Methods To Improve Freight Highway Performance, Reliability, and Bottlenecks

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16. Abstract

Helping freight move efficiently through reduced congestion and bottlenecks along with safety is a key factor in supporting supply chains. This report focuses on freight mobility by looking at the State Department of Transportation (DOT) and metropolitan planning organization (MPO) freight performance measurement, bottleneck reporting, and freight improvement strategies to improve freight mobility and reliability. State DOTs and MPOs have been implementing transportation performance management, including measuring truck travel time reliability (TTTR) and freight truck bottlenecks. Most State DOTs and MPOs use other freight mobility performance measures in addition to the TTTR measure to assess freight mobility and reliability. The most common measures are analyses of delay, including hours of delay and delay per mile, the planning time index (PTI) and travel time index (TTI), a level of service (LOS), or volume-to-capacity ratio, and average truck speed. Also, the National Performance Management Research Data Set (NPMRDS) is the primary data source used by the State DOTs and MPOs for mobility analysis. A Toolbox of Solutions is provided in this document to help States DOTs and MPOs improve freight mobility, reliability, and bottlenecks.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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LIST OF ABBREVIATIONS

AADT	annual average daily traffic
AAM	active arterial management
AASHTO	American Association of State Highway and Transportation Officials
ADS	automated driving systems
AMHP	America's Marine Highway Program
API	application programming interface
ARDOT	Arkansas Department of Transportation
ARP	Appalachian Regional Port
ATDM	active traffic and demand management
ATM	active traffic management
ATRI	American Transport Research Institute
ATSPM	automated traffic signal performance measures
AV	automated vehicle
BSM	basic safety messages
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CATT	Center for Advanced Transportation Technology
CAV	connected and automated vehicles
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CHART	Coordinated Highways Action Response Team
CMM	capability maturity model
CMP	congestion management process
COG	councils of government
COMPAT	Congestion Management Process Assessment Tool
CV	connected vehicle
CVISN	commercial vehicle information systems and networks
DDOT	District Department of Transportation
DMS	dynamic message signs
DOT	department of transportation
DPCS	dynamic parking capacity signs
DSRC	dedicated short range communications
DSWS	downhill speed warning system
EB	eastbound
EDC	Every Day Counts
ELD	electronic logging device
FAC	Freight Advisory Committee
FAF	Freight Analysis Framework
FCV	freight congestion value
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMT	Freight Mobility Trends
FRATIS	Freight Advanced Traveler Information Systems
GDOT	Georgia Department of Transportation

GHG	greenhouse gas
GIS	geographic information systems
GPA	Georgia Port Authority
GPS	Global Positioning System
HAR	highway advisory radio
HOS	hours of service
HOT	high-occupancy toll
HPMS	Highway Performance Monitoring System
HUT	highway use tax
IBC	international border crossing
ICM	integrated corridor management
IDOT	Illinois Department of Transportation
IFTA	International Fuel Tax Agreement
ILD	inductive-loop detector
IRP	International Registration Plan
ITS	intelligent transportation system
ITTS	Institution for Trade and Transportation Studies
I2V	infrastructure-to-vehicle
KDOT	Kansas Department of Transportation
LaDOTD	Louisiana Department of Transportation and Development
LED	light-emitting diode
LiDAR	Light detection and ranging
LIRC	Louisville and Indiana Railroad
LOS	level of service
LPR	license plate recognition
MAASTO	Mid America Association of State Transportation Officials
MAP-21	Moving Ahead for Progress in the 21st Century Act
MARAD	Maritime Administration
MDOT	Maryland Department of Transportation
MDOT SHA	Maryland Department of Transportation State Highway Administration
MDSS	Maintenance Decision Support System
MIT	Major Incident Tow
MNDOT	Minnesota Department of Transportation
MoDOT	Missouri Department of Transportation
MPO	metropolitan planning organization
MRPT	Maryland Roadway Performance Tool
NCDOT	North Carolina Department of Transportation
NHS	National Highway System
NITTEC	Niagara Transportation Technology Coalition
NJDOT	New Jersey Department of Transportation
NJTPA	New Jersey Transportation Planning Authority
NPMRDS	National Performance Management Research Data Set
NS	Norfolk Southern
NYCDOT	New York City Department of Transportation
NYSDOT	New York State Department of Transportation
OBU	onboard unit
ODOT	Oregon Department of Transportation
OEM	original equipment manufacturers

OHD	off-hour delivery
OME	Otay Mesa East
OSCAR	One-Stop Credentialing and Registration
PeMS	performance measurement system
PNWR	Portland and Western Railroad
POE	port of entry
PSA	Port Statistical Area
PTI	planning time index
P3	public-private partnerships
RISC	rapid incident scene clearance
RITIS	Regional Integrated Transportation Information System
RFID	radio frequency identification
RMT	Richmond Marine Terminal
RSU	roadside units
RV	recreational vehicle
RWIS	road weather information systems
RWMP	Road Weather Management Program
SBCTA	San Bernardino County Transportation Authority
SCPA	South Carolina Ports Authority
SDDOT	South Dakota Department of Transportation
SFAC	State Freight Advisory Committee
SHRP2	Strategic Highway Research Program 2
SIS	Statewide Intermodal System
SOC	Statewide Operations Center
SRI	Smart Roadside Initiative
STAMP	Statewide Arterial Management Program
SWZ	Smarter Work Zones
TAMS	Truck Activity Monitoring System
TAP	Taxpayer Access Point
TCAT	Truck Congestion Assessment Tool
TCFC	Texas Connected Freight Corridors
TEA-21	Transportation Equity Act for the 21st Century
TETC	The Eastern Transportation Coalition
TEUS	twenty-foot equivalent container units
THEA	Tampa Hillsborough Expressway Authority
TIM	traffic incident management
TMC	transportation management center
TNC	transportation network company
TOC	Traffic Operation Center
TPAS	Truck Parking Availability System
TPIMS	Truck Parking Information System
TROWS	Truck Rollover Warning System
TRB	Transportation Research Board
TRS	Truck Reservation System
TTI	travel time index
TTTR	Truck Travel Time Reliability
TSMO	transportation systems management and operations
TxDOT	Texas Department of Transportation

UDOT	Utah Department of Transportation
USACE	United States Army Corp of Engineers
USDOT	United States Department of Transportation
VIP	Virginia Inland Port
VMS	variable message signs
VSL	variable speed limits
VSS	variable speed signs
V/C	volume-to-capacity
V2I	vehicle-to-infrastructure
V2V	vehicle-to-vehicle
WIM	weigh-in-motion
WRTM	weather-responsive traffic management
WSDOT	Washington State Department of Transportation
WSP	Washington State Patrol
WYDOT	Wyoming Department of Transportation
WZDx	Work Zone Data Exchange

EXECUTIVE SUMMARY

The United States' economic vitality and quality of life rely on the safe and efficient movement of goods. Transportation is a vital component of business supply chains as it is the function that moves goods from ports to distribution centers, farm to store, mine to the factory, and factory to retail consumer.

Supply chains depend on high-functioning transportation, production, and sourcing of materials. When freight movement is compromised by delay due to congestion, there are economic impacts. Delay can result in more time and fuel, as well as a negative ripple effect of impacts on supply chains.[1]

The Freight Analysis Framework (FAF) estimates that freight tonnage moved by all modes will increase approximately 37 percent between 2018 and 2045.[2] The increased freight demand will likely place further stress on the Nation's transportation network. With freight expected to grow at approximately 1.2 percent a year through 2045, it is important to focus on freight mobility and how to improve efficiency.[3]

The freight system continues to experience growth in demand as the economy recovers from the conditions in 2020 global COVID-19 pandemic and adjusts to new demands. In 2021, a Supply Chain Disruptions Task Force was established to identify freight supply and demand mismatches and diagnose surface transportation problems, as well as to alleviate bottlenecks and other constraints.[4] Helping freight move efficiently through reduced congestion, enhanced reliability, and improved bottlenecks, along with safety, is a key factor in supporting supply chains and improving freight transportation performance.

