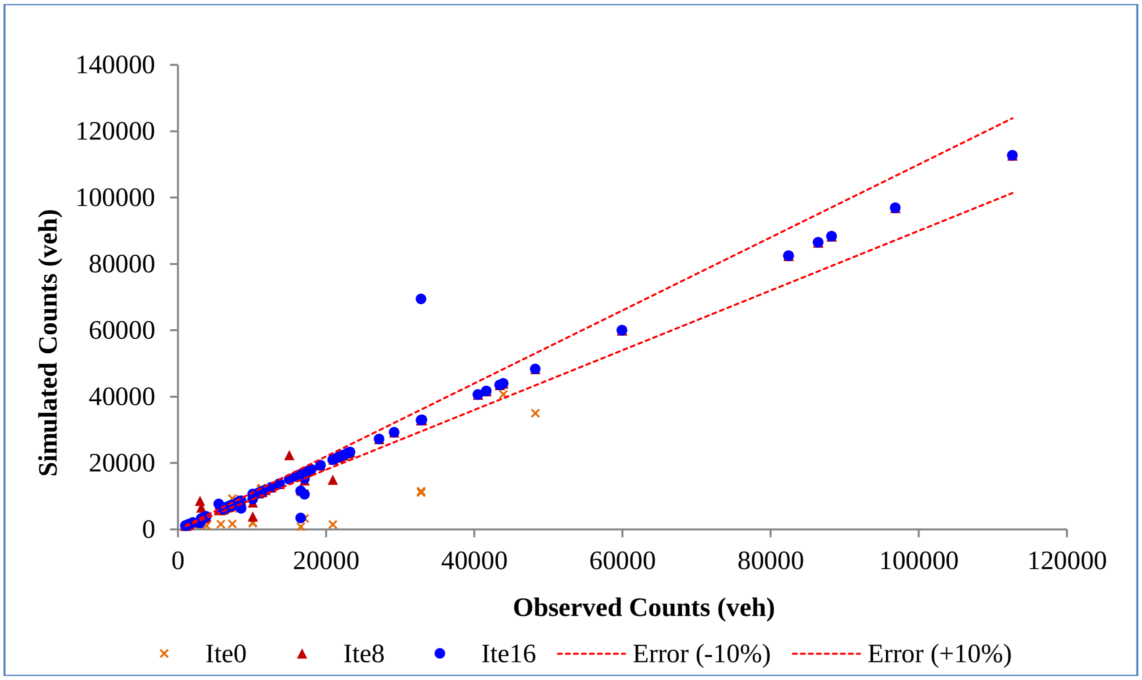

Figure 108. Calibration of OD Matrix with Observed Counts—Cars.

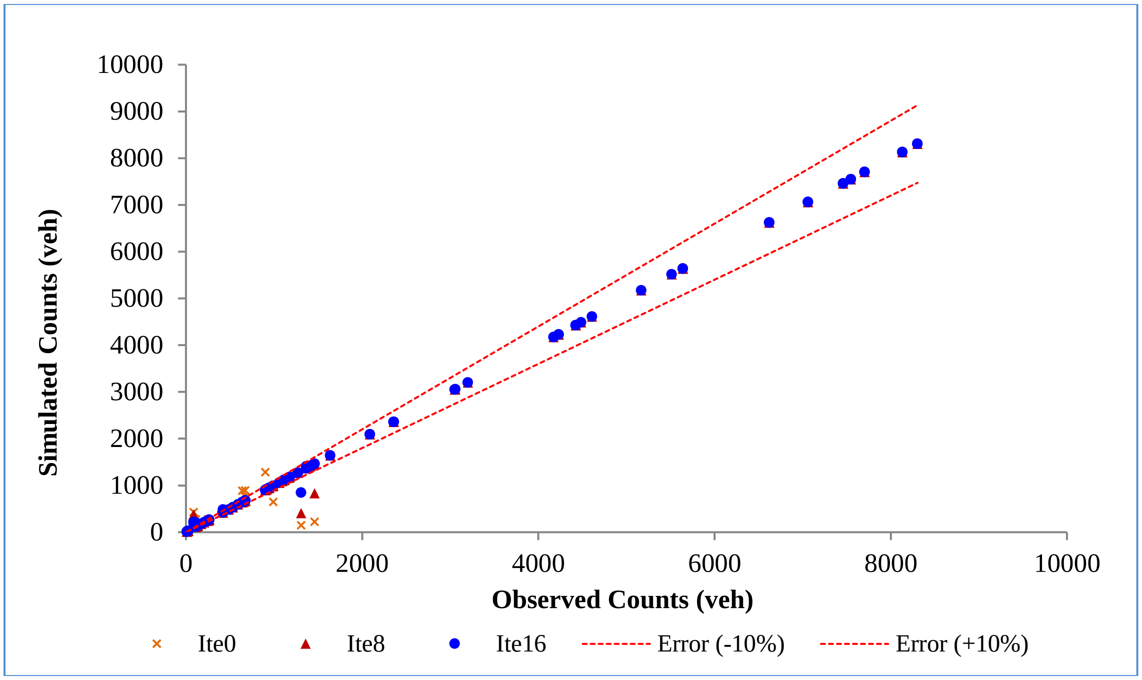

Figure 109. Calibration of OD Matrix with Observed Counts—Trucks.

Once OD matrices are calibrated and the network is ready, the model needs to be validated using speed and travel time data. Researchers recommend short-listing some specific corridors and obtaining speed and travel time data either through field data collection or traffic information (INRIX®, HERE, etc.) to validate the model. Some DTA platforms allow probe vehicles that can be used as part of the validation process. Trying to match captured real-world travel times from the field and match with simulated travel times can be a challenging but critical step. Departure times, exact route choice, and the like all create challenges when trying to match simulated data with field data. The specific probe vehicles should be sent at predefined departure times and through predefined routes to capture model performance. The travel times for each of the vehicles should be matched with actual vehicles traveling the same routes and departing at the same departure time.

The current and future conditions should be modeled irrespective of modeling platform or approach. Researchers also recommend modeling for at least a 5-year planning horizon. The comparison of PMs on the alternate routes (do-nothing[15] versus designated truck routes) should be studied to understand the mobility benefits of these strategies to trucks and local traffic.

Preferred Modeling Approach: Macroscopic or Mesoscopic Modeling

[15] Do-nothing, also referred to as a base case, is used as a basis of comparison to which all other scenarios are compared.

Truck Route Diversion

Truck route diversions are typically due to facility (street/highway) closures. Duration of closures could be short term (1–2 days) or long term (several months), so it is imperative to understand the duration of the closure and what type of simulation tool and assignment procedure is needed. Truck route diversions involve rerouting, so a simulation-based DTA assignment is best suited for this type of analysis. Rerouting information can be both pre-trip and/or en route information. In order to understand the impacts of traffic diversion, a base model must first be developed and used as a basis of comparison. The base model (do-nothing scenario) is run to UE conditions without any diversions in place.

Short-Term Approach

A non-equilibrium DTA approach is used when evaluating unexpected events such as incidents, evacuation, or temporary port-of-entry closure. The premise to this type of modeling is that vehicles who typically travel on preferred routes will continue to take the same habitual route given that the anticipated closure is temporary—even though they encounter delays. Using the last iteration of the base model UE simulation assignment, a one-shot assignment is employed where the routing algorithm uses the vehicle and path information from the last UE iteration. Modeling this type of scenario can also include the use of pre-trip information, which implies a driver can access real-time information (e.g., TV, mobile application) and chooses a route that is the best at the time of his or her departure. If the perceived delay exceeds a certain threshold, then vehicles may choose to divert to a different route. En route information in the form of DMS can also be used when analyzing short-term route diversions. Diversions can be an optional detour—where a certain percentage (user-defined) of vehicles obey the DMS information and take an alternate route—or mandatory detour, where all vehicles change routes based on a predefined path.

Long-Term Approach

An equilibrium-based DTA approach is used when closures are several weeks to months long. The premise to this type of modeling is that drivers have experienced repetitive delays associated with the closure and now search for a new optimal route that minimizes their associated travel time. The DTA shortest-path algorithm is used to search for a new solution in the current iteration using the network traffic data produced. In DTA, travel times vary in time increments, so a time-dependent shortest path (TDSP) is calculated for each OD pair. The distinct feature of TDSP compared to a traditional static assignment from planning models is that the shortest-path search considers the experienced travel time of the next searched link based on the arrival time at the previous link (*65*).

When modeling a truck route diversion strategy, care must be taken when rerouting freight onto alternative facilities (i.e., does the altered route support freight vehicles). For example, diverting large freight vehicles to a downtown district, university campus, or residential area is sometimes unrealistic. Therefore, the model should be developed so that altered routes support this type of vehicle classification. Some modeling tools have the option to restrict certain vehicle classes on link types, while other modeling platforms use a penalty (e.g., increased generalized cost) to route freight onto larger arterials or freeway facilities. In the case of a port-of-entry closure, alternative ports may not allow freight movement. Therefore, additional restrictions should be added to keep unrealistic traffic flows on alternate truck routes.

When analyzing a do-nothing scenario with a truck diversion route alternative, several different PMs are used for comparison. At a minimum, PMs should include total delay time and total travel time. Additional PMs include average speed, average delay time per vehicle, average stopped delay per vehicle, number of stops, and total stopped delay. In scenarios where designated truck routes are assigned due to port-of-entry closure, queue lengths should also be considered.

Macroscopic models can be used to analyze truck route diversions but are limited to complete closures for the entire simulation time period. In addition, macro models do not have a time component and cannot simulate real-time information in the form of pre-trip or en route.

Preferred Modeling Approach: Macroscopic or Mesoscopic Modeling

Grade Separation

The purpose of area grade separation is to improve freight operations for both truck and rail, as well as to improve traffic and safety conditions by eliminating vehicular delay and rail-vehicular conflicts at the mainline tracks. Grade-separation improvements in areas where truck traffic and rail interact are most appropriate when (a) high concentration of truck traffic on a particular corridor leads to severe local congestion; (b) the rail network structure has at-grade crossings or other features that restrict roadway performance; and (c) problems with the network infrastructure restrict rail from offering a viable alternative to trucks for freight movement (*66*).

Microscopic models are best suited for simulating grade separation. Microscopic models are lane-based, which implies that they take into account individual vehicle movements and trajectories, and can distinguish vehicle flows when there are multiple lanes of traffic. In addition, microscopic models can simulate multiple modes of traffic (e.g., freight, rail, passenger cars) simultaneously within the same modeling framework, whereas mesoscopic and macroscopic models are link-based and cannot distinguish individual lanes or grade elevations. Microscopic models require a high level of detail and data input to simulate grade separation between trucks and rail.

Traffic Signals

Typically, the modeled corridor leading to the junction between rail and freight includes traffic signals. Timing plans for traffic signals are represented in terms of phases, split time, cycle lengths, and offsets—depending on the type of intersection (e.g., diamond interchange). Traffic signals consist of minimum and maximum green time per approach, yellow time, and clearance time between changing phases. Minimum and maximum green times are dictated by the number of vehicles traveling through that approach. If the minimum green time has been exceeded and vehicles are still traveling through the corridor, the green time is extended by a certain time period (vehicle gap time). This process is repeated until there are no more vehicles triggering the extension, or the maximum green time is reached, and the next phase begins.

Modern U.S. practice for signal control arranges phases in a continuous ring (also known as a loop) and separates the conflicting traffic approaches with time between when they are allowed to operate, either by making the movements sequential or adding a barrier between the movements. The ring identifies phases that may operate one after another and are typically conflicting phases organized in a particular order. Common modeling techniques follow this same logic. Figure 110 outlines a typical ring of signal phases and how an eight-phase intersection might be coded in a microscopic model. It is also imperative that loop detectors are defined and placed on the roadway (links) upstream of the traffic signal.

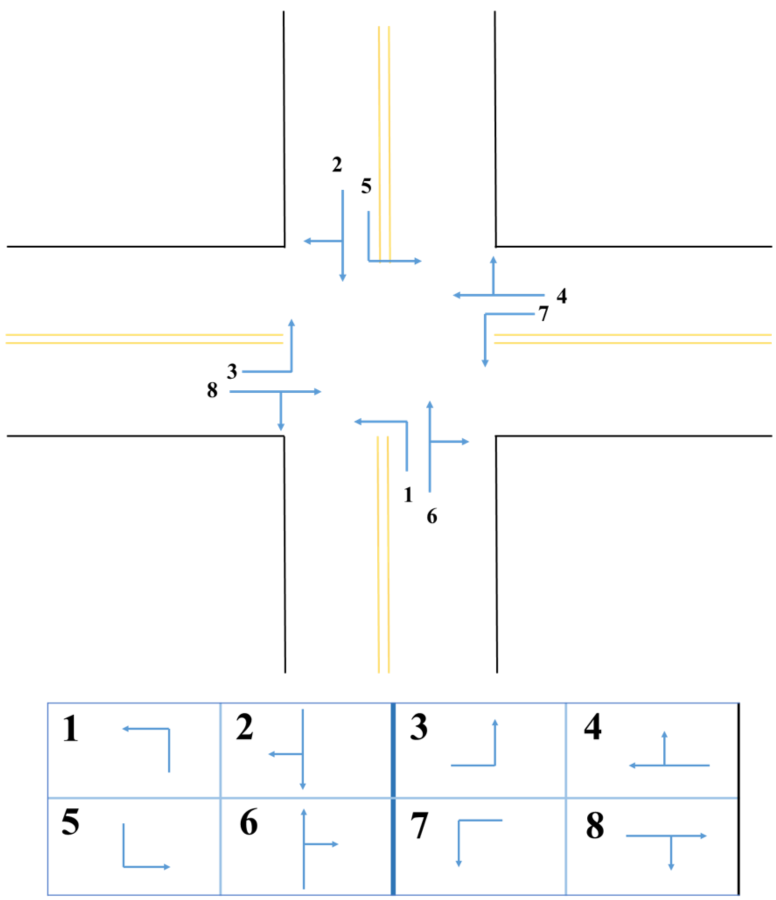

Figure 110. Typical Traffic Signal Timing Plan and Ring Barrier.

Speed Profiles

Modeling grade separation also requires the definition of speed limits and speed reduction areas. Speed data are usually collected in the field in the form of tube counters or radar guns and used as input into the model. When field data are not available, speed limits can be defined as a weighted range of speeds that vehicles can travel through the specified corridor. In addition, speed reduction areas where vehicles slow down (e.g., turns on cross streets) also need to be defined in the simulation model. Speed reductions for freight vehicles are usually defined as a lower threshold than passenger cars due to the size and weight of the vehicles.

Modes of Transport

Different vehicle types (compositions) are defined when modeling grade separation. If there are both freight trucks and passenger cars, then classes should be differentiated. Traffic compositions can be simplistic, where default settings are used to define vehicle types or more distinct types that are more representative of the vehicle on the defined corridor.[16] Other modes of transportation should also be defined, if warranted. For example, if there is heavy pedestrian traffic crossing an intersection, then that mode should be included in the model. If pedestrian traffic is considered light to almost non-existent, then that mode can be ignored given that there will be little influence on traffic flow. Rail must also be defined if the grade separation is between rail cars and freight trucks. Rail definition includes infrastructure (i.e., tracks), stop locations, idling time in a stationary position, length of rail (number of cars), speed of travel in the defined model area, and frequency of rail line (scheduled arrivals).

The simulation run time should be long enough to cover the arrival and departure of the rail line—typically several hours. PMs should include total delay time and total travel time at a minimum. Additional PMs include average speed, average delay time per vehicle, average stopped delay per vehicle, number of stops, and total stopped delay. A do-nothing model where freight and rail are both at-grade must be developed and used for comparative purposes.

Preferred Modeling Approach: Microscopic Modeling

Time-of-Day-Based Strategies

Off-Peak Use of Managed Lanes

Commercial freight mobility on urban area roadways is key to minimizing delays and reducing congestion for both passenger cars and trucks. A possible strategy that does not require developing new facilities is giving access to trucks on managed lane facilities during off-peak hours—if no roadway design limitations are present. This practice provides an alternative for freight vehicles and can benefit roadways by (a) lowering the cost of congestion for freight operations and removing them from the GP traffic lanes that can potentially benefit all other

[16] The Texas Truck Classification in Figure 107 can be used to define a freight vehicle composition.

commuters; and (b) efficiently using additional capacity on the HOV lanes during off-peak hours.

Managed lane facilities usually span several miles and contain multiple entry/exit points along the corridor. In order to capture all traffic behavior in and around the managed lane, a mesoscopic DTA software platform is ideal for the simulation period of interest. Detailed information can be obtained on the temporal and spatial dynamics of vehicle trajectories near the study area. Furthermore, the software platform should support different vehicle types (e.g., SOVs, HOVs, trucks), different link types (e.g., freeway, HOT lanes), and time-of-day vehicle-type restrictions to properly code the operational strategy.

Simulating this strategy will require access to the hours of operations for the particular freeway being studied. There are two ways to restrict specific vehicle types from entering a managed lane: (a) placing a vehicle class restriction flag on every ingress point along the managed lane corridor for a specific time period, and (b) placing an inflated toll rate to restrict certain vehicle types from entering the managed facility. Existing vehicle type restriction flags or inflated tolls would need to be removed or modified to replicate the desired strategy.

The software platform outputs, such as time-space heat diagrams, Avg TTs, and speed or density profiles can then be used to calculate different PMs along the GP and HOV lanes to quantify the impact of the implemented freight strategy.

Preferred Modeling Tool: Mesoscopic

Change in Departure Time

The time-of-day departure choice of individual vehicles is an important determinant of the temporal pattern of traffic on the transportation infrastructure. This determinant has an impact on planning future infrastructure development to accommodate temporal demands and assess potential results from improved operational strategies. As traffic congestion increases, the K-factor, defined as the proportion of the 24-hour traffic volume that occurs during the peak hour, may decrease. This change in driver behavior is known as peak spreading. As congestion increases during the peak periods of the day, motorists may shift their departure time to a nonpeak hour. Knowing whether K-factors remain constant or change will affect the estimation of travel demand and the resultant system performance since the traffic volume on roadways during any given hour affect speeds and resulting calculations for TDSP (*67*).

In most mesoscopic DTA-based models, vehicle trajectories are provided for every OD pair and all departure time intervals. Time-dependent trip tables represent the impact of time-dependent dynamics throughout peak and off-peak time periods. The time interval for each trip table might vary (e.g., 1 hour, 30 minutes, or 15 minutes) depending on the desired modeling accuracy. Macroscopic static models are less suited to assess congestion effects at a more detailed temporal level due to their limitations in reflecting traffic flows over time (see Figure 111). However, macroscopic models (travel demand models) can be used to adjust the departure time profile and generate new OD matrices. If using strictly a mesoscopic DTA modeling platform, changes in departure time can be achieved by developing a customized script in which adjustments are user-defined. Special attention should be given to ensure that total freight trips are the same before and after adjusting the departure profile.

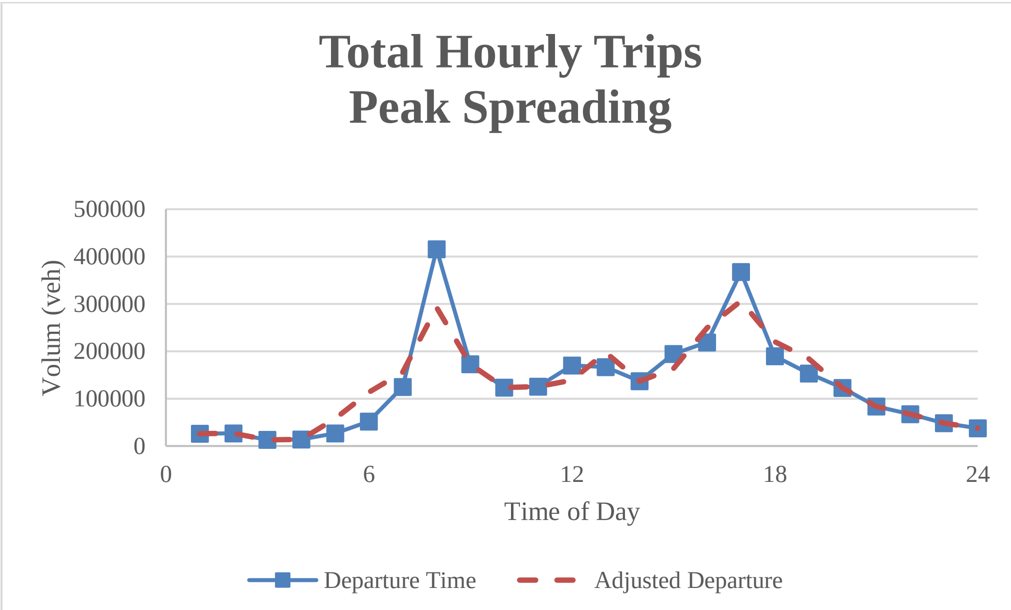

Figure 111. Temporal Departure Time Comparison.

Preferred Modeling Tool: Multiresolution Modeling (Mesoscopic/Macroscopic)

ITS/ATM-Related Strategies

ATIS

ATIS is a system that acquires and presents information to assist travelers in moving from respective starting locations to their destinations. ATIS may operate through information supplied entirely within the vehicle (e.g., real-time information) or it can be supplied by TMCs (via DMS) and include locations of incidents and possible diversion routes or speed advisories, road conditions, and work zones/lane restrictions.

Traffic accidents and work zone analysis are the most widely used applications for modeling ATIS. Typically, traffic accidents are random events, so modeling ATIS centered on a specific accident location is challenging. There are two approaches to take when modeling traffic accidents: (a) use historical data that highlight hotspot locations where there is a high frequency of accidents; and (b) model what-if scenarios where an accident location is chosen by some logic to understand traffic flow patterns and congestion in and around the study area. Once an incident area has been defined, ATIS can be coded in using DMS on an upstream link. Incident data input includes start/end time of incident and the severity. Severity of an incident refers to the reduction of capacity on the link as a percentage of the whole capacity (e.g., four lanes reduced to two lanes is a 50 percent reduction in capacity). En route information from the DMS is used to divert a percentage of vehicles at the next available roadway/ramp or to divert all vehicles using a mandatory detour where all vehicles change paths to a user-defined alternative route.

Temporary work zones can also be considered random events. Work zone locations are coded onto specific links where the start/end time and roadway capacity reduction are defined in addition to the vehicle discharge rate—defined as the number of vehicles per hour per lane exiting the work zone. Similar to incidents, en route information (e.g., DMS) placed upstream of the work zone location can either divert a percentage of vehicles away from the work zone or divert all the vehicles to a user-defined detour route. Comparable to a truck route diversion scenario, a non-equilibrium DTA approach is used to evaluate incidents where habitual route patterns for travelers remain intact.

Preferred Modeling Tool: Mesoscopic

Freight Signal Priority

Decision makers seek new alternatives and technologies to manage and improve the operation of freight with the existing transportation infrastructure. An ITS option such as a signal control strategy has the potential to be adapted to different traffic and user conditions. This option in turn can help achieve an efficient and safe operating environment for freight traffic without major capital investment.

Modeling signal priority requires the aid of a microsimulation package to ensure that all the needed signal controller parameters are available to the user. The network can be developed by either multiresolution modeling or by strictly microsimulation software. If the study area or corridor being analyzed extends for several miles with multiple signalized intersections, a multiresolution approach is desirable. Such a method facilitates the OD patterns for all vehicle classes considered (e.g., passenger cars and trucks) obtained from the mesoscopic model. The vehicle flows can then be imported into the micromodel software package. The user can consider using only the microsimulation software if the corridor being analyzed is of smaller magnitude and requires a shorter simulation period. However, coding the vehicle demand into the model will require field traffic data at each intersection for the period of interest.

Signal timing data are necessary to code the required parameters for all the signalized intersections throughout the study area. These data include but are not limited to base timings, phase sequence, signal flags (e.g., min recall, dual entry, max recall), and coordinated phases. Careful attention should be given to traffic control coding, and researchers suggest that each intersection is thoroughly tested before proceeding to the next one to ensure proper operation of the signal controller.