PROJECT OBJECTIVES

The purpose of this research was to focus on freight mobility by looking at the State department of transportation (DOT) and metropolitan planning organization (MPO) freight performance measurement, bottleneck reporting, and freight improvement strategies to improve freight mobility and reliability. State DOTs and MPOs have been implementing transportation performance management, including measuring truck travel time reliability (TTTR) and freight truck bottlenecks.[5] This project included an assessment of how States are using the TTTR performance measure, how States are considering freight bottlenecks, and what strategies are used to improve freight mobility. This included:

- The role that TTTR measures and freight bottlenecks have in State DOT and MPO decisionmaking
- Innovative approaches that DOTs and MPOs are using to improve TTTR and improve the performance of freight bottlenecks
- Tools and resources to improve TTTR and the performance of freight bottlenecks using solutions such as transportation systems management and operations (TSMO), capacity projects, and congestion management process (CMP)

Ultimately, the goal of this research is to demonstrate to State DOTs and MPOs how to go beyond merely reporting TTTR and freight bottlenecks and use this information to implement strategies to improve freight performance. A key outcome of this research are strategies for improving freight reliability and delay at freight bottlenecks in the form of a Toolbox of Solutions. States and MPOs can use the Toolbox of Solutions to address freight mobility problems, using strategies encompassing:

- TSMO options
- Freight-related capacity improvements
- Technologies that monitor freight vehicles and integrate data
- Performance-based planning and measurement processes
- Congestion management processes

FINDINGS

This research collected freight performance information from State DOT baseline and 2-year performance reports, State-submitted freight bottleneck reports, and inputs collected from peer exchange workshops. Key findings include:

Freight Performance Measurement

- The majority of States used other freight mobility performance measures in addition to the TTTR measure to assess freight mobility and reliability.
- The most common measures are analyses of delay, including hours of delay and delay per mile, the planning time index (PTI) and travel time index (TTI), a level of service (LOS), or volume-to-capacity ratio, and average truck speed.
- The majority of States identified the National Performance Management Research Data Set (NPMRDS) as the primary data source.
    - Sixteen States also incorporated additional raw data directly from a third-party data provider.
    - Some States used data platforms to access NPMRDS and third-party speed/travel time data to calculate the TTTR measure.
- Many States identified challenges with the current TTTR measure methodology and the NPMRDS dataset, including data accuracy and accessibility.
- Approximately 30 State DOTs described noteworthy practices for meeting TTTR targets in their performance reports. These include general improvement projects such as road-widening projects, pavement maintenance, and bridge improvements targeted at identified truck bottleneck locations, as well as the use of TSMO solutions such as crash clearance systems, ramp metering, and road weather management systems to improve mobility.

Bottleneck Analysis

- States use a variety of data sources and methods for bottleneck identification and reporting. Two-thirds of the States used NPMRDS data to calculate delay, while 16 relied on other truck global positioning system (GPS) data sources. Seventeen States reported using internal data sources or analytical models as data inputs for their bottleneck analyses. Less common sources of data include infrastructure condition data, commodity flow data, and road crash data.

- States also use the following methods:
  - Travel time delay per mile
  - TTTR measure
  - PTI
  - Volume-to-capacity (V/C) ratio
  - Infrastructure and operational condition methods
  - Freight congestion value (FCV)
  - State and regional travel demand models

Collaborative Efforts To Identify and Communicate Bottlenecks

States used the following to collaborate and communicate bottlenecks:

- Stakeholder outreach to coordinate and educate on bottlenecks
- Multi-State partnerships to address bottlenecks and prioritize corridor projects
- Communication tools like dashboards and reports

Truck Bottleneck Mitigation Measures and Decisionmaking

A total of 30 States reported using bottlenecks for decisionmaking to some extent. Twenty-five States used bottlenecks to select, identify, and prioritize infrastructure projects, and the other five used bottleneck analysis to direct other planning activities.

State truck bottleneck reports categorized mitigation and decisionmaking activities into the following five components:

- Measurement programs
- Freight bottleneck prioritization
- Prioritization of bottleneck improvement projects
- Program monitoring
- Ongoing public information and outreach

TOOLBOX OF SOLUTIONS

This report provides a Toolbox of Solutions that States and MPOs can use to help improve freight mobility, reliability, and bottlenecks. The toolbox represents a spectrum of solutions that agencies can use to improve freight mobility through technology, operational, capacity, and performance management solutions. Many solutions include TSMO approaches that maximize the operational performance of the existing transportation system and provide flexible solutions to manage dynamic conditions.

The Toolbox of Solutions covers the following strategies:

1. Freight traveler information systems
2. Electronic credentialing and permitting
3. Smart roadside commercial motor vehicle monitoring
4. Weigh-in-motion
5. Truck queue management and appointment systems at ports
6. Truck parking information management systems
7. Border wait time information
8. Truck safety warning systems
9. Work zone management for trucks
10. Connected and automated vehicles
11. Road weather management
12. Arterial management and traffic signal timing for trucks
13. Access management at major interchanges and freight facilities
14. Off-peak deliveries
15. Curb loading zone management
16. Active traffic and demand management
17. Ramp management and metering
18. Integrated corridor management
19. Traffic incident management
20. Managed lanes and congestion pricing
21. Truck lanes
22. Truck climbing lanes
23. Intermodal connectors
24. Marine Highway Program
25. Inland ports
26. Rail intermodal corridors
27. Short line rail
28. Organization and planning for operations to include freight stakeholders
29. Operations and freight performance measurement and management

Additionally, there are six case studies to show how certain solutions have been applied and how States and MPOs could replicate them. Table ES-1 describes each of the case studies.

Table ES-1. Case Study Descriptions

Case Study	Description
1. Georgia High-Risk Commercial Motor Vehicle Notification Program Pilot Project **Toolbox Solution:** Truck Safety Warning Systems	The Georgia Department of Transportation (GDOT) partnered with Drivewyze® to conduct a High-Risk Commercial Motor Vehicle (CMV) Notification Program pilot project in metro Atlanta that would evaluate if safety messages to commercial vehicle drivers would reduce the number of hard-braking events. The goal of the project was to improve safety for commercial vehicles, which have a high rate of fatalities and serious injury due to rear-end collisions.

Case Study	Description
2. Texas Connected Freight Corridors **Toolbox Solution:** Connected and Automated Vehicles	Texas is a leading State working to implement a freight-connected and automated vehicles (CAV) ecosystem through its Texas Connected Freight Corridors (TCFC) project. This project will develop the concept of operations, designs, and plans and then ultimately begin the implementation of the technological elements to support CAV. This included technologies to improve safety, such as queue warnings, work zone warnings, wrong-way driving alerts, and truck signal priority.
3. Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program **Toolbox Solution:** Road Weather Management	This Wyoming program tests mobile and roadside technologies that advance multiple connected vehicle applications. The Wyoming Department of Transportation (WYDOT) supports driver awareness by providing road closure information, road weather forecasts, and restrictions. The system can provide advanced notice of crashes, slow-moving or stopped vehicles, work zones, speed reduction, and road conditions. Additionally, the system can help drivers with parking, detours, reduced roadway speed, and safe stopping.
4. Iowa Inland Waterways **Toolbox Solution:** Marine Highway Program	In Iowa, freight shippers have the convenience of multiple modal options for moving goods and materials. The two navigable rivers bordering Iowa—the Missouri River and Mississippi River—form Iowa's waterway system. Waterways provide a lower cost and higher volume intermodal option to move goods. They can also help to reduce landside congestion. Iowa DOT is looking to address performance, reliability, and bottlenecks on its waterway system through its State Freight Plan.
5. Georgia's Inland Ports **Toolbox Solution:** Inland Ports	The Georgia Ports Authority's (GPA) inland ports have proven valuable in reducing highway and seaport congestion, as well as supporting local economic development. Containers can be trucked for shorter distances and staged at the inland port intermodal yard, where they are loaded onto trains moving hundreds of containers in a single trip. This extends GPA's reach and capacity to meet growing demands, offers important opportunities for economic development, stages cargo closer to population centers, extends port gates, saves millions of truck miles, and attracts new businesses.
6. Texas and Maryland Freight Performance Visualization **Toolbox Solution:** Operations and Freight Performance Measurement and Management	Visualizing freight performance through pictures, graphs, maps, and other visuals helps tell freight stories to multiple audiences and stakeholders in an easily digestible way. The Texas Department of Transportation (TxDOT) developed Texas' 100 Most Congested Road Sections tool that identifies freight bottlenecks. The Maryland Department of Transportation State Highway Administration (MDOT SHA) is also developing visual decisionmaking resources, including the Maryland Roadway Performance Tool (MRPT).

CONCLUSION

This research provides an overview of how States are using the TTTR performance measure, reporting on bottlenecks, and implementing other measures to improve freight mobility. This report provides tools and examples of how States are mitigating freight mobility challenges that other States, MPOs, and even local governments or corridor and regional organizations can deploy. States are working to improve freight mobility, and these strategies show a range of efforts, from capacity expansion to more technologically driven TSMO solutions.

Technology and connected data play a role in performance analytics. This aligns with freight performance management efforts and new initiatives to collaborate on supply chain analytics that provide the information needed for the public and private sector to work together to support United States businesses.