Prior to calibrating and validating the model, the user should have at a minimum all signalized controllers coded, traffic volume input, desired speeds for all the transportation infrastructure, and route guidance for all vehicle classes considered. The calibration of the model can be carried out by comparing field data to simulated data, such as travel times along the corridor and corresponding speed profiles. FSP should be included once the model is properly calibrated and validated to represent existing traffic conditions.

The signal priority strategy requires modelers to identify the best priority detector location and amount of green time extension needed for the controller. This process will vary depending on the freight corridor being analyzed and the traffic signal configuration used. Once identified, a before and after analysis should be conducted to evaluate the truck priority logic in terms of delay experienced, travel time, and achieved speeds for both passenger cars and trucks.

Preferred Modeling Tool: Multiresolution Modeling (Mesoscopic/Microscopic)

Land-Use Practices and Policies Promoting/Facilitating Freight Movement

Smart Parking

An example of smart truck parking is the TPIMS, which is a virtual environment where information about safe, secure, and convenient truck parking is available in real time to truck drivers. The idea is that real-time information about availability of truck parking will motivate truck drivers to park in designated parking areas rather than on ramps or on the roadside, where they become both a mobility and a safety hazard. There is no single best way in which the benefits of smart truck parking can be studied.

One way of studying the impact of smart parking is to employ multiresolution modeling to understand the mobility issues created by truck parking on the roadside and/or on ramps. However, such types of models require extensive data collection along the corridors where trucks park to realistically model the field conditions. The mesoscopic models can be used to model the trips between various origins and destinations, where a truck parking location can be either origin or destination. The microscopic models can be used to understand the mobility issues created by truck parking on ramps or the roadside instead of parking stops. The performance measure comparison with and without truck parking or the shift of some percentage of trucks to parking should provide some insight into benefits or impacts of truck parking. Surveys are recommended to understand the percentage of trucks that will shift to the parking stops after availability of real-time information.

In this study, due to the lack of available data and resources, the impact of smart truck parking in the DFW region was not studied using multiresolution modeling. However, the analysis was done by leveraging the data on the location of truck parking stops, typical parking spaces near major corridors, and truck traffic on various corridors in the region. The visualization data provided showed truck parking stops near major corridors where truck parking is a major issue.

Preferred Modeling Tool: Multiresolution Modeling (Mesoscopic/Microscopic)

MODELING LEVEL OF EFFORT

The level of effort needed to run the DFW model was considerably larger than the required for the other urban areas. The modeled urban areas varied in network size, number of TAZs, tolled facilities, and total number of trips per user class. Table 31 provides a comparison of the DFW model with the other urban area DTA models.

Table 31. Mesoscopic Regional DTA Models—Network Structure.

Total	El Paso	Austin	Houston	DFW
Links	14,060	29,487	46,212	60,951
Nodes	6189	13,366	17,740	25,683
TAZs	836	1462	3531	5386
Signalized Intersections	602	2112	2396	5068
Tolled Links	78	167	815	614
Trips (Millions)	3.25	5.22	12.43	18.92

Developing and modeling each strategy requires a different level of effort, which depends on factors such as user expertise, network size, case study location, modeling resolution, software platform, simulation time periods, and computing power available. In this study, researchers used a customized computer with 64 gigabits of memory and an i9 Intel processor. Eight days of runtime was needed to simulate 24 hours of demand for 15 iterations using OD matrices. In order to calibrate the demand, the model was split into three distinct time periods, including morning peak, afternoon peak, and off-peak. An OD matrix estimate (calibration) was done using peak and off-peak periods. The final demand profile was determined using diurnal factors provided by the NCTCOG. Researchers estimated the level of effort required to develop and simulate each freight management strategy depending on network size and structure, as shown in Table 31.

SELECTION AND DEPLOYMENT

The second set of guidelines will assist TxDOT in the selection and deployment of freight management strategies. They are based on findings of previous studies and results obtained from the modeling activities conducted in this research project. The following section includes draft guidelines for the implementation of three types of freight management strategies:

- Lane- and Route-Based Strategies.
    - Dedicated Truck Lanes.
    - TOT Lanes.
    - Truck Route Designations.
- Time-of-Day-Based Strategies.
    - OPD.
    - Off-Peak Use of Managed Lanes.
    - Change in Departure Time.
- ITS/ATM Related Strategies.
    - ATIS.
    - FSP.
- Land-Use Strategies.
    - Smart Parking.

Freight flow characteristics are often site-specific and vary depending on time and location. Therefore, implementation guidelines may need to be customized for different corridors. Freight management strategies are provided based on the benefits they can provide and/or conditions under which they might be employed.

Lane- and Route-Based Strategies

Dedicated Truck Lanes

Dedicated truck lanes may be used to improve safety and mobility on some major freight corridors, particularly at those locations where physical segregation of truck traffic from passenger cars is feasible. The primary purpose of this freight management strategy is to reduce car-truck interactions on freeway segments where a high volume of trucks can make passing and weaving maneuvers difficult and dangerous. Therefore, implementation of this strategy is likely to be most beneficial on freight corridors where the number of crashes involving trucks is unusually high.

In the United States, the dedicated truck lane concept has been mostly applied as a lane restriction on urban freeways where trucks are restricted to use certain lanes only at any time or during congested periods during the day. Only a few exclusive truck facilities have been constructed (e.g., the New Jersey Turnpike, Clarence Henry Trackway, South Boston Bypass, and Los Angeles I-5 truck bypass lanes). Some of the initial research conducted at these locations shows promising results in terms of improved travel speeds for trucks and improved safety for both trucks and cars (*13, 14, 15, 34*).

Dedicated truck-only lanes typically require either the construction of a new traffic lane or the conversion of an existing one to a truck-only lane. Preliminary evaluation and inspection of the existing roadway geometry of the surrounding area is necessary to determine the feasibility of implementation. If geometric conditions and constraints do not prevent the use of dedicated truck-only lanes on a selected freeway segment, additional criteria can be applied to determine if the expected benefits warrant its implementation.

However, due to the limited number of applications of dedicated truck-only lanes, widely accepted implementation warrants have not been established. A recent study (*13*) has analyzed data from 25 freight corridors in six states (California, Georgia, Washington, Virginia, Oregon, and New Jersey), and developed warrants for the implementation of dedicated truck lanes on freeway segments in the Bay Area in California, as shown in Table 32. The metrics evaluated are based on data related to traffic volumes, crash history, freight significance, and site and location characteristics. The following set of criteria and implementation warrants were developed for the dedicated truck-only lane strategy:

Table 32. Implementation Warrants for Dedicated Truck Lanes—California (*13*).

Data Types	Metrics	Criteria
Traffic characteristics	AADT	> 10,000
	Truck percentage	> 6%
Crash history	Percent of crashes involving trucks	> 12%
	Percent of fatalities involving trucks	> 70%
Freight significance	Distance to freight gateway (ports, etc.)	< 50 miles
Site and location characteristics	Freeway segment length	> 10 miles
	Existing lanes	> 2
	Proximity to metropolitan area	< 40 miles

The dedicated truck lanes strategy was modeled along César E. Chávez Border Highway in El Paso. Two scenarios were considered: first, prohibiting cars to enter the truck-only lanes (basic definition of dedicated truck lanes), and second, incentivizing trucks for using dedicated truck lanes.

TOT Lanes

TOT lanes, similarly to dedicated truck lanes, segregate trucks from the mixed traffic flow where a tolling rate schedule is implemented for trucks using the facility. This strategy has been considered in several urban areas to aid truck traffic flow from major traffic generators. For example, TOT lanes were proposed on SR 60 and I-710 in Miami, Florida, and Los Angeles, California, respectively, with the intention of helping traffic getting into and out of busy ports. Furthermore, in Atlanta, Georgia, TOT lanes were considered to help reduce urban traffic congestion and improve freight mobility around the region (*16*).

Separation of trucks from other vehicles can significantly reduce fatal and serious injury crashes involving trucks. Thus, freeway segments experiencing high numbers of truck-involved crashes can be considered good candidates for implementing TOT lanes.

TOT Design Issues

TOT lanes have special design and configuration requirements compared to other toll facilities (e.g., pavements to accommodate the heavier/overweight loads, staging areas for assembling and disassembling long combination vehicles, and on/off-ramps specifically designed for safe exit/access of trucks). Potential implementation issues related to the engineering design of TOT lanes are (*17*):

- Number of TOT lanes—how to determine by direction.
- Lane placement.
  - Inside or outside?
  - Trade-off between operational efficiency and construction cost.
- Barrier separation.
  - Concrete traffic barriers, grass—safer but costly.
  - Pavement marking—less safe but less expensive.
- Access points—Separate entry and egress points to minimize weaving conflicts.
- Truck parking areas—how to locate them along TOT corridor?

TOT Operation Issues

The major challenge with TOT lane implementation is to find optimal system-level toll pricing that does not discourage use and unintentionally shift truck traffic to non-tolled facilities, through residential neighborhoods, or to facilities that are not adequate to support heavy truckloads. Potential implementation issues related to the operation of TOT lanes are (*17*):

- Tolling strategy.
  - Dynamic based on real-time traffic conditions.
  - Time-of-day pricing (peak/off-peak).
- Speed limit on TOT lanes—higher than GP lanes?
- Voluntary or mandatory usage TOT lanes—how to determine by direction.

Applications of TOT lanes in the United States are limited, and only very few site-specific implementation guidelines are available. A study conducted at the Georgia Institute of Technology has developed a methodology for planning the implementation of TOT lanes at state, regional, and corridor levels in Georgia. As part of the study, they developed five corridor screening criteria for TOT lane implementation, as shown in Table 33. The screening criteria can be applied to other states, but the threshold values will be different.

Table 33. Implementation Warrants for TOT Lanes on Freeway Segments in Georgia (*17*).

Metrics	Criteria
Level of service	E–F
Truck volume (daily)	> Median daily truck volume on all highway links
Truck percentage (daily average)	> Median truck percentage on all highway links
Truck-related crash rate (annual)	> Average regional crash rate
Travel time savings (am/pm peak)	> 90th percentile truckers' cost-saving threshold

Designated Truck Routes

In urban areas, trucks typically share the roadways with other modes of transportation and significantly contribute to congestion, emission, and noise. Designating certain roadways as truck routes is the most commonly implemented strategy employed by cities to manage freight traffic more efficiently and at the same time reduce its negative impacts to residents. The literature has examples of various types of truck route designation strategies that cities use to efficiently meet the needs of all modes of transportation (*16*, *19*).

A specific type of truck route designation strategy was modeled on the Houston roadway network. SH 99 was designated as a freight bypass for trucks that otherwise used I-610 or Beltway 8 when traveling through Houston from the north-northeast to the southwest portion of the region. However, designating the bypass was not enough to attract truck traffic onto SH 99 due to the longer length and perceived travel time. Therefore, the toll for through trucks was removed/waived on all segments throughout the bypass. Trucks taking the bypass saved up to 12 percent in travel times and experienced 7 percent less stopped times during afternoon peak hours. All planning authorities with responsibilities for roads in the urban area and the freight transport industry should be involved in the process of identifying truck routes to ensure that they link key destinations, avoid sensitive populations, and are coordinated across jurisdictional boundaries.

Before implementing truck route designation, it is critical to identify candidate routes with appropriate road geometries and infrastructure elements that are adequate for safely accommodating heavy trucks. Table 34 shows some of the major roadway infrastructure design elements that need to be evaluated (*68*).

Table 34. Infrastructure Elements To Be Evaluated in Truck Route Designation.

Infrastructure Element	Reason for Concern
Road vertical grade	Trucks require greater distance to stop and are slower to climb hills.
Roadway and ramp curvature	Trucks require greater stopping distance and less curvature to safely navigate a ramp.
Access ramp acceleration lanes	Trucks accelerate more slowly and require longer acceleration lanes.
Underpass/overpass height	Trucks have a taller vehicle height and require greater vertical clearance.
Bridge/overpass design for weight	Structures used by heavy vehicles require different structural designs and/or materials.
Pavement thickness—roadway and shoulder	Heavy vehicles impose more load on pavements.
Shoulder width	Wider vehicles require more room for a breakdown lane.
Crash barriers	Roadside safety hardware may need to be adjusted for roadways carrying heavy vehicles.
Drainage systems; storm grate design, culvert size and design	Heavier vehicles impose more load on these systems.
Entrance gates for reversible-flow lanes	Wider vehicles require more lateral clearance.
Weave and merge areas	Trucks are slower to change lanes and require longer weave/merge distances.
Number of lanes	Trucks are slower to accelerate and may operate at lower speeds, posing an impediment to overtaking by passenger vehicles.

Additionally, truck routes should be clearly mapped and identified with road signs, and cities should consider adjusting signal timing along arterials designated as truck routes (e.g., increase the yellow and green signal phases to meet increased acceleration and deceleration requirements) to improve the overall flow of truck traffic (*19*).

Time-of-Day-Based Strategies

OPD

OPD is a relatively simple and effective freight management strategy, but its implementation can be challenging. Nighttime delivery reduces congestion during the day but may cause noise concerns for residents at night. Businesses often resist and do not want to participate in OPD programs unless they get special incentives. Businesses that are open during off-peak hours (e.g., supermarkets, restaurants, hotels) are more likely to participate in OPD. The more receiving businesses participate in OPD, the more cost effective the program is because the additional cost is shared among more customers (*69*). An effective implementation of an OPD program will balance the benefits and costs between carriers, receivers, shippers, customers, and the community. OPD can save time and money for carriers but can add costs for receiving businesses.

In general terms, OPDs fall into four different groups. The first group consists of businesses that require OPD because of the type of work they do (e.g., newspaper distributions). A second group includes companies that operate 24 hours a day, 7 days a week, so deliveries during nonpeak hours are more beneficial. The third group is geared toward companies/businesses for which OPDs do not make business sense either because the additional costs are too high or because the marginal benefits are too small. The last group includes companies/businesses that could do OPDs if proper incentives are in place.

There are five different entities involved with OPDs: shippers, receivers, warehouses, trucking companies, and third-party logistic providers. Shippers begin the process by looking for trucking companies or third-party logistic providers to coordinate the transport of goods. Typically, shippers determine the pickup time, though they sometimes do not have control of the delivery time. Trucking companies usually determine departure times and optimal routes for delivery. Receivers are the entities that set the delivery times, most frequently in mutual agreement with the carriers. For OPDs to be successful, carriers must coordinate with receivers the time that loads will be delivered; otherwise, drop boxes or other special arrangements are needed (*6*).

Receivers often incur the majority of problems associated with OPD. OPDs force receivers to have additional staff on hand to accept deliveries (which may require additional staff), bear the associated labor costs, and deal with the alteration of employee shifts. In addition, receivers have to bear the burden of heating and lighting costs, and in some instances, additional security.

However, the benefits of OPD could outweigh the associated costs. Travel times to and from business are reduced because speeds during off-peak hours are typically higher. That element could result in less traffic congestion, reduced cost of goods, economic benefits, and an improvement on the environment. OPDs are also less likely to disrupt the receiver’s day-to-day business operations.

Off-Peak Use of Managed Lanes

This unique strategy seeks to leverage existing managed lanes by incentivizing (e.g., waived or reduced toll for trucks) truckers to use them during off-peak periods when there is typically spare capacity. This strategy can be effective in reducing travel time and improving TTR to ports and other urban freight generators.

Most of the managed lanes in Houston are reversible and have geometric constraints, such as access points, that cannot easily accommodate trucks due to their turning radius and size. Consequently, researchers modeled this strategy on the I-10 Katy Freeway managed lanes since they are not reversible lanes. It was found to significantly increase truck volumes in the managed lanes while reducing travel times, particularly in the EB direction.

Although this strategy could potentially yield significant benefits if deployed system-wide in metro areas, the following issues should be considered on a corridor-by-corridor basis:

- Increased maintenance of managed lanes, such as concrete traffic barriers, arresting barriers (if present), and others.
- Retrofit of some access points to allow for safer truck maneuverability, such as widening inside shoulders, particularly with the reversible lane configuration. This issue may not be as critical with concurrent lane configurations.
- Installation/upgrade of vehicle classification detection at access points to loops and/or other technology that can detect vehicle length/axles.
- Possible political opposition and/or legislative changes required, such as for HOV lanes.

There should also be an educational campaign geared to the freight industry to maximize awareness of the strategy.

Change in Departure Time

Change in departure time has no specific guidelines on selection or deployment. However, there are multiple factors that come into play when considering changes in departure time, including the time availability of freight recipients and availability of truck drivers. Some businesses will not accept freight deliveries during peak business hours (e.g., restaurants).

In addition, state and local agencies should consider how changes in departure time will affect overall traffic conditions. The NCTCOG official travel demand model has a total of 18.9 million trips with combined user classes. However, freight accounts for only 4 percent of all trips. In addition, the temporal pattern of freight departure times does not mimic the departure time profile for passenger cars. Freight peak period begins at approximately 9:00 a.m. and continues until 2:00 p.m. Shifting freight departure times to a few hours before or after will actually increase overall congestion. Therefore, it is imperative that freight trips be shifted to hours of the day where they can improve their overall travel time while simultaneously improving overall congestion conditions (Figure 112). There are multiple commercially available routing applications that can assist with optimal routes and departure times.

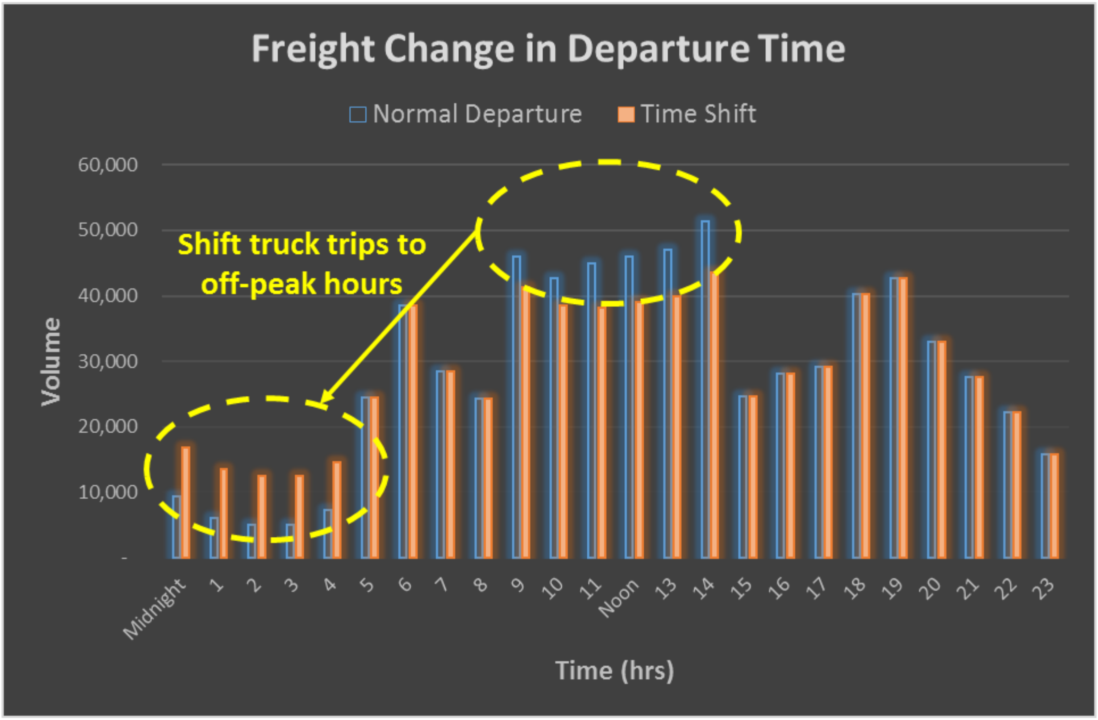

Figure 112. Departure Time Profile—NCTCOG Model.

ITS/ATM-Related Strategies

Freight ATIS

The lack of freight-specific traveler information that could be provided through ITS has many negative effects on the freight industry, such as reduced efficiency in freight movement, less than optimal planning of daily truck activities, underperforming logistics management systems, increased energy consumption, and negative effects on roadway safety and the environment. (*70*). In order to improve information flow, U.S. DOT developed the FRATIS program to promote improved urban freight mobility. FRATIS focuses on integrating regional ITS data, DOT commercial fleet data, third-party truck-specific movement data, and intermodal terminal data to disseminate toward various FRATIS applications, as shown in Figure 113.

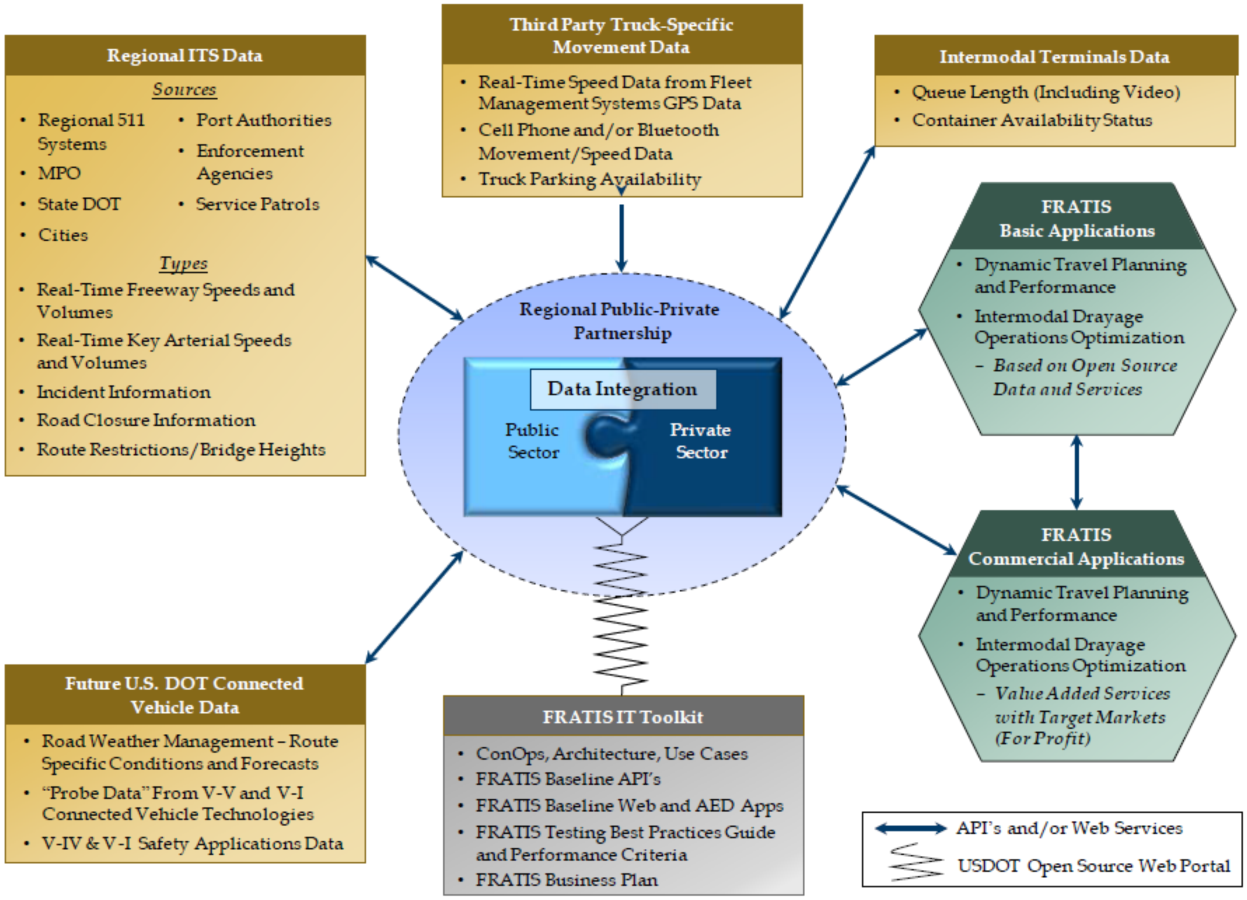

Figure 113. High-Level FRATIS System Concept (*71*).