1. Introduction

The United States' economic vitality and quality of life rely on the safe and efficient movement of goods. Multimodal transportation infrastructure in the United States supports over 50 million tons of freight valued at over $51 billion daily. Transportation is a vital component of business supply chains as it is the function that moves goods from ports to distribution centers, farm to store, mine to the factory, and factory to retail consumer. With freight expected to grow at approximately 1.2 percent a year through 2045, it is important to focus on freight mobility and how to improve efficiency.[6]

Supply chains depend on high-functioning transportation, production, and sourcing of materials. When supply chains function well, prices are lower, goods are available when needed, and American jobs are maintained or increased. However, American supply chains have had challenges such as:

- Growing demand
- Changing preferences and buying by consumers, including growth in e-commerce and rapid delivery
- Workforce challenges
- Globalization of supply chains to include products or components from multiple countries
- Climate change impacts
- Technological disruptions[7]

When freight movement is compromised by delay due to congestion, there is an economic impact. Delay results in more time in transit, wasted fuel, and negative ripple effects on supply chains. For example, congestion affects economic productivity such that businesses need more operators and equipment to deliver goods when there are delays, more inventory when transportation elements of supply chains are unreliable, and more distribution options for contingencies.[8]

Congestion occurs for numerous reasons, but some of the key causes include:

- Growth in freight demand placing more stress on the transportation network
- Increase in recurring congestion due to growth in travel demand for both freight and passenger vehicles
- Unreliability of travel times due to unpredicted incidents, such as weather, crashes, and work zones
- Restrictions in freight movement, such as lack of space for trucks in urban areas, limited delivery options, and shortages in truck parking
- Increase in delay at transportation bottlenecks
- Impacts from equipment shortages, labor issues, and delays.[9]

A COORDINATED FEDERAL RESPONSE TO SUPPLY CHAIN IMPACTS

The recent supply chain events brought a new understanding of the importance of supply chains to Americans as shutdowns impacted the availability of goods and businesses. What was mostly understood by those in industry and economic circles became a topic of importance to Americans as goods during the COVID-19 pandemic became scarce and industries throughout the world experienced closures and shutdowns.

The COVID-19 pandemic's supply chain impacts affected the United States transportation network with port closures, worker and equipment shortages, increased congestion, and delay due to the backups that were created by shutdowns. Changes in consumer spending caused a surge in demand for goods. This, coupled with unpredictable interruptions to manufacturing and port operations, caused delays in deliveries and increasing prices.

The COVID-19 pandemic called for quick, targeted actions to support recovery of supply chains. The United States Department of Transportation (USDOT) developed the Freight and Logistics Supply Chain Assessment in accordance with Executive Order 14017: America's Supply Chains, which called for a coordinated Federal response. The Administration launched several important supply chain actions including:

- Coordination and commitment from ports to unlock bottlenecks and reduce the number of long-dwelling shipping containers at the ports
- Working with ports to establish pop-up inland ports to relieve capacity
- Working with the United States Department of Agriculture (USDA) and ports to improve exporter access to available empty shipping containers
- Launching a trucking action plan to recruit drivers and improve job quality and retention
- Providing tools to States to expedite licensing of commercial drivers
- Developing a fast-pass system for global transport of medical products

In addition to the above, the Freight and Logistics Supply Chain Assessment provided more long-term options, including:

- Investing in freight infrastructure to improve capacity and connectivity
- Providing technical assistance to support the planning and coordination of freight investments and operations, as well as supporting freight workers
- Improving data and research for supply chain performance
- Strengthening and streamlining governance for efficiency, workforce development, competitiveness, and improving safety and environmental risks
- Partnering with freight stakeholders throughout the supply chain to coordinate and identify solutions that can help freight flow

A major element of USDOT's previous freight efforts and the Freight and Logistics Supply Chain Assessment is understanding and improving freight mobility. Helping freight move safely and efficiently through reduced congestion and bottlenecks has been a priority to support United States businesses, during the COVID-19 pandemic and at all times.

Freight demand is expected to increase significantly, which will place further stress on the Nation's transportation network. The Freight Analysis Framework (FAF) estimates that freight tonnage moved by all modes will increase approximately 37 percent between 2018 and 2045.[10]

Increasing demand in freight activity and the need for resilient supply chains reinforce the significance of measuring and addressing mobility, reliability, and other freight performance issues. It is critical for State DOTs and MPOs to have an awareness of freight mobility performance and locations of freight bottlenecks and to work collaboratively with freight stakeholders to implement solutions.

This report describes State DOT and MPO approaches to identify and address freight reliability and bottlenecks and provides strategies and actionable solutions to mitigate these bottlenecks. The Toolbox of Solutions within this report lists over 30 strategies to support freight mobility, as well as provides information on assessing where an agency is in the level of freight mobility awareness and capability to determine how to plan and map out ways to improve.

PROJECT OVERVIEW

The Federal Highway Administration (FHWA) oversees State DOT and MPO freight performance and freight planning and has sought to review how agencies are implementing freight performance management and identify tools to support freight mobility. The FHWA, States, and MPOs use performance measures for truck travel time reliability (TTTR) and freight highway bottlenecks to assess freight movement on the Interstate system. The research for this report was conducted to answer three key questions:

1. What role do performance measures such as TTTR and freight bottlenecks have in State DOT and MPO decisionmaking?
2. What are the existing, emerging, and innovative approaches that State DOTs and MPOs are using to improve TTTR and improve mobility at freight bottlenecks?
3. What tools and resources are needed for State DOTs and MPOs on the approaches to improve TTTR and mobility at freight bottlenecks using solutions such as transportation systems management and operations (TSMO), multimodal capacity improvements, and CMP?

WHAT IS TTTR?

TTTR is a performance measure for reliability of truck movement on the Interstate system. The TTTR metric is the ratio of the 95th percentile truck travel time and the 50th percentile truck travel time on the Interstate system calculated during 5 different time periods of the day.

This research provides strategies transportation agencies can use to improve freight performance by reducing truck delay, improving reliability, and addressing freight bottlenecks, including:

- TSMO strategies to support freight movement
- Multimodal capacity improvements
- Addressing congestion at truck freight bottlenecks
- Monitoring effectiveness
- Performance-based planning and programming processes
- Congestion management processes

Transportation Performance Management

State DOTs monitor freight performance as part of the Transportation Performance Management program.[11] This includes the TTTR freight performance measure and addressing freight highway bottlenecks.

In 2018, States established 2- and 4-year targets for the TTTR measure (see "Approaches to Freight Mobility Performance Measurement" for a description of this index) and identified major highway freight bottlenecks. In 2020, States submitted their 2-year performance reports on progress toward meeting TTTR targets[12] and reported on the ways in which they are addressing congestion at freight bottlenecks.

METHODOLOGY

This research collected information from State DOT baseline and 2-year performance reports, State-submitted freight bottleneck reports, and inputs collected from peer exchange workshops.

The information collected from each of the 50 States, the District of Columbia, and Puerto Rico performance reports related to TTTR and truck bottlenecks included the following:

1. **Truck Travel Time Reliability Performance Information**: Information was assembled on baseline TTTR Index, 2-year TTTR Index, 2-year and 4-year TTTR targets, and progress made toward TTTR targets. Notable accomplishments reported by the States related to TTTR and other freight reliability performance measures provided in TTTR reports were also identified.
2. **Truck Bottleneck Reporting Overview**: Information was assembled on the number and functional class of truck bottleneck segments listed in DOT reports, as well as the data sources and methodologies used to identify bottlenecks. Noteworthy practices in bottleneck analysis, such as collaboration with regional and local transportation agencies, were also identified.
3. **Actions to Improve Reliability and Congestion**: Information was assembled on the types of actions States undertook to improve truck reliability or congestion, including TSMO solutions, capacity enhancements, and system design solutions.
4. **Other Notable Characteristics**: Information was captured on best practices and lessons learned related to meeting TTTR targets and improving truck bottleneck performance.

More details regarding TTTR and truck bottleneck identification methodologies are described in chapter 3.

FHWA hosted a virtual peer exchange with a geographically diverse group of State DOTs to discuss the challenges in freight mobility and reliability analysis and describe noteworthy practices in conducting these activities. The peer exchange reviewed various measures States used to identify and evaluate freight bottlenecks and demonstrated best practices in addressing freight mobility and reliability needs. Representatives from State DOTs described their processes for producing the data included in their reports, along with strategies to mitigate freight bottlenecks in their States.

The information was used to develop a comprehensive Toolbox of Solutions for improving freight mobility, reliability, and bottlenecks. This information was shared through a virtual workshop that was open to all State DOTs and MPOs to provide feedback and comments. These strategies were refined based on the workshop and are presented in chapter 4. Case studies are also identified and detailed in chapter 4 to illustrate the application of certain Toolbox solutions used to address freight mobility and reliability issues.

The final chapter of this document summarizes the approaches to addressing freight performance, reliability, and bottlenecks and includes an implementation maturity model that agencies could use to understand where they stand in terms of capability with freight mobility and where they can improve. Using a maturity model helps in encompassing the recommendations, ideas, and explanations in a concise format. It is intended to provide a starting point for agencies, as well as the direction toward success in achieving freight performance goals.

2. State Implementation of Freight Performance Management

This chapter describes how States are conducting and using freight transportation performance management. Biennial Performance Reports that each of the 50 States, the District of Columbia, and Puerto Rico submitted to FHWA identify practices related to performance measures for TTTR and truck freight bottlenecks. Recent State freight plans and other publicly available information provided supporting information. The information from these documents was assembled into the following four categories listed in table 2-1.