Researchers modeled the regional ITS data component of FRATIS and evaluated its performance and expected benefits through two case studies with different hypothetical incident scenarios in the roadway networks of DFW and Austin, Texas. The modeling results from the two case studies showed that the maximum travel time savings that trucks can experience by diverting to the recommended alternate routes is about 14 minutes per truck in DFW and 18 minutes per truck in the Austin case studies. In addition to travel time savings, they also avoid frequent stopping and accelerating maneuvers in the stop-and-go traffic and at the lane drops approaching the incident location, which minimizes regional emissions and the risk of being involved in secondary incidents.

The FRATIS Impact Assessment report examined the costs of congestion and whether those costs can be reduced by the technology improvements in FRATIS. The report shows the estimated fuel savings, CO_2 reductions, and total drayage cost reductions for three types of improvements that could be affected by FRATIS, including reducing the time within a terminal, reducing the time in a queue outside the terminal, and a reduction in idling (Table 35). If the three improvements could all be achieved nationwide, there would be a potential 11.3 percent reduction in drayage costs.

Table 35. Modeled Impacts of Selected FRATIS-Related Drayage Improvements (*72*).

Drayage Improvement Scenario	Fuel (miles/gallon)	CO_2 (Kilo-tons)	Cost ($/mile)
2012 national estimate	80.0	891.05	$1,640
Reduced terminal time (30 min vs 40 min)	−2.0 −2.5%	−17.82 −2.0%	−$90 −5.5%
Reduced queue time (10 min vs 20 min)	−2.0 −2.5%	−24.95 −2.8%	−$79 −4.8%
Reduced idling (reduced by 50%)	−5.9 −7.3%	−65.74 −7.4%	−$17 −1.0%

U.S. DOT is interested in seeing more commercial applications of the technologies demonstrated by the three FRATIS prototypes and two current follow-up pilot projects. The lessons learned cut across all the technologies or the prototype sites. Some of the findings also deal with how these and other prototype tests could be conducted more effectively and how they should be considered when developing new FRATIS-related applications/systems. The lessons learned from the FRATIS Impact Assessment report include:

- Optimization requires major changes in dispatching policy that must be advantageous to drivers and dispatchers to succeed.
- For optimization to be successful, the optimization software needs to be run frequently and have both the inputs and outputs integrated with the drayage[17] company's dispatch system; otherwise, optimization will not be used consistently.
- Effort needs to be expended at the very beginning of a pilot project to ensure alignment between stakeholder needs and sponsoring agency objectives. This effort should concentrate resources on problems that best address user requirements.
- Pilot users are extremely busy with current operations, so developers need to have enough resources to be able to assist the users. Financial incentives to users may be appropriate.
- Care is needed in selecting stakeholders to represent all the interests in a pilot project and to assist with project coordination and cooperation of pilot users.
- Wider implementation of queue measurement devices and a consistent method of providing the information to any and all potential users will benefit operations at multiple terminals in a region.
- Proponents of advanced technology pilots should concentrate development efforts on technologies that do not exist in the commercial marketplace.

[17] Drayage is defined as the transportation of goods over a short distance, often as part of a longer overall move.

FSP

FSP is another ITS application that has the potential to significantly improve freight operations. FSP involves providing preferential treatment (e.g., traffic signal priority) for freight and commercial vehicles traveling within an urban area or in a specific area of high-volume freight traffic, such as near a port, railyard, or other freight generator. FSP reduces stops and delays to commercial vehicles at signalized intersections by extending the green signal when a truck is nearing the intersection. This practice can increase TTR for freight traffic, enhance safety at intersections, and provide environmental benefits by reducing acceleration and deceleration emissions for trucks.

The FSP simulation results showed no sign of improvement in terms of overall travel time for trucks traveling along the NB approach of Burnet Rd. in Austin. This result is in part due to the NB approaches already using their maximum split during the heaviest peak traffic flow periods, making the minimum green extension have little to no impact on the overall throughput. Travel time on the NB approach showed a 1.90 percent and 0.87 percent increase for passenger cars and trucks, respectively. Furthermore, some of the cross streets experienced higher queue lengths (e.g., Palm Way), while others remained basically unchanged.

However, a 2014 research study of FSP had different conclusions (*71*). The study focused on evaluating the impacts of FSP on a high truck-density intersection by adding 11 seconds of green time extension. Major findings included:

- Priority may contribute to improved truck operations and service reliability. When priority was provided, 13 percent to 21 percent improvement occurred in the travel delay, and 20 percent to 32 percent improvement occurred in the stopped delay at major truck moving direction.
- Priority may contribute to improved operations and service reliability for all vehicles in the major truck travel direction. When priority was provided, 0 percent to 8 percent improvement occurred in the travel delay and 2 percent to 9 percent improvement occurred in the stopped delay for all vehicles at major truck moving direction.
- Priority may also improve carbon emission and reduce pavement damage (reducing hard stop of heavy vehicles) by reducing total number of stops by 1 percent to 7 percent for all vehicles and 9 percent to 16 percent for trucks only at major truck moving direction.
- Provision of priority resulted in improved truck travel delay and reduced number of stops with little to no negative impacts on all traffic at the intersection.

Based on the findings above and other literature, the following issues should be considered before implementing the FSP strategy:

- Corridors with high percentage of truck traffic.
- Amount of traffic volume on cross streets that may be affected.

- Land uses such as industrial parks and/or intermodal facilities where major freight generators are located.
- Capacity analysis and possibly microsimulation to see potential operational impacts.
- Areas with air quality issues, such as non-attainment areas.

Land-Use Practices and Policies Promoting/Facilitating Freight Movement

Smart Parking

A recent study in Minnesota compiled results of a pre-implementation usability survey on the truck parking information system (*73*). The study found that 60 percent of drivers ranked onboard computers as the most preferred method for receiving truck parking availability information, followed by roadside DMSs, a smartphone application, and a website. Almost 45 percent of the truck drivers preferred receiving advance notification 20 miles ahead of the rest stop. In the same study, when asked, "What factors are most important in selecting a truck parking location?" most drivers indicated "nearing their federal hours-of-service (HOS) daily driving limit" or "nearing HOS 30-minute rest break requirement" as an important factor in selecting a truck parking location. Almost 38 percent of drivers would prefer a message that displayed the exact number of spaces available, while 50 percent indicated they would prefer either a categorical message, such as low availability, or the exact number of spaces available. Approximately 67 percent of drivers indicated that the truck parking information system has had a significant impact on their ability to comply with HOS regulations, and most of the drivers responded that the truck parking information system has had a significant impact on the ability to find available parking.

Another study in California (*74*) that discussed a system for truck parking estimation and rendering of parking information mentioned the following critical components for development of smart truck parking. The mentioned components are directly borrowed from that study; however, they may change based on the truck parking information system that TxDOT selects or plans to implement. Systems include:

- Source of Parking Information (SPI): The system describes parking availability at the location of interest.
- Central Database Server (CDS): The central database of the system receives and stores information forwarded from the SPI at each location.
- Parking Availability Estimation and Forecasting Algorithm (PAEFA): A PAEFA is produced using the historical information archived within the central database.
- Parking Ground Truth Recalibration System (PGTRS): Parking locations within the system may require recalibration of parking availability information.
- Remote Computer and Storage (RCS): Depending on the system design of the SPI, a remote computer and accompanying storage capacity may be needed locally on site.

- Information Delivery System (IDS): The estimated parking availability information forecast by the PAEFA using data from CDS is then projected to the IDS. The IDS may constitute various delivery mechanisms.
- System Operations Computer Cluster (SOCC): The SOCC is a single computer or set of computers that centrally manages the system data. The SOCC may be distributed or centralized. Collectively, the SOCC communicates with the RCS to send commands to the parking locations' SPI and recalibration cameras (PGTRS).

Figure 114 provides one example of an inventory management system at the parking location that reports information to the Internet access point and RCS. As mentioned in the study (*74*):

> The inventory management system is generally a check-in, check-out system, where each vehicle entering the system is registered in a database. The information is stored on the RCS, and later forwarded to the CDS. The SOCC then processes information on the CDS using various algorithms defined within the PAEFA. The IDS communicates with the CDS to query information desired by the user (Driver), and this communication may be supported by the SOCC directly or indirectly.

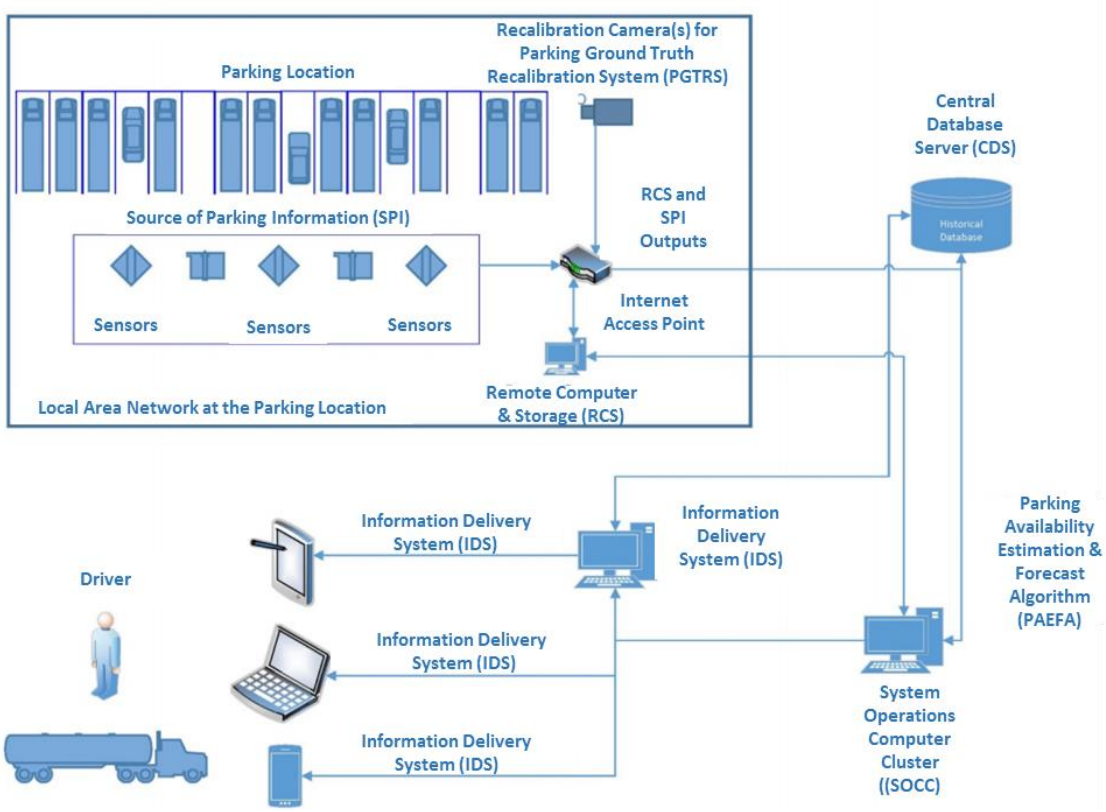

Figure 114. Sample Schematic of Parking Forecasting Sensing through Inventory Management (*74*).

POLICY

The third set of guidelines will assist TxDOT in developing guidelines as they relate to policy implications. They are based on findings of previous studies and results obtained from the modeling activities conducted in this research project. The following section includes:

- Lane- and Route-Based Strategies.
    - Dedicated Truck Lanes.
    - TOT.
    - Truck Route Designations.
- Time-of-Day-Based Strategies.
    - Incentivized OPD.
    - Incentivized Off-Peak Managed Lanes.
- ITS/ATM Related Strategies.
    - ATIS.
    - FSP.

Lane- and Route-Based Strategies

Dedicated Truck Lanes

What It Is/Where Applicable

Dedicated truck lanes as part of existing roadways or as part of dedicated truck facilities aim to segregate truck traffic from passenger traffic to reduce car-truck interactions in terms of weaving and passing maneuvers. This segregation has the potential to improve safety and operations for both trucks and passenger vehicles, which leads to less congestion and more reliability. This strategy can be implemented along major freight corridors, congested corridors, and roadways serving major freight facilities, such as port facilities.