Table 2-1. Categories and information.

Category	Information Collected
Truck Travel Time Reliability (TTTR) Performance Information	• Baseline TTTR Index, 2-year TTTR Index, 2-year and 4-year TTTR targets, and progress made toward TTTR targets • Notable accomplishments related to TTTR • Other freight performance measures • Data sources and analysis approaches • Challenges in measuring truck travel time reliability
Truck Bottleneck Reporting Overview	• Number of truck bottlenecks • Functional classification and types of roads • Geocoded bottleneck locations • Data sources and bottleneck analysis approaches • Case studies of regional and local collaboration • Types of truck bottlenecks • Other sources that describe bottlenecks
Actions To Improve Reliability and Congestion	• Implementation programs • Monitoring programs • Capacity enhancements • Operational solutions • System design solutions • Case studies of TTTR Index and bottleneck considerations in statewide decisionmaking
Other Notable Characteristics	Information on noteworthy practices and lessons learned related to meeting TTTR targets and improving truck bottleneck performance

APPROACHES TO FREIGHT MOBILITY PERFORMANCE MEASUREMENT

States report TTTR measures to FHWA using the following methodology.

The first step of calculating the TTTR measure is to generate the travel time reliability, which is the ratio of the 95th percentile time by the normal time (50th percentile) for each roadway segment (eq. 1).

$$Travel\ Time\ Reliability\ Ratio\ = \frac{95th\ Percentile\ Travel\ Time}{50th\ Percentile\ Travel\ Time}$$

(Eq. 1)

The TTTR ratio is calculated for five time periods: morning peak (6–10 a.m.), midday (10 a.m.–4 p.m.), and afternoon peak (4–8 p.m.) Mondays through Fridays; weekends (6 a.m.–8 p.m.); and overnight for all days (8 p.m.–6 a.m.).

Then, the largest TTTR ratio of the five periods is selected as the final TTTR for each road segment.

Finally, the TTTR measure is calculated as the sum of the maximum TTTR for each reporting segment, divided by the total Interstate highway system miles (eq. 2 and eq. 3).

$$TTTR\ Index = \frac{\sum All\ Segment\ length\ weighted\ TTTR}{\sum All\ Segment\ length}$$

(Eq. 2)

$$= \frac{\sum Segment\ length \times Maximum\ TTTR}{\sum Segment\ length}$$

(Eq. 3)

The majority (44 out of 52) of States (including the District of Columbia and Puerto Rico) used additional freight mobility performance measures to complement the TTTR Index to assess freight mobility and reliability. Table 2-2 lists these performance measures and the State DOTs that incorporated them into freight mobility analyses. The most common measures are analyses of delay, including hours of delay and delay per mile, the planning time index (PTI) and travel time index (TTI), a level of service (LOS), or volume-to-capacity ratio, and average truck speed. Each of these measures was identified in at least seven States.

Table 2-2. Additional performance measures and the frequencies of usage.

Measurement Area	Performance Measure	States That Mention Using the Measure	No. of States
Related to Truck Travel Time and Speed	Planning travel time index	AK, AZ, CO, FL, MD, NJ, TX, WV, VA	9
	Truck buffer time index	NC, VA	2
	Travel time index	MD, TX	2
	Level of service (LOS) or volume-to-capacity ratio	AR, CO, FL (percent of travel meeting LOS), GA, IN (percent of lane miles better than LOS C), MI, NC, OR, SC, UT	10
	Hours of truck delay	AZ (annual), CA (total peak-hour delay), FL, IN (reduction in hours of truck delay), PR, WA, WI, WY	8
	Delay per mile	KY, LA, NH, MI, MD, TX, VA	7
	Delay cost	MI, WA	2
	Peak-hour excessive delay	RI	1
	Congestion speed (avg. peak-hour speed)	CA, MI	2
	Average truck speed	HI, ME, MO, NE, NJ, NV, WV	7
	Truck traffic annual average daily traffic (AADT)	MA, RI, TN, VT	4
Related to Other Factors	Incident clearance time	NC, TN, RI, WA, WI	5
	Truck crash data	NJ, NM	2
	Response to weather-related incidents	OH, TN, WI	3
	Pavement and bridge condition	DC, IL, MA, WY	4

Data Sources and Tools for Freight Performance Measurement

For the TTTR Index, the majority of States (44 out of 48) that provided information on their data sources identified the National Performance Management Research Data Set (NPMRDS) as the primary data source. Sixteen States that used NPMRDS also incorporated additional raw data directly from a third-party data provider into their TTTR Index analyses. Three States relied primarily on a third-party data source.

California was the only State to use an internally derived data source, the California Performance Measurement System (PeMS), to calculate the TTTR Index. Three States did not report their data sources. Table 2-2 lists the number of States that used a range of data sources to calculate the TTTR Index.

Some States (Maryland and Georgia, for example) used data platforms such as the Regional Integrated Transportation Information System (RITIS) developed by the Center for Advanced Transportation Technology (CATT) Laboratory to access NPMRDS and third-party speed/travel time data and to measure the TTTR Index as described in the following section.

CHALLENGES AND GAPS IN MONITORING FREIGHT MOBILITY AND RELIABILITY

Many States identified challenges with the current TTTR Index methodology and the NPMRDS dataset, including data accuracy and accessibility. In response to these challenges, some States enhanced their TTTR Index methodology, while other States incorporated third-party raw data to improve data inputs.

Noteworthy Practices and Lessons Learned in Freight Mobility and Reliability Performance Monitoring and Reporting

Approximately 30 State DOTs described noteworthy practices for meeting TTTR targets in their performance reports. These include general improvement projects such as road widening, pavement maintenance, and bridge improvements targeted at identified truck bottleneck locations, as well as the use of TSMO solutions such as crash clearance systems, ramp metering, and road weather management systems to improve mobility.

A few States also documented lessons learned in prior attempts at meeting TTTR targets, such as:

- West Virginia commented that construction on the interstate increased its TTTR index more than anticipated.
- Iowa noted that the extreme 2019 floods had a significant impact on reliability and were likely a major reason why the State missed its TTTR target in 2019. Iowa expects reliability to improve dramatically during the next performance period, assuming there will not be another extreme flood. The State also intends to increase the resilience of its transportation system to flooding and other extreme weather events moving forward.
- Arizona noted that when switching to a new dataset in 2017, there was a discontinuity between previous and new data. The State DOT attempted to address this issue by assigning the slope derived from the previous data to the first data point in the new dataset. However, in retrospect, the State DOT recognized that this method underestimated future truck travel time.
- Rhode Island DOT anticipated reduced travel time reliability for a number of reasons, including increased construction, socioeconomic changes, and precipitation levels. Rhode Island set its TTTR target accordingly. However, the State DOT simultaneously took actions to reduce delays caused by work zones, offsetting some of the anticipated deterioration in reliability. Because of these countermeasures, the State's TTTR was well within its target.

APPROACHES TO BOTTLENECK IDENTIFICATION AND ANALYSIS

Bottleneck identification is an important component of freight mobility efforts because it shows where the worst-performing segments are in terms of freight mobility. Knowing these locations helps transportation agencies to identify causes and solutions. The following provides information on data sources and measurement.

Bottleneck Analysis Primary Data Sources and Methodologies

States use a variety of data sources and methods for bottleneck identification and reporting. Two-thirds of the States (35) used NPMRDS data to calculate delay, while 16 relied on other truck GPS data sources such as American Transport Research Institute (ATRI) or INRIX[1]. Nineteen States reported using Highway Performance Monitoring System (HPMS) volume data, and 17 reported using internal data sources or analytical models as data inputs for their bottleneck analyses. Less common sources of data include infrastructure condition data, commodity flow data, and road crash data.

States used the following five analytical methods to indicate whether a specific highway segment is a truck bottleneck:

1. **Travel Time Delay per Mile** is the most frequently used delay measure to identify and report truck bottlenecks, with 22 States using this method to identify bottlenecks. Three of the States that used delay per mile did not use any other mobility measure in their bottleneck analyses.

USING DELAY PER MILE MEASURE TO IDENTIFY RECURRING AND NONRECURRING BOTTLENECKS

Florida DOT (FDOT) used two performance measures to analyze recurring and nonrecurring truck congestion: Vehicle hours of delay (VHD), estimated by adding the ratio of average travel times to the free-flow travel time for each segment; and vehicle hours of unreliability (VHU), calculated as the difference between the 95th percentile and average travel times along each segment. Both VHD and VHU were then normalized by segment length and used to identify the State's top 100 recurring and top 100 nonrecurring bottlenecks.

Source: FDOT Bottleneck Performance Report (2017 and 2019).

2. **TTTR** Fifteen States used the Index method to describe truck bottlenecks. Two States (Utah and Kansas) did not combine the TTTR measure with other mobility-related performance measures or evaluation methods. Other performance measures used in conjunction with the TTTR Index include delay per mile, volume-to-capacity ratio, and truck percent of total traffic volume.

[1]The names of data sources appear in this document for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

USING THE TRUCK TRAVEL TIME RELIABILITY INDEX TO IDENTIFY BOTTLENECKS

Utah DOT relied solely on the TTTR Index to identify and report 45 baseline (2017) truck bottlenecks to FHWA. All these truck bottlenecks were located along the interstate system. Kansas DOT identified truck bottlenecks based on peak and off-peak TTTR indices using low and high thresholds. The Kansas DOT reported 21 bottlenecks reported located along the interstate system. Both States reported on progress made toward improving their 2017 bottlenecks.

3. **PTI** is another reliability measure that is similar to the TTTR Index and is calculated as the ratio of the 95th percentile travel time to the free-flow travel time. Four States used PTI to identify truck bottlenecks. However, all four States used PTI in combination with other measures such as truck volumes and delay per mile values.
4. **Volume-to-capacity (V/C) ratio** was used by 13 States to identify bottleneck locations. Four States relied exclusively on this method. Nine States that used truck volumes in identifying bottlenecks also used other measures, including delay per mile, TTTR Index, infrastructure condition, severe weather impacts, and truck crash rates.
5. **LOS** was also used by some State DOTs, including Arkansas, Montana, South Carolina, and Tennessee, along with other measures, such as delay per mile and truck speed profiles. Only one State, Montana, relied solely on LOS to identify truck bottlenecks.

MODIFYING BOTTLENECK ANALYSIS ACCORDING TO THE NEEDS OF THE STATE

In addition to using the truck travel speed and travel time delay data to identify bottlenecks, Arkansas DOT (ARDOT) analyzed LOS on its State highway system based on methods recommended in the *Highway Capacity Manual*. The LOS data, along with roadway vertical grades and construction location information, were used to validate and prioritize truck bottlenecks and ensure that nonrecurring congestion effects were captured. These additional measures also helped ARDOT determine the probable causes of truck bottlenecks and potential mitigation strategies.

Source: ARDOT Bottleneck Performance Report submittals to the FHWA (2017 and 2019).

6. **Infrastructure and operational condition methods** use the attributes of physical infrastructure, including steep grades, bridge and tunnel restrictions, numerous local-access locations, lane width changes, weaving areas, interchange ramps, and queueing areas (e.g., ports of entry, terminal gates, roadway traffic signals) to identify freight bottlenecks. Operational conditions that can cause nonrecurring delays include work zones, weather impacts, road/bridge closures, and roadway crashes. Five States used infrastructure characteristics and operating conditions to identify truck bottlenecks. Three of these States also assessed weather-related impacts on truck mobility, and two other States analyzed work zone and crash data in combination with infrastructure condition factors. Many States used these factors to identify projects in their list of

priority investments that directly impact truck mobility and reliability. These included safety improvement projects, structural upgrades at low-clearance and weight-restricted bridges, efficiency enhancement at port of entry/border crossing facilities, traffic signal redesign and adaptation to freight needs, and highway–railroad crossing-grade separation projects.

IDENTIFYING CAUSES OF RECURRING AND NONRECURRING DELAYS

Wyoming DOT (WYDOT) identified 50 priority locations with the highest estimated daily delay costs for trucks. The daily delays were calculated as the difference between the 75th percentile and the 50th percentile truck travel times. Once the truck bottlenecks were identified, WYDOT used a predetermined list of potential causes to validate and prioritize the list of bottlenecks and identify projects and strategies to improve truck mobility.

Source: WYDOT Bottleneck Performance Report submittals to the FHWA (2017 and 2019).

7. **Other methods** States used to identify truck bottlenecks included the freight congestion value (FCV) method the American Transportation Research Institute (ATRI) developed[13] and analytical models such as State and regional travel demand models.

Collaborative Efforts To Identify and Communicate Bottlenecks

The following sections describe ways that States are working with stakeholders and other State or regional partners to identify and communicate freight bottlenecks.

Stakeholder Outreach on Truck Bottlenecks

The majority of States used stakeholder engagement to validate their bottleneck analysis results. About half of the States mentioned outreach and coordination with MPOs, councils of government (COGs), and regional freight councils as an important tool for truck bottleneck identification and verification, while about one-third of States mentioned ongoing coordination efforts with their State Freight Advisory Committee (SFAC) as a means of identifying or validating freight bottlenecks.

Multi-State Partnerships

Several States highlighted their regional partnership efforts for addressing bottlenecks in their report to FHWA. Multi-State partnerships enable the States to prioritize corridor projects that have benefits for more than one State.

An example is the Mid America Association of State Transportation Officials (MAASTO), a collaborative effort among 10 Midwestern States (Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) to address regional issues related to transportation, including freight. In 2018 and 2019, the member States conducted a study of marine and highway bottlenecks in the MAASTO region to prioritize freight corridor improvement projects. MAASTO identified truck bottlenecks along multi-State corridors based on aggregated delays along highway segments. Multi-State, corridor-level mobility improvement projects identified in this study had the support of multiple States. These improvements included highway capacity enhancement projects, ramp metering projects, and variable speed limit solutions.[14]

The Institute for Trade and Transportation Studies (ITTS) Regional Bottleneck Assessment for Goods Movement is an ongoing study to assess the extent, duration, and severity of truck bottlenecks in the southeastern United States. The region spans the 13 States of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia. The assessment focuses on the National Highway Freight Network, Critical Urban Freight Corridors, and Critical Rural Freight Corridors in the region, using the HPMS and NPMRDS datasets to calculate total truck delay. The study will apply an innovative trips-based methodology to calculate time-of-day bottlenecks along routes for top trade lanes in the region. In addition, a geographic information system (GIS) information-sharing platform will be developed to document regional bottleneck issues and facilitate multi-State collaboration to enhance goods movement across the region.[15]

Communicating Truck Bottleneck Information

The majority of States provide lists of high-priority truck bottlenecks in their State freight plans and long-range transportation plans. However, some States communicate bottleneck information using online maps and interactive platforms. For example, the TxDOT Texas' 100 Most Congested Roadways tool has been effective in communicating bottlenecks. The tool is an interactive list and map of the 100 most congested roadways in the State that provides the top congested segments that have been identified primarily based on delay per mile. However, users can rank the bottlenecks by applying other measures such as congestion costs and (freight and all vehicle) traffic volumes.[16]

Texas' 100 Most Congested Roadways has been replicated by other States such as Maryland. The Maryland Department of Transportation (MDOT) publishes a mobility report that includes the locations of freight bottlenecks and also provides a web-based tool, the Maryland Roadway Performance Tool (MRPT).[17] This tool is in the process of being widely disseminated and coordinated with MPOs and modal representatives. MDOT uses the MRPT to collaborate with local and regional stakeholders on planning efforts and investment decisionmaking.

Unique Practices for Improving Truck Bottlenecks

The following summarizes unique practices implemented by States to address truck bottlenecks:

- Virginia DOT uses truck delay per mile to identify bottlenecks in the State. Once identified, a suite of other measures, including the TTTR Index, Buffer Index, and PTI are used to further understand the root causes of congestion at bottleneck locations and determine the best approaches to address them (e.g., capital or operations projects). Information on all of these metrics is included in an online tool that is accessible to all of the State's transportation agencies. Additionally, local jurisdictions can recommend projects for statewide funding to relieve congestion based on the statewide analysis.[18]

- Oregon uses a wide range of measures and methods to identify truck bottlenecks. The State invests in ITS and TSMO projects to relieve congestion and improve freight operations and safety. The State also identified expansion and improvement of the public transit system as a solution that can contribute to improving freight mobility. The Oregon DOT has tested programs to move freight during nonrush hours in densely developed urban areas. The State is also conducting pilot projects that allow buses on select shoulders of I–5 and I–205 to improve overall mobility. Oregon had previously conducted a bus-on-shoulder pilot program along a portion of SR–14 in 2017.[19,20]

- Both Arizona and Louisiana identified truck parking improvement projects as a means of addressing truck bottleneck issues.[21,22,23]

- Louisiana, Massachusetts, and Wyoming identified relatively low-cost modernization and reconstruction projects, including restriping (to streamline flow and reduce weaving), variable message signs (to communicate road closures), variable speed limits, and improved ice/snow removal operations to address infrastructure-related recurring and nonrecurring truck bottlenecks.[24,25,26,27]

- To ensure the effectiveness of traffic operations improvement strategies in enhancing travel time reliability, North Carolina DOT established freight-specific congestion and bottleneck metrics that are tracked monthly as part of a collection of agency-wide multimodal performance analyses.[28]

- TxDOT uses its Texas 100 tool to assess key supply chain routes and identify bottlenecks from a trip-based perspective. The tool helps decisionmakers contextualize bottlenecks by allowing them to see the issues from the lens of truck-intensive companies. The Texas 100 tool has advanced the development of two additional tools by TxDOT: the Congestion Management Process Assessment Tool (COMPAT) and Truck Congestion Assessment Tool (TCAT), both of which take congestion and truck bottleneck analytics further into detail for users. A truck parking analysis tool is being added to this collection.[29]

TRUCK BOTTLENECK MITIGATION MEASURES AND DECISIONMAKING

Thirty States reported using bottlenecks for decisionmaking to some extent. Of those States, 25 used bottlenecks to select, identify and prioritize infrastructure projects, and the other 5 used bottleneck analysis to direct other planning activities.