Policy Considerations/Implications

The purpose of dedicated truck lanes is to promote safer traffic flow, reduce congestion, and increase freight-hauling productivity. Application of the strategy needs to occur along corridors with sufficient truck traffic levels. Additionally, if converting an existing lane of traffic for this purpose, the remaining roadway lanes should sufficiently accommodate the passenger vehicles without negative operational impacts. Reductions in the level of service along remaining GP lanes could reduce public support for the truck lanes.

Development of dedicated truck lanes should include a plan to counter the negative effects of heavy freight vehicles on the roadway pavement. Depending on the location and length of dedicated truck lanes, these lanes could be used in the future by automated/connected and/or autonomous trucks, especially offering a location for truck platooning.

Impediments/Hurdles

Implementing dedicated truck lanes may require sizable levels of initial investment and continuous maintenance costs. Significant involvement and regular interaction among public and private stakeholders is critical to the success of this type of project. The identification of corridors in which to apply this concept will require agreement by private truck operators, shippers, and industry leaders. Public support may largely depend on the perceived impacts on passenger vehicle operation on the remaining roadway lanes.

Who Decides/Responsibility for Implementation

In order to promote improved freight movement through an urban area, the implementation of dedicated truck lanes will require cooperation between the DOT and local MPO and, in specific instances, local agencies. The urban corridors handling significant freight volumes are generally part of the state highway system. Local agencies may become involved if implementation involves roadways connecting freight facilities on roadways off the state highway system. The MPO would play a major role in both roadway planning and in coordinating cooperation between public and private stakeholders.

Truck-Only Toll Lanes

What It Is/Where Applicable

TOT lanes represent dedicated truck lanes developed as toll facilities. They would require special designs compared to other toll lanes and would be best suited in heavy truck corridors, corridors serving major freight facilities, corridors between major freight facilities, or locations where truck traffic is sensitive to travel time and reliability.[18]

Policy Considerations/Implications

The purpose of TOT lanes is to improve safety and provide greater system reliability while collecting toll revenue to cover facility financing, maintenance, and operational costs. Use of the facility could be mandatory, especially if located at a freight-specific facility (such as a seaport), or voluntary. Managed TOT lanes could vary facility pricing to maintain system operations. The major challenge with TOT lane implementation is to find optimal system-level toll pricing that does not discourage use and unintentionally shift truck traffic to non-tolled facilities, through residential neighborhoods, or to facilities that are not adequate to support heavy truckloads.

[18] Although TxDOT is considering only strategies that incorporate the removal of tolls or non-toll freight management, we still included this strategy in our research as an alternative strategy due to its proven mobility benefits on busy ports in other states. This may be useful if TxDOT would like to consider this strategy in future.

Impediments/Hurdles

Gaining support from the trucking industry is a major challenge in implementing TOT lanes. The TOT lanes must address a major travel constraint by providing reliable operations at a reasonable expense to the truckers. The TOT lanes will likely require significant initial and continued investments to handle the heavy vehicle usage. The location of the TOT must attract enough users to the necessary revenue stream required to meet financial obligations. Heavy involvement by public and private stakeholders is required from the onset.

Who Decides/Responsibility for Implementation

Implementation of TOT lanes will likely require DOT, MPO, and regional tolling authority cooperation. As with dedicated truck lanes, the MPO would play a major role in both roadway planning and in coordinating cooperation between public and private stakeholders.

Designated Truck Routes

What It Is/Where Applicable

Designating specific routes for trucks to use is a traffic management strategy used by local governments to manage freight transportation demand. It involves restricting truck traffic to designated roadways, usually to avoid residential areas or other unsuitable locations. The strategy could also apply to restrict truck traffic from entering congested urban core roadways by designating freight bypass routes.

Policy Considerations/Implications

Designated truck routes is a strategy to direct trucks over roadways designed to accommodate their specific operational characteristics and to bypass truck traffic from sensitive areas or from highly congested roadways. The restrictions could be in place all the time or could involve temporary restrictions (e.g., peak periods of the day). It is very important to understand truck traffic trends, ODs, roadway geometry and other characteristics to best place truck movements. Pavement design and maintenance considerations are a major consideration. Directing trucks to use a limited network of roadways designed to accommodate the heavier loads could improve pavement management as a whole. Extensive stakeholder involvement is required when considering any network restrictions. In cases where it might be desired to direct trucks to bypass urban core roadway congestion, such as along a loop, those roadways may be toll facilities, so planning and cooperation between the regional transportation planning entities will be required.

Impediments/Hurdles

Trucks generally travel to deliver shipments from their origin to destination. Designated truck routes must not restrict a truck company’s ability to serve its customers. Restricting trucks to certain roadways will likely increase the miles traveled and operational costs associated with truck operations. Planning organizations will need to manage commercial land use to maintain truck flow patterns along those designated roadways. Changes over time in the pattern of truck movements may require adjustments to the designated truck routes.

Who Decides/Responsible for Implementation

Most designated truck routes are performed at local levels. Examining the bigger regional truck flows to consider routing trucks around heavily congested urban core roadways will need to involve the DOT and MPO.

Time-of-Day-Based Strategies

Incentivized OPD

What It Is/Where Applicable

OPD strategies move freight trips to evening, night, or weekend hours to reduce truck-caused congestion. At the same time, the congestion experienced by trucking firms is also reduced greatly, allowing for better productivity and efficiency for a given number of trucks/drivers within existing fleets. The term OPD, as generally employed, is usually applicable at the regional or subregional levels for describing policies for local delivery and last-mile drop offs to businesses; however, similar practices by truckload/long-haul trucking companies to time travel through major urban areas have also been employed.

Policy Considerations/Implications

Implementation of OPD policies and practices has been largely on a voluntary basis and/or part of research pilot projects testing the efficacy of such policies to date. Costs are generally borne by the participants in the private-sector businesses and trucking companies taking part. These costs include (a) shifting crew and receiving business staff work hours to accommodate OPD of goods, (b) provision of a secure area where unattended off-peak delivered goods can be cached until store staff can process and stock the items, and (c) additional lighting/security/noise-canceling needs for overnight delivery within an urban context. In some cases, local zoning ordinances must be addressed to allow for delivery during hours when residents might be asleep or business traffic levels are high.

Impediments/Hurdles

Several impediments/hurdles to implementing OPD widely exist. These include:

- Business needs/impacts—switching all freight deliveries to an off-peak time would be nearly impossible due to the business need for delivery of freight items and work products during the regular course of daily work while most of the workforce is present.

- Time-of-day restrictions—evening and nighttime business might also face several hurdles in implementing this scheme. An example would be a bar or restaurant that has normal evening/night hours and high traffic during typical off-peak hours, which would conflict with freight deliveries during high business hours. Also, many commercial districts in urban areas have nighttime noise restrictions that might limit loading and unloading activities during night or early morning hours. Isolated or specialized land-use areas such as separate retail zones might not face such constraints.
- Parking availability/loading zone conflicts—on-street truck parking, unloading, and associated activity near traffic zones during later delivery hours might disrupt business disproportionally compared to the current typical daytime delivery hours. Additionally, daytime loading zone use might also be problematic during these times because the loading zone might be taken up by customers rather than available for use.
- Service and fuel availability—off-peak transit times by long-haul trucks on major thoroughfares through an urban area might be improved during night hours due to traffic speed increases, but truck services and potential drop-off locations are more limited at this time of night, thereby reducing parcel delivery and less than load[19] applicability.
- Additional physical infrastructure and labor costs of implementation—many stores have neither personnel available nor a secure area that can be accessed by delivery crews to make off-peak deliveries. Building a special secure locker or storage area or allowing crews access to part of the existing store by giving them keys both require costs to either construct new facilities or add security features and potentially may increase insurance costs. If personnel are required to be on site, potential overtime/outside normal working hours wage rates might also become a cost issue.

Who Decides/Responsibility for Implementation

As previously stated, OPD programs to date have been primarily implemented at the local/regional level by partnerships between the public and private sectors. In most cases, a city government or MPO-type agency will work with local freight-based or retail business to implement such a program. Typically, a state DOT-level agency would not directly implement such a program but might work with a more local agency to do so, especially during a special event (e.g., hosting of Olympic Games, Super Bowl) or during a major construction project to relieve congestion impacts during peak traffic times.

Incentivized Off-Peak Managed Lanes

What It Is/Where Applicable

This strategy incentivizes trucks through reducing or waiving tolls to utilize existing managed lanes during off-peak periods. Increasing truck utilization of managed lanes during off-peak

[19] Less than load is the transportation of relatively small parcel packages of less than 150 lb.

periods has the potential to lower overall freight operational costs, improve traffic operations on the GP lanes, and facilitate the use of otherwise underutilized roadway capacity. This practice could be effective in providing access routes/corridors to major freight terminals and generators.

Policy Considerations/Implications

The purpose of this strategy is to facilitate more efficient operations for trucks on existing managed lanes and for those on the GP lanes. This practice could be focused on corridors in which major freight generators exist or could be applied wide-scale across the managed lane system throughout the urban area. Utilizing the existing system of managed lanes may allow for implementation without considerable construction of added capacity. One of the major considerations is the toll rate paid by trucks in the managed lanes during the off-peak period. Whether the rate would be waived or reduced could dramatically impact utilization and realization of benefits to truck and GP lane users.

Impediments/Hurdles

Each considered managed lane facility will need to be evaluated to ensure the geometry accommodates expected truck configurations. At minimum, there may be a need to retrofit some access points to allow for safer truck maneuverability. Additionally, there may be increased costs associated with increased maintenance required for pavement, concrete traffic barriers, arresting barriers (if present), and more. There may be a need to incentivize shippers and trucking companies to shift their operations to move freight during the off-peak periods. If the tolls are reduced or waived to encourage truck use, then there could be a loss of revenue compared to light use by autos during off-peak periods. Clear messages are required to indicate the periods in which trucks can exclusively use the managed lanes and to which segments this practice applies.

Who Decides/Responsibility for Implementation

Implementing the strategy that allows trucks to use managed lanes during off-peak periods requires agreement and coordination between all owners and operators of managed lanes within the area. Determination to move forward with this strategy is largely impacted by whether this strategy is applied to a single corridor or throughout the managed lane system in the urban area.

ITS/ATM Related Strategies

ATIS

What It Is/Where Applicable

As described previously, ATIS is a system that acquires and presents information to assist travelers in moving from respective starting location to their destination. ATIS may operate through information supplied entirely within the vehicle (i.e., broadcast real-time information), or it can be supplied by outside agencies through TMCs (via DMS) and include locations of incidents and possible diversion routes or speed advisories, road conditions, and work zones/lane restrictions. For the purposes of this project, seeking to move freight more efficiently through urban areas, ATIS is seen as a potential route diversion/decision-making aid for either individual truck drivers or truck dispatching centers to allow them to make choices on their best route through an urban area. Passing on information of accident locations and other road constraints, such as work zone capacity reductions, early enough and/or the use of historical transit time data could allow freight to move more efficiently through the urban area. Such information is applicable not only for major trucking roadway approaches to urban areas but also for routing once within the urban core to connecting roadways and/or to terminal locations.

Policy Considerations/Implications

The usefulness of developing a policy supporting ATIS is not limited to trucking/freight movement alone; these types of systems can benefit all drivers. For trucking, however, the need for roadway operational and/or blockage information is vital to trucking companies and truck drivers because strict HOS safety rules limit truck driver operational time, and the need for potential identification of available truck overnight parking is needed prior to entering an urban area. Otherwise, trucks might be required to pull over and remain stranded until a relief driver can take over the operation of the vehicle to move it to a safer/proper service or parking location.