The review of truck bottleneck reports categorized mitigation and decisionmaking activities into the following five components described below:

1. Measurement programs
2. Freight bottleneck prioritization
3. Prioritization of bottleneck improvement projects
4. Program monitoring
5. Ongoing public information and outreach

Measurement Programs

Twenty-four States identified data collection and performance measurement programs in their bottleneck reports, State freight plans, or related documents. Highlights from these programs include the following:

- Delaware is using Bluetooth® devices to develop statewide reliability data and assessments. The State DOT also intends to perform ongoing data collection coverage expansion.

- Idaho noted that it would continue to measure four indicators: the percent of the time that the highway is clear of snow/ice during winter storms, the percent of pavement in good/fair condition, the percent of bridges in good condition, and the percent of highway project design completed on or ahead of time.

- Wyoming is developing winter maintenance performance measures to assess the effectiveness of snow removal techniques the State DOT uses.

- New Hampshire will install permanent volume and classification counters on select roads.

- Tennessee mentioned candidate metrics that the State DOT will likely track in the future: a maintenance rating index; rail speed restrictions, travel time delivery, combined truck average travel speed, travel time variability, truck level of service, and incident response time.

- Iowa plans to provide real-time information on system conditions to support the movement of freight.

Freight Bottleneck Prioritization

Several States reported strategies for prioritizing truck bottlenecks. Highlights of their approaches are as follows:

- Arkansas prioritizes bottlenecks based on delay per mile.

- Arizona prioritizes bottlenecks according to TTI, PTI, and annual hours of delay and their associated costs.

- Delaware ranks bottlenecks according to six criteria: travel time, truck volume, truck percent, truck trip generation, route type, and crash frequency.

- Maryland, Texas, and Virginia rank bottlenecks based on delay per mile.

- New Jersey identifies and ranks bottlenecks as either first tier, second tier, or third tier based on TTTI, crash data, and travel speed.

- Rhode Island identifies bottlenecks using travel time indices and then ranks them based on vehicle miles traveled on these segments.

It is important to note that not all States explicitly use bottleneck locations in their project prioritization processes. For example, Massachusetts assigns programs to one of three capital priorities: reliability, modernization, and expansion. Reliability programs and projects receive the majority of capital funding. However, it is unclear whether the State DOT uses bottlenecks to determine whether a program will improve reliability. Wisconsin addresses congestion by prioritizing projects that improve mobility on freight routes. Wyoming uses approximated annual truck delay per mile to identify and rank bottleneck locations, but the State DOT uses the TTTR Index to prioritize projects.

Prioritization of Bottleneck Improvement Projects

Truck bottleneck analysis was also used to prioritize improvement projects, including the following specific examples.

- Hawaii uses congestion (speed difference) as a criterion to prioritize projects. Speed difference is also one of the methods the State DOT uses to identify and prioritize bottlenecks.

- North Dakota identifies projects under the State DOT's prioritization protocol, including those that improve truck bottlenecks.

- Nebraska prioritizes projects according to certain policy goals, one of which is mitigating truck bottlenecks.

- Nevada uses bottlenecks as one metric to prioritize State infrastructure projects.

- Oklahoma ranks projects according to a prioritization process, which involves the use of criteria such as mobility and economic vitality. Under this criterion, there is a subcriterion denoting whether a project targets an identified bottleneck location.

- Oregon intends to leverage its bottleneck list to direct funds to solve specific freight network issues.

- Tennessee prioritizes projects based on eight criteria, one of which is the project's ability to reduce congestion. Under this criterion, projects located in bottleneck locations will receive high priority.

Program Monitoring

States conduct program monitoring to determine how implemented freight projects are performing. Highlights of program monitoring include the following:

- Mississippi monitors performance using the National Performance Management Research Data Set (NPMRDS) Analytics Tool.

- New Jersey is performing ongoing monitoring of numerous truck datasets.

- New York plans to develop a framework for evaluating capital projects in terms of how the projects address the needs of freight within the State.

- Rhode Island evaluates the effectiveness of projects by using system-level monitoring and integrating bottlenecks into the CMP, which identifies how planned projects align with congested corridors and bottlenecks.[30]

- Virginia monitors and assesses the effectiveness of maintenance and rehabilitation activities.[31]

Ongoing Public Information and Outreach

Many States report ongoing outreach with State FACs on the performance of truck bottlenecks, as well as data tools and media that are made available to the public or local agencies. For example:

- California produces an online, public-facing performance data reporting tool (PeMS).[32]
- Georgia continues to coordinate with MPOs for monitoring and reporting performance targets.
- Iowa takes advantage of social media, which provides the opportunity for the public to send feedback.
- Texas has its 100 Most Congested Roadways tool that has worked well in engaging stakeholders, and Maryland recently developed an online, public-facing performance data reporting tool (MRPT).
- Utah aims to develop a freight toolbox for local governments that provides information about truck routes.
- Vermont is considering topical focus groups and a regularly published freight stakeholder newsletter providing information on current Vermont Agency of Transportation activities.

Conclusion of Findings

States are using a variety of methods to understand freight performance, identify bottlenecks, and improve freight mobility. States are using other measures such as delay per mile and hours of delay, as well as other reliability and mobility measures to understand freight performance. They are primarily using the NPMRDS, but many States also use other data sources. Bottleneck identification is performed in several different ways and is communicated or done in partnership with many States. Overall, many States employ a suite approach to performance analytics, relying on primary measures and then other measures to help understand bottlenecks in further detail.

There were many approaches to mitigating bottlenecks gleaned from the sources of this research. These strategies range from performance measurement and monitoring to capacity and technological solutions. These tools are detailed in chapter 3.

3. Toolbox of Solutions

State DOTs, MPOs, and local governments can deploy a diverse range of solutions that are critical to improving freight highway performance and reliability. These programs can support State, local, and regional efforts to move freight mobility results in a positive direction. This chapter describes a Toolbox of Solutions that transportation agencies have incorporated or could incorporate to address freight highway bottlenecks.

WHAT IS THE TOOLBOX OF SOLUTIONS?

This chapter serves as a resource for State DOT, MPO, and local transportation planners, policymakers, and system operators to incorporate freight technology and operational, capacity, and performance management solutions into their freight strategy. It is intended to help illustrate the various ways that transportation agencies at all levels have attempted to improve TTTR and mobility at freight bottlenecks.

The Toolbox of Solutions is intended as a holistic, multimodal approach to improve freight bottlenecks to address more comprehensive multimodal transportation needs of the supply chain. The Toolbox of Solutions comprises 29 strategies (see sidebar) that can be described as a combination of:

1. Technology solutions that generate, aggregate, collect, and/or distribute data in realtime to save time that is otherwise spent in manual processes or queues, thereby optimizing the movement of freight to its destination
2. Operational solutions that prepare for and meet changing conditions on the freight transportation network and evolving supply chain demands
3. Capacity solutions that encompass highway and multimodal capital improvements to enhance the capability of the transportation system to safely accommodate existing and projected freight volume
4. Performance management strategies that use data analysis and visualization resources to illuminate freight performance and assist communication and decisionmaking

STRATEGIES IN THE TOOLBOX OF SOLUTIONS

1. Freight traveler information systems
2. Electronic credentialing and permitting
3. Smart roadside commercial motor vehicle monitoring
4. Weigh-in-motion
5. Truck queue management and appointment systems at ports
6. Truck parking information management systems
7. Border wait time information
8. Truck safety warning systems
9. Work zone management for trucks
10. Connected and automated vehicles
11. Road weather management
12. Arterial management and traffic signal timing for trucks
13. Access management at major interchanges and freight facilities
14. Off-peak deliveries
15. Curb loading zone management
16. Active traffic and demand management
17. Ramp management and metering
18. Integrated corridor management
19. Traffic incident management
20. Managed lanes and congestion pricing
21. Truck lanes
22. Truck climbing lanes
23. Intermodal connectors
24. Marine Highway Program
25. Inland ports
26. Rail intermodal corridors
27. Short line rail
28. Organization and planning for operations to include freight stakeholders
29. Operations and freight performance measurement and management

The toolbox represents a spectrum of solutions that agencies can use to improve the performance of freight movement in their State or region and address technology, operational, capacity, and/or performance management needs. Many solutions address multiple functions and correspond with TSMO approaches. TSMO strategies focus on operational improvements that maximize the operational performance of the existing transportation system before extra capacity is needed (figure 3.1). The goal with TSMO is to get the most performance out of the transportation facilities already in place. Under TSMO, performance is viewed from a systems perspective, spanning corridors, jurisdictions, modes, and agencies. In this way, a TSMO approach can help transportation agencies balance supply and demand in the system and provide flexible solutions to manage dynamic conditions.