Impediments/Hurdles

Providing ATIS systems on the major freeway approaches that advise of time delays due to accidents or work zone activity and giving estimated transit times to major connecting roadways should be relatively simple to implement in major cities where robust DMS systems and traffic monitoring centers are in place. In urban areas without these systems, development of a way to broadcast this information in real time over radio or via GPS-based services would be needed. Accident information/incident management progress would also need to be communicated in real time or near real time to facilitate proper decision making. Once methods for transmitting the information are determined, a final hurdle would be ensuring that trucks are equipped to receive and interpret the broadcasts and that drivers/dispatchers know how to use and process the information provided. Since ATIS or ATIS-type systems are generally in place for all drivers, state and local planners may have to instead make decisions on specialized information needs for freight vehicle drivers/freight companies in regions where a high amount of freight traffic exists. Costs in equipment and personnel time to provide this additional information would need to be determined.

Who Decides/Responsibility for Implementation

Use of ATIS and distribution of information would be a strategy that would require DOT and local transportation planning agency cooperation. The state DOT would be highly involved because most major roadway approaches to urban areas are roads operated and maintained by the DOT or its contractors. Passing information from the DOT to local transportation management centers and then on to the public requires constant monitoring and updating of DMS and/or other information channels. Responsibility would be shared between state and local transportation agencies.

Freight Signal Priority

What It Is/Where Applicable

FSP is an ITS treatment in which traffic signals monitor and identify freight vehicles/trucks approaching a traffic signal and extend the green signal cycle to allow the freight vehicle to travel the intersection without having to stop. Adoption of this policy can have several potential environmental and traffic flow benefits. FSP is not widely used at the present time, but it is similar to transit signal priority systems that are more widespread and allow similar priority treatment at intersections for transit vehicles. FSP would most likely be applicable in corridors serving freight generators, such as seaports, inland port areas, or manufacturing regions.

Policy Considerations/Implications

By not having to stop and then accelerate once again after the signal changes, trucks use less fuel and produce fewer emissions. Both are highly desirable policy outcomes and can add up to large impacts if the number of trucks is high enough. In addition, truck flow/movement along the FSP-equipped corridor can improve dramatically if implemented over a long-enough route, and other vehicle types will likely also face less impedance from truck acceleration/deceleration in response to signal changes. While the flow of trucks and traffic may improve along the main corridor, crossing traffic on roadways along that corridor may face additional delay when green cycles are extended for trucks. Depending on the number of roadways impacted and the volume and type of vehicles delayed, this could theoretically diminish or outweigh the truck flow benefits along an FSP-equipped corridor.

Impediments/Hurdles

As with most ITS-based strategies, cost is an issue in implementing FSP in heavy truck corridors. Most of this cost is associated with sensing truck locations/speeds in the corridor and transmitting this information to the signaling system to calculate when and for how long to extend the green cycle. Various methods (e.g., roadside or V2I) exist for collecting and transmitting this signal, but all have additional costs associated with them. Existing signal control boxes along the corridor would also have to be adjusted/programmed to take this new input and then use other existing or new traffic sensors to adjust cross-traffic movements.

Who Decides/Responsibility for Implementation

Setting an FSP policy would generally be made at the local/regional level by transportation planners seeking to alleviate truck delay, truck-induced delay to other vehicles, or truck-related environmental impacts near a major freight generator. In addition to MPOs or other local transportation planning agencies, the freight-generating facility might have an interest in increasing truck movement speeds—especially if it is a public or quasi-public agency, such as a seaport. Moving goods more expeditiously along a defined, FSP-enabled corridor could also have an economic benefit that might lead to implementation support from local business or industry interests. The state DOT role in implementing FSP would generally be complementary to local efforts; however, that role might increase should the corridor happen to be planned for a state/U.S. highway or Farm to Market/Ranch to Market-designated roadway.

FINDINGS AND RECOMMENDATIONS

The purpose of TxDOT Project 0-6851, Strategies for Managing Freight Traffic through Urban Areas, was to examine the potential of implementing several proven strategies for managing freight movement in specific urban areas using advanced transportation modeling tools and other evaluation methods as described in this final report. To that end, this report provides transportation planners and traffic operations professionals with an organized list of state-of-the art approaches to managing freight traffic on urban freeways, including novel techniques focused on Texas urban area needs. The findings can help guide the deployment of various freight management strategies and provide guidance on policies concerning freight traffic movement through Texas' urban areas.

FINDINGS

Researchers identified plausible freight management strategies and their effectiveness by examining each strategy for deployment feasibility, legislative and policy requirements, technology maturity and market penetration needs, and design and operational requirements. Researchers short-listed the freight management strategies that are feasible and can be readily implemented in Texas.

Strategies that are most effective based on the combined ranking of selected criteria and the TFMP goal applicability are:

- Dedicated truck lanes.
- Truck route designations.
- Off-peak use of HOT/HOV lanes.
- Reliable truck route information.
- Advanced traveler information.

Researchers selected feasible and implementable strategies from the short-listed freight management strategies to model on specific corridors in different urban areas. Researchers used a combination of MRM, DTA, microscopic, and/or sketch planning tools to assess the impact of the strategies, as shown in Table 36.

Table 36. Freight Management Strategy Modeling Results.

City/ Region	Freight Management Strategy	Facility/Area	Major Findings
Houston	ATIS	I-45 SB, just north of I-610	• 23–38% travel time savings in case of incident
	Off-peak use of HOT lanes	I-10 Katy Freeway HOV/HOT lanes	• significant increase in truck volumes • 5–8% travel time savings in GP lanes
	Freight bypass designation	SH 99	• increase in truck volumes • 1–2% travel time savings for SOV and trucks, respectively • 2–8% stop time savings for SOV and trucks, respectively
	Converting at-grade rail/highway crossing to a grade separation	E. Barbour's Cut Blvd. in Morgan's Point	• 96% decrease in avg. delay per vehicle • 33% decrease in number of stops • 75% decrease in total travel time
El Paso	Conversion of underused toll lanes into dedicated truck lanes	César Chávez Border Highway	• 15–33% travel time savings in dedicated truck lanes • 10% travel time increase in GP lanes • 37–68% increased TTR in dedicated truck lanes
	ATIS with incident	I-10 near Executive Center Boulevard	• 12–63% travel time savings on incident route • 37–71% travel time savings on one of the non-mandatory (optional) detour
Austin	ATIS with incident (varying number of lanes blocked) and no tolls for truck diversion to SH 130	I-35 NB, where the upper and lower decks diverge (MM 334)	• Diverted trucks had 18 minutes travel time savings despite increasing distance by 12 miles • 224, 303, and 399 vehicle-hours saved for one lane, two lanes, and three lanes blocked, respectively
	FSP	Burnet Rd. NB, from 183 to Gault Ln.	• no travel time improvement mainly because NB approaches already used their maximum splits during peak periods, thus the minimum green extension had little to no impact on the overall throughput
DFW	ATIS	I-30 near President George Bush Turnpike	• Diverted trucks had 14 minutes travel time savings despite increasing distance by 12.3 miles in case of incident
	Off-peak use of HOT lanes	I-635 LBJ Expressway TEXpress Lanes	• 4–5% travel time savings in GP lanes • 1–2% increase travel time in TEXpress lanes but maintained 50 mph minimum
	Smart parking near freight-related facilities	I-20, between I-35E and I-45	• Assuming TPIMS could reduce parking time by 15 min. per truck then 10% of daily trucks, or 1435/day, would result in 359 hours (truck) travel time saved per day

Strategies to manage freight in urban areas can be analyzed in several different ways, including by the locations where they are most applicable and how they are deployed, what tools are needed to make sound judgment on various strategies and alternatives, and the policy implications for those strategies. Thus, guidelines for state-of-the-art modeling techniques, selection and deployment, and policies related to freight management strategies in urban areas were developed.

The modeling guidelines highlight the most applicable tools and techniques needed when managing urban freight movement. They can help TxDOT understand the analytics behind the modeling approach of various defined scenarios and the type of model resolution most applicable (macro, meso, micro, or multiresolution [combination of macro/meso/micro]). Table 37 summarizes the preferred modeling tools by each freight management strategy.

Table 37. Freight Management Strategy Preferred Modeling Tool.

Freight Management Strategy	Preferred Modeling Tool
Lane- and Route-Based Strategies	
Dedicated Truck Lanes	Meso, Micro
Designated Truck Route	Macro, Meso
Truck Route Diversion	Macro, Meso
Grade Separation	Micro
Time-of-Day-Based Strategies	
Off-Peak Use of Managed Lane	Meso
Change in Departure Time	MRM
ITS/ATM Related Strategies	
ATIS	Meso
FSP	MRM
Land-use Practices and Policies Promoting/Facilitating Freight Movement	
Smart Parking	MRM

A set of guidelines that can assist TxDOT in selecting and deploying freight management strategies was developed. They are based on findings of previous studies and results obtained from the modeling activities. Draft implementation guidelines were developed for three types of freight management strategies.

- Lane- and Route-Based Strategies:
  - Dedicated truck lanes may be used to improve safety and mobility at locations where physical segregation of truck traffic from passenger cars is feasible. The primary purpose is to reduce car-truck interactions on freeways where a high volume of trucks can make passing and weaving maneuvers difficult and dangerous. Therefore,

implementation of this strategy is likely to be the most beneficial on freight corridors where the number of crashes involving trucks is unusually high. The concept has been mostly applied as lane restrictions on urban freeways where trucks are restricted to use certain lanes only at any time or during congested periods during the day. Dedicated truck-only lanes typically require either the construction of a new traffic lane or the conversion of an existing GP to a truck-only lane. Preliminary evaluation and inspection of the existing roadway geometry of the surrounding area is necessary to determine the feasibility of implementation. If geometric conditions and constraints do not prevent the use of dedicated truck-only lanes on a selected freeway segment, additional criteria, such as those used by Caltrans, can be applied to determine if the expected benefits warrants its implementation.

  - TOT lanes are used to segregate trucks from the mixed traffic flow where a tolling rate schedule is implemented for trucks using the facility. This strategy has been considered in several urban areas to aid truck traffic flow from major traffic generators. TOT lanes have potential implementation design issues/considerations, such as number of TOT lanes by direction, lane placement, barrier separation, access points, and truck parking areas (if needed). The potential implementation issues include tolling strategies, optimal system-level toll pricing that does not discourage use and unintentionally shift truck traffic to non-tolled facilities, speed limit, and voluntary or mandatory use of TOT lanes.
  - Truck route designation designating certain roadways as truck routes is the most commonly implemented strategy employed by cities to manage freight traffic more efficiently while minimizing its negative impacts to residents. However, identifying candidate routes with appropriate road geometries and infrastructure elements, such as the ones listed in Table 36, is critical before implementing truck route designations. Truck routes should be clearly mapped and identified with road signs, and cities should consider adjusting signal timing along arterials designated as truck routes to improve the overall flow of truck traffic.
- Time-of-Day-Based Strategies:
  - OPD is a relatively simple and effective freight management strategy, but its implementation can be challenging. It needs to balance the benefits and costs between carriers, receivers, shippers, customers, and the community for it to be effective. OPD can save time and money for carriers but can negatively affect receiving businesses by requiring additional staff on hand to accept deliveries, requiring the alteration of employee shifts, increasing the cost of labor, and in some cases increasing heating and lighting costs and/or requiring additional security.
  - Off-Peak Use of Managed Lanes seeks to leverage existing managed lanes by incentivizing (e.g., waived or reduced tolls) truckers to use them during off-peak periods. This strategy can be effective in reducing travel time and improving TTR to ports and other urban freight generators. Although this strategy could yield significant

benefits if deployed system-wide, potential issues should be considered, such as increased maintenance of managed lane, retrofit of some access points to allow for safer truck maneuverability, installing/upgrading vehicle classification detection at access points that can detect vehicle length/axles, political opposition, and possible legislative changes required (such as for HOV lanes).