Figure 3.1. Transportation systems management and operations strategies.

Source: United States Department of Transportation Intelligent Transportation Systems/Joint Program Office.

TSMO is a programmatic way to complement capacity projects or provide lower cost, more quickly implemented alternatives to capacity improvements. TSMO improvements can also be incorporated into capacity projects to ensure the long-term effectiveness of the new facility.

The Toolbox of Solutions focuses on the TSMO strategies that are most directly related to freight transportation. However, it is also broader in that it covers multimodal capacity strategies that go beyond operations and technology.

HOW TO USE THE TOOLBOX

> **HOW TO USE THE TOOLBOX**
>
> **Step 1:** Define the problem(s) that need to be addressed.
>
> **Step 2:** Compare the benefits and costs of toolbox solutions against available resources.
>
> **Step 3:** Select the toolbox solution(s).

Table 3-1 provides a matrix that you can use to determine which toolbox solution would help address freight-related issues most appropriate and relevant given your role and the resources available to you. To use this information, you can follow the steps discussed below:

Step 1: Consider the freight problems that need to be addressed to help narrow which toolbox solutions to examine. To do this, it may be helpful to ask questions that can help narrow down what the current transportation is lacking. Are freight congestion, reliability, safety, or performance issues the result of a lack of highway capacity, foreseeable events (e.g., road work, steep grades, seaport congestion) or nonrecurring events (e.g., weather, crashes)? The matrix on the following pages lists problems that each solution addresses.

Step 2: Look at the potential implementation opportunities and challenges for each solution that could address the freight problems. The matrix on the following pages provides a summary of potential benefits and costs associated with each toolbox solution. Compare these with the resources you have available to you for implementation. This may help you further narrow potential solutions down to the most feasible for your agency.

Step 3: Select the relevant and appropriate Toolbox solution. Table 3-1 provides hyperlinks to more detailed information on each toolbox solution to help you make this determination.

Table 3-1. Matrix of toolbox solutions.

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Freight Traveler Information Systems	• Lack of integrated data on wait times at ports, traffic conditions, incident alerts, work zones, and routing restrictions • Inefficient drayage operations from a lack of combined container load matching and freight information exchange systems	• Real-time information and dynamic routing for drivers • Adaptive communication between drayage company, drivers, and port terminals • Performance-monitoring elements • Individual trucks assigned best time windows for pickup or dropoff • Travel information and information on port terminal conditions to optimize operations • Minimizes wasted miles and spreads truck arrivals at port terminals throughout the day	• Low—Development and maintenance of web-based information systems; installation and maintenance of detection and communication equipment
Electronic Credentialing and Permitting	• Resource inefficiencies from paper-based or manual processes for truck credentialing and permitting, inspections, or enforcement • Congestion in and around weigh stations	• Systems are available 24 hours a day • Reduces costs and time • When coupled with roadside electronic screening, trucks can be identified at highway speeds, which allows legal trucks to bypass weigh stations, provides inspectors real-time data to decide whether to call in vehicles, and controls the volume of traffic through and around weigh stations • Safety information exchange allows electronic collection and exchange of safety performance information among States, Federal agencies, and motor carriers	• Low—Development and maintenance of web-based information systems; purchase and maintenance of vehicle, roadside, and/or weigh station equipment

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Smart Roadside Commercial Motor Vehicle Monitoring	• Lack of automation and dynamic monitoring of data from trucks • Inefficiencies in data collection, inspection, or enforcement	• Collects truck data and screens trucks at highway speeds beneficial for weigh station prescreening, freight planning, congestion planning, pavement studies, safety studies, and corridor management • Facilitates more efficient and dynamic inspection and enforcement	• Medium—Installation and maintenance of roadside technology hardware and software; mobile website and application development and maintenance
Weigh-in-Motion (WIM)	• Lack of automation and dynamic identification of data from trucks • Inefficiencies in data collection, inspection, or enforcement	• Collects truck data and screens trucks at highway speeds beneficial for weigh station prescreening, freight planning, congestion planning, pavement studies, safety studies, and corridor management • Allows for continuous measurement of trucks traveling on the highway, without diverting or stopping them	• Low—Installation and maintenance of WIM sensors
Truck Queue Management and Appointment Systems at Ports	• Excessive drayage congestion and delay at ports • Driver queues due to a lack of predictability and reliability at ports	• Allows drayage firms to make efficient dispatching plans with reduced driver queue times • Allows marine terminals to control workloads, thereby reducing drayage congestion and delay	• Low—Development and maintenance of web-based information systems
Truck Parking Information Management Systems	• Inefficient use of existing truck parking sites (e.g., lots regularly too full or empty) • Truck parking occurring in unofficial parking locations (e.g., on-ramps, off-ramps, shoulders)	• Maximizes use of existing truck parking sites • Reduces congestion from trucks roaming to locate parking spaces • Enhanced safety due to reduced parking in unofficial parking locations	• Medium—Installation, and maintenance of parking detection at rest areas and communication hardware and software

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Border Wait Time Information	• Excessive delays and congestion at border crossings • Queues due to lack of predictability and reliability at border crossings	• Reduces congestion as travelers make informed decisions about where and when to cross the border • Safety during major events (trucks can be directed to temporary parking areas)	• Medium—Installation and maintenance of speed and travel time detection and communication hardware and software; mobile website and application development and maintenance
Truck Safety Warning Systems	• Crashes involving trucks due to high speeds • Bridge and tunnel strikes due to overheight vehicles	• Reduces crashes involving trucks • Dynamically warns truck drivers to reduce speeds or use alternate routes	• Medium—Installation and maintenance of the vehicle, speed detection, or height measurement and communication hardware and software and warning systems
Work Zone Management for Trucks	• Lack of truck considerations in work zone transportation management plans and traffic impact analyses • Recurring crashes involving trucks in work zones	• Safer work zones for all roadway users and construction personnel • Truck travel optimization that considers work zones	• Medium—Planning resources to consider trucks in work zone transportation management plans and traffic impact analyses; installation of additional warning systems and equipment to accommodate trucks through work zones

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Connected and Automated Vehicles	• Congestion and other inefficiencies from safety-critical control functions (e.g., steering, throttle, or braking) requiring direct driver input, lack of coordination between vehicles and infrastructure, and inability to interface with automated equipment and facilities	• Cooperative automation applications (e.g., vehicle platooning, speed harmonization, and cooperative lane change and merge functions) enhance reliability • Provides means of automating the monitoring and reporting of road conditions • Provides capabilities for automated terminal equipment and autonomous freight delivery	• Medium—Planning resources to prepare for vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-vehicle (I2V) connectivity; installation of V2V, V2I, and/or I2V equipment to automate supply chain
Road Weather Management	• High incidence of crashes and congestion involving trucks due to inclement weather • Delays caused by road closures	• Minimizes or eliminates impacts of weather on safety and mobility	• Medium—Installation and maintenance of detection and communication hardware and software (e.g., road weather information systems (RWIS), speed management systems, warning systems, 511 systems)

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Arterial Management and Traffic Signal Timing for Trucks	• High truck volumes, queues, and blockages at signalized intersections, especially near port terminals	• Reduces delays caused by the longer time it takes trucks to accelerate • Increased vehicular capacity of intersection through minimizing truck startup lost time • Provides safer phase termination for trucks (i.e., decision zone protection) • Reduces truck red-light running and potential crashes • Reduces truck emissions	• Medium—Installation and maintenance of vehicle detectors, information communication technologies, and traffic signal systems
Access Management at Major Interchanges and Freight Facilities	• Congestion and safety issues due to poorly planned access along arterials and near interchanges and freight facilities	• Enhances safety and capacity along arterials and near interchanges • Improves movement of traffic and number of vehicle conflicts	• Low—Coordinated planning and establishment of access standards with local agencies that can be implemented as development occurs along a corridor
Off-Peak Deliveries	• Lack of peak-period curb space for deliveries in urban areas, leading to double parking and other types of illegal parking • Deliveries that need to be made where there are high pedestrian volumes and traffic congestion	• Increases business efficiency for suppliers and retailers • Reduces fuel consumption and carbon dioxide (CO_2) emissions • Reduces traffic during peak hours	• Medium—Research, planning, software, signs, and striping costs associated with selecting and marking curb spaces; taking inventory of potential users, needs, and value propositions; developing technology tools; implementing pilots at selected locations; promoting the program; and incentivizing companies to use it