- ITS/ATM-Related Strategies:
  - ATIS seeks to improve FRATIS directly to the freight industry by integrating regional ITS data, DOT commercial fleet data, third-party truck-specific movement data, and intermodal terminal data to disseminate toward various FRATIS applications. The FRATIS Impact Assessment report shows the estimated fuel savings, CO_2 reductions, and total drayage cost reductions for reducing the time within a terminal, reducing the time in a queue outside the terminal, and reduction in idling (see Table 37). The lessons learned from the FRATIS Impact Assessment report include:
    - Optimization requires major changes in dispatching policy that must be advantageous to drivers and dispatchers to succeed.
    - For optimization to be successful, the optimization software needs to be run frequently and have both the inputs and outputs integrated with the drayage company’s dispatch system; otherwise, optimization will not be used consistently.
    - Effort needs to be expended at the very beginning of a pilot project to assure alignment between stakeholder needs and sponsoring agency objectives. This should concentrate resources on problems that best address user requirements.
    - Pilot users are extremely busy with current operations, so developers need to have enough resources to be able to assist the users. Financial incentives to users may be appropriate.
    - Care is needed in selecting stakeholders to represent all of the interests in a pilot project and to assist with project coordination and cooperation of pilot users.
    - Wider implementation of queue measurement devices and a consistent method of providing the information to any and all potential users will benefit operations at multiple terminals in a region.
    - Proponents of advanced technology pilots should concentrate development efforts on technologies that do not exist in the commercial marketplace.
  - FSP seeks to provide preferential treatment for freight vehicles within high freight generator areas, such as near ports or railyards. This process reduces stops and delays at signalized intersections by extending the green signal when a truck is approaching the intersection. This practice can increase TTR, enhance safety at intersections, and reduce acceleration and deceleration emissions for trucks. Planning and operational issues that should be considered include corridors with a high percentage of truck traffic, cross-street traffic volumes, land uses such as industrial parks and/or

intermodal facilities, capacity analysis and possibly microsimulation to see potential operational impacts, and areas with air quality issues, such as non-attainment areas.

- Land-Use Strategies:
  - Smart Parking—a recent Minnesota study highlighted the following trucker parking preferences:
    - 60 percent of drivers ranked onboard computers as the most preferred method for receiving truck parking availability information, followed by roadside DMSs, a smartphone application, and a website.
    - Almost 45 percent of the truck drivers preferred receiving advance notification 20 miles ahead of the rest stop.
    - Almost 38 percent of drivers would prefer a message that displayed the exact number of spaces available, while 50 percent indicated they would prefer either a categorical message, such as low availability, or the exact number of spaces available.

Another study in California discussed the key components, such as SPI, CDS, PAEFA, PGTRS, RCS, IDS, and SOCC, that should be considered when developing a smart truck parking system.

The final set of guidelines can assist TxDOT as they relate to policy implications. More specifically, it addresses the key questions/considerations relative to the strategies above, as shown in Table 38.

Table 38. Freight Management Strategy Policy Guidance.

Freight Management Strategy	Applicability/ Implementation	Policy Considerations/ Implications	Impediments/Hurdles	Responsibility for Implementation
Dedicated Truck Lanes	• Along major freight corridors, congested corridors, and roadways serving major freight facilities, such as port facilities	• If converting an existing lane of traffic, the remaining roadway lanes should sufficiently accommodate the passenger vehicles without negative operational impacts • Should include a plan to counter the negative effects of heavy freight vehicles on the roadway pavement	• Significant initial investment and maintenance costs • Significant public and private stakeholders involvement • Agreement by private truck operators, shippers, and industry leaders • Public support may depend on the perceived impacts	• Cooperation between the DOT and local MPO, and in specific instances, local agencies
Truck-Only Toll Lanes	• Corridors serving major freight facilities • Locations where truck traffic is sensitive to travel time and reliability	• Use of the facility could be mandatory (e.g., freight-specific facility such as a seaport), or voluntary • Managed TOT lanes could vary facility pricing to maintain system operations • Determine optimal system-level toll pricing that does not discourage use	• Support from trucking industry is a major challenge • Will likely require significant initial and continued investments • Location (and toll) must be able to attract enough users to meet financial obligations • Heavy involvement by public and private stakeholders	• Cooperation among the DOT and local MPO and regional tolling authority
Designated Truck Routes	• Restricting truck traffic to designated roadways, usually to avoid residential areas or entering congested urban core roadways	• Direct trucks over roadways designed to accommodate their specific operational characteristics and to bypass sensitive areas or highly congested roadways • Restrictions could be in place 24/7 or by time of day, such as peak periods of the day	• Routes must not restrict truckers' ability to serve their customers • Routes will likely increase the miles traveled and operational costs associated with truck operations • Planning organizations will need to manage commercial land use to maintain truck flow patterns along those designated roadways	• Most designated truck routes are performed at local levels • Bigger regional truck routes around heavily congested urban cores will need to involve the DOT and MPO

Freight Management Strategy	Applicability/ Implementation	Policy Considerations/ Implications	Impediments/Hurdles	Responsibility for Implementation
		• Pavement design and maintenance considerations • Extensive stakeholder involvement is required (e.g., designating a bypass loop with toll facilities will require planning and cooperation between the regional transportation planning entities)	• Changes over time in the pattern of truck movements may require adjustments to the designated truck routes	
Incentivized OPD	• OPD is usually applicable at the regional or subregional levels for describing policies for local delivery and last mile drop offs to businesses; however, similar practices by truckload/long-haul trucking companies to time travel through major urban areas have also been employed	• Costs are generally borne by the participants in the private-sector businesses and trucking companies taking part • In some cases, local zoning ordinances must be addressed to allow for delivery during hours when residents might be asleep or business traffic levels are high	• Switching all freight deliveries to an off-peak time would be nearly impossible due to the business need for delivery of freight items and work products during the regular course of daily work • Evening and nighttime business might face several hurdles • On-street truck parking, unloading, and associated activity near traffic zones during later delivery hours might disrupt business disproportionally compared to the current typical daytime delivery hours • service and fuel availability; off-peak transit times by long-haul trucks might be improved during night hours but truck services and potential drop-off locations are more limited • additional physical infrastructure and labor costs of implementation	• City government or MPO-type agency would mostly work with local freight-based or retail business to implement such a program

Freight Management Strategy	Applicability/ Implementation	Policy Considerations/ Implications	Impediments/Hurdles	Responsibility for Implementation
Incentivized Off-Peak Managed Lanes	• Using existing managed lanes during off-peak periods could be effective in providing access routes/corridors to major freight terminals and generators	• Focus on corridors in which major freight generators exist or apply across the entire managed lane system • Whether the toll rate would be waived or reduced could dramatically impact utilization and realization of benefits	• Managed lane facility will need to be evaluated to ensure the geometry accommodates expected truck configurations • May need to retrofit some access points to allow for safer truck maneuverability • Increased operating and maintenance costs associated with pavement, concrete traffic barriers, arresting barriers, etc. • Loss of revenue compared to light use by autos during off-peak periods if tolls are reduced or waived • Dissemination of clear information is required to indicate the time periods, tolls, and which segments can be used	• Agreement and coordination between all owners and operators of managed lanes within the area (e.g., Central Texas Regional Mobility Authority)
ATIS	• May operate through information supplied entirely within the vehicle or can be supplied by outside agencies through TMCs	• The need for roadway operational and/or blockage information is vital to trucking companies and truck driver because strict HOS safety rules limit truck driver operational time and the need for potential identification of available truck overnight parking is needed prior to entering an urban area	• In urban areas without DMS and TMCs, development of a way to broadcast this information in real time over radio or via GPS-based services would be needed • Accident information/incident management progress needs to be communicated in real time or near real time to facilitate proper decision making • Ensure trucks are equipped to receive and interpret the broadcasts and that	• DOT, MPO, and local transportation planning agency cooperation. Responsibility would be shared between state and local transportation agencies

Freight Management Strategy	Applicability/ Implementation	Policy Considerations/ Implications	Impediments/Hurdles	Responsibility for Implementation
			drivers/dispatchers know how to use and process the information • State and local planners may have to decide on specialized information needs for freight vehicle drivers/freight companies • Costs in equipment and personnel time to provide this additional information would need to be determined	
FSP	• Applicable in corridors serving freight generators such as seaports, inland port areas, or manufacturing regions	• Can have several potential environmental and traffic flow benefits, especially if the number of trucks is high enough and/or if implemented over a long-enough route • Cross-street traffic may face additional delay	• Implementation costs (sensors, communication, etc.) • Reprogramming of existing signal control boxes to take this new input and then using other existing or new traffic sensors to adjust cross-traffic movements	• Generally at the local/regional level by transportation planners/engineers • The state DOT role would be complementary to local efforts; however, that role might increase if it was on a state/U.S. highway

RECOMMENDATIONS

Based on the overall findings in the study, TxDOT now has a general framework to examine and consider various freight management strategies that can be employed in most Texas urban areas. TTI recommends leveraging these findings to guide the implementation of specific strategies or ITS technologies as well as to revise or develop freight-traffic-related policies.

Although the modeling frameworks and techniques developed during this project should enhance TxDOT's analytical capabilities for managing urban freight traffic, future research could be done to refine the techniques/results to include specific corridors (subarea analysis), sensitivity tests, or a combination of strategies. This research could provide insights to other possible outcomes that were not explored in this project.

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APPENDIX A: DETAILS OF POST-PROCESSING SPEED DATA

CALCULATING DATA

After post-processing and exporting directional files to Excel, researchers sorted the data on a pivot table so that the newly created JOIN field was on the left side of the pivot table and the hour field was on top. The hour field consisted of numbers from 20 to 83, representing 15-minute time intervals between 5:00 a.m. and 9:00 p.m. The columns were filled with "allspd" (the average speed of all vehicles in that 15-minute period) and "trkspd" (the average speed of all trucks in that 15-minute period). New columns were then created to show the difference in speed throughout the day: "K_allspd" and "K_trkspd." A speed change field was created to show how much the traffic speed had changed throughout the day. The change in speed was calculated by taking the current average speed and subtracting the speed from 5:00 a.m. In the absence of free-flow speed data, the speed at 5:00 a.m. was assumed to be the free-flow speed.

CREATING MAP AND COLOR CODE

Once the data were rearranged and the differences in speeds were calculated, the new speed data files—North, South, East, and West—were imported back into GIS. The RHiNo file was then separated into four files—North, South, East, and West—and joined with the corresponding speed data files. After the RHiNo and speed data sets were joined, the data were split into different layers representing hourly data points from 5:00 a.m. to 8:00 p.m.

The Dallas data set was created the same way except for the hourly speed color coding. Orange segments represent traffic that has slowed more than 30 mph in Houston and Austin. For Dallas, orange represents a slowdown of more than 10 mph. Dallas is on a different scale due to lower measured levels of congestion. Yellow represents traffic that has slowed more than 50 mph in Houston and Austin and 30 mph in Dallas. The color code is meant to be an accurate representation of where traffic is having the most trouble getting through the city. The color code gives the map user the ability to locate and visualize congested segments in the region throughout the day.

ADDITIONAL INFORMATION TO CONSIDER

The speed congestion shown on the maps is a representation of the data provided in the city speed file. Some of the speeds in the files were over 100 mph for the average speed. This anomaly brings into question the accuracy of the data at particular parts of the map. Overall, the data appear to be an accurate representation of the traffic patterns. However, the user's discretion is required at all times when analyzing data points to determine if the data are valid.

HOW TO USE SPEED AND VOLUME DATA MAPS

The regional speed and volume maps are set up as a tool for the calibration and validation of the regional DTA models. The maps are meant to convey as much information as possible while still remaining simple enough to read. The first layer in the map is the base map, and the reference for the data is placed on top of it. The data are represented by colored dots and lines. The lines represent the INRIX speed data.

APPENDIX B: CAVEATS WITH DETECTOR DATA IN HOUSTON

For the City of Houston, TTI researchers identified the current radar locations where manual main lane classification counts were performed for 8-hours to update the truck lane restriction effort in 2012-2013. However, there are multiple caveats with this dataset related to detector reliability, including:

- The sensors' reliability in terms of proper communication is not known. Information about whether all the lanes for each direction are covered is not available.
- Any data provided by sensor may not be comparable to actual field conditions if the sensor was not properly installed, tested with actual counts, and/or adjusted as required.
- Some sensors (especially those along US 290) have been impacted by roadway construction and may not have been adjusted to reflect temporary relocation of traffic lanes as required by the construction sequencing.
- The sensors on the I-10 Katy Freeway on the west side of town also have data for the managed HOV lanes and the freeway main lanes.