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Curb Loading Zone Management	• Lack of peak-period curb space for deliveries in urban areas, leading to double parking and other types of illegal parking	• Provides delivery and service providers drivers incentive to load in designated locations where it is safe, efficient, and legal • Data collection	• Medium—Research, planning, software, signs, and striping costs associated with selecting and marking curb spaces; taking inventory of potential users, needs, and value propositions; developing technology tools; and implementing pilots at selected locations
Active Traffic and Demand Management (ATDM)	• Issues related to reliability, safety, and throughput due to recurring and nonrecurring congestion	• Improves reliability, safety, and throughput by dynamically managing and controlling travel and traffic demand and available capacity based on prevailing and anticipated conditions, using real-time operational strategies	• Medium—Though ATDM builds upon existing capabilities, assets, programs, and investments, certain strategies require technology (hardware and software), operations centers, and infrastructure (e.g., dynamic message signs (DMS), markings, signs)
Ramp Management and Metering	• Congestion and safety issues that may be attributable to vehicles entering the freeway	• Reduces overall freeway congestion by managing the amount of traffic entering the freeway	• Medium—Installation, and maintenance of vehicle detection and traffic signal systems

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Integrated Corridor Management	• Inefficient movement of freight along a corridor from a lack of awareness among motor carriers of work zones, incidents, closures, travel times, and alternate routes or modes along the corridor	• Improves truckers' situational awareness of conditions along a corridor to make informed decisions about avoiding congested routes, scheduling off-duty and rest periods, and notifying shippers and receivers of pickup and delivery times • Provides freight stakeholders with a forum for collaboration	• Low—Planning, design, and deployment costs associated with establishing institutional agreements and operational approaches and policies, and multimodal ICM plans and systems
Traffic Incident Management	• Disruptions to traffic flow and safety (e.g., crash victim and emergency responder safety, secondary crashes) following crashes involving trucks • Slow incident response times	• Reduces the duration and impacts of traffic incidents • Improves the safety of motorists, crash victims, and emergency responders • Reduces the frequency of secondary crashes	• Low—Procurement, contract management, and funding resources required to plan, procure, and deploy major incident response program that may include performance incentives and bonuses
Managed Lanes and Congestion Pricing	• Recurring and nonrecurring congestion and limitations in the ability to expand highway capacity due to construction costs, right-of-way constraints, and environmental and societal impacts	• Reduces delays • Increases predictability of trip times with more deliveries made on time • Improves transportation services without tax increases or large capital expenditures • Provides additional revenues for funding transportation • Shortens incident response times for emergency personnel	• High—Planning, design, right-of-way, and construction costs associated with deploying limited-capacity expansion and operational strategies. Managed lanes could be delivered through innovative delivery methods (e.g., public-private partnerships) that require additional investments

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Truck Lanes	• Congestion and safety issues posed by relatively high current and projected percentages of trucks or steep grades that cause inefficient interaction between trucks and other vehicles	• Improves safety by reducing weaving maneuvers during passing to prevent truck conflicts and crashes with vehicles • Separates trucks from other vehicles	• High—Planning, design, right-of-way, and construction costs associated with deploying capacity expansion (e.g., separated truck-only lanes, interchange bypasses for trucks, connectors to/from ports); note, however, that lane restrictions for trucks are an exception
Truck Climbing Lanes	• Steep, sustained grades cause heavy vehicles, particularly trucks, to travel at slow speeds	• Reduces collisions and backups by providing slower-moving trucks and vehicles an additional safe lane to travel in • Reduces conflicts between slower moving trucks and passing vehicles	• High—Planning, design, right-of-way, and construction costs associated with deploying capacity expansion
Intermodal Connectors	• Roads that provide the “last-mile” connection between major rail, port, airport, and intermodal freight facilities but are in need of capacity and state-of-good-repair improvements	• Reduces congestion and safety issues at key roadways connecting to major freight facilities	• High—Planning, design, right-of-way, and construction costs associated with adding auxiliary lanes, driving lanes, or turn lanes; upgrading exit ramps and access; pavement resurfacing and reconstruction; and grade separation projects

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Marine Highway Program	• Existing landside highway and railway corridors suffering from congestion, excessive air emissions, or other environmental challenges	• Relieves landside congestion • Provides new and efficient transportation options • Increases productivity of the surface transportation system	• Medium—Designation of Marine Highway Routes may require some planning and coordination costs; capital improvements (e.g., specialized equipment, infrastructure, and vessels) require a more significant investment
Inland Ports	• Congested seaports are located in areas where land is scarce and/or expensive for expansion • Congested roadways to and from seaports	• Relieves highway congestion where containers would otherwise be trucked through congested urban areas • Relieves port congestion by transferring processing and distribution of goods to an inland location, away from the congested port • Provides flexibility and control to manufacturers running tight production lines and retailers in need of velocity and reliability in their supply chain	• High—Planning, design, right-of-way, and construction costs associated with converting an inland property into an intermodal dry port facility; temporary "popup" container facilities do not require a great investment
Rail Intermodal Corridors	• Highway congestion and bottlenecks on routes that trucks use to carry containers between ports and inland markets	• Reduces air emissions, reduces congestion, and enhances reliability since one intermodal train can carry up to several hundred containers and trailers, which removes that many trucks from the road • "Double stacking" of containers sharply increases productivity and keeps intermodal competitive with all-truck movements	• High—Investments of funding and staff resources to establish rail intermodal corridors, along with funding for improvements on private rail infrastructure, as well as engagement with communities that may be affected by new intermodal facilities and increased freight rail traffic

Solutions	Problems Solution Addresses	Potential Benefits	Potential Implementation Costs
Short Line Rail	• Urban freight (truck) congestion from lack of use of short line railroad infrastructure with access to larger (Class 1) freight railroad systems • Degraded short line railroad infrastructure	• Provides shippers an alternative to shipping goods by truck by connecting to larger freight rail networks • Reduces congestion by providing first- and last-mile rail access to industries that otherwise ship by truck • Lowers pavement damage costs associated with truck traffic	• High—Investments of funding and staff resources to partner with private or quasi-governmental entities to improve short line railroad infrastructure
Organization and Planning for Operations to Include Freight Stakeholders	• Difficulties in implementing freight plans and projects due to stakeholder opposition	• Fosters freight champions and provides a face for freight to build trust with industry stakeholders and the public • Provides important information on the market, economic factors, industry practices, trends, and commodity movements on the network useful in planning, transportation analyses, impact assessment, project selection, and managing operations	• Low—Planning, organizational, and communications resources may be needed to make changes to stakeholder and advisory group composition and gather information from stakeholders
Operations and Freight Performance Measurement and Management	• Challenges with describing freight movement, connections or routes, and performance (including bottlenecks) to internal and external stakeholders	• Provides capability to convey freight performance at a glance and tell the freight "story" in a way that is easy for agency staff and the public to understand	• Low—Development and maintenance of web-based information systems

Freight Traveler Information Systems

Description

Also referred to as freight advanced traveler information systems (FRATIS), this toolbox solution refers to freight-specific technology applications that can be used to improve freight operational efficiency. Two tested applications of FRATIS cover (1) Freight-Specific Dynamic Travel Planning and Performance, and (2) Intermodal Drayage Operations Optimization.

- The *Freight-Specific Dynamic Travel Planning and Performance* application bundles traveler information, dynamic routing, and performance-monitoring data on wait times at ports, traffic conditions, incident alerts, work zones, and routing restrictions. It has proven beneficial to agencies looking to provide real-time information and dynamic routing for drivers, as well as adaptive communications between drayage companies, drivers, and port terminals.

- The *Intermodal Drayage Operations Optimization* application combines container load matching and freight information exchange systems to provide real-time information on container status and pickup/delivery appointments. Individual trucks are assigned best time windows for pickup or drop-off, using travel information and information on port terminal conditions to optimize drayage operations. This minimizes wasted miles and spreads truck arrivals at the port and intermodal terminals throughout the day.[33]

Where To Apply This Solution

Freight traveler information systems bring real-time messages on incidents, congestion, and travel time to the freight industry, allowing vehicles to be optimally and dynamically routed. FRATIS is also used to optimize drayage operations so that load movements are coordinated between freight facilities to reduce empty-load trips.

Due to these applications, freight traveler information systems have proven useful in alleviating truck bottlenecks where advanced information about terminal queue lengths is available and in situations where dispatchers are able to adjust truck departures to avoid long queues. Such systems are also useful where advanced departure information from dray companies is available for terminals to use in planning their operations.[34]

Examples

FRATIS pilot projects have been deployed in Los Angeles, Dallas/Fort Worth, and South Florida. The prototypes tested software for drayage companies seeking to improve movements of containers between intermodal terminals and inland shipping points.

Los Angeles Freight Advanced Traveler Information Systems Project

The Los Angeles FRATIS project centered around improved communications between trucking companies and intermodal terminals, applying advanced algorithms to optimize truck routing and deliveries, and providing dynamic routing of trucks to avoid congestion. A key component of the project was the development of a Drayage Optimization Algorithm, which was applied during the preplanning dispatch stage through an in-vehicle tracking, traveler information, and information exchange system. The trucks were then asked to follow the given optimized plan for that day, with hopes of achieving significant reductions in miles traveled, time spent, and fuel usage.[35]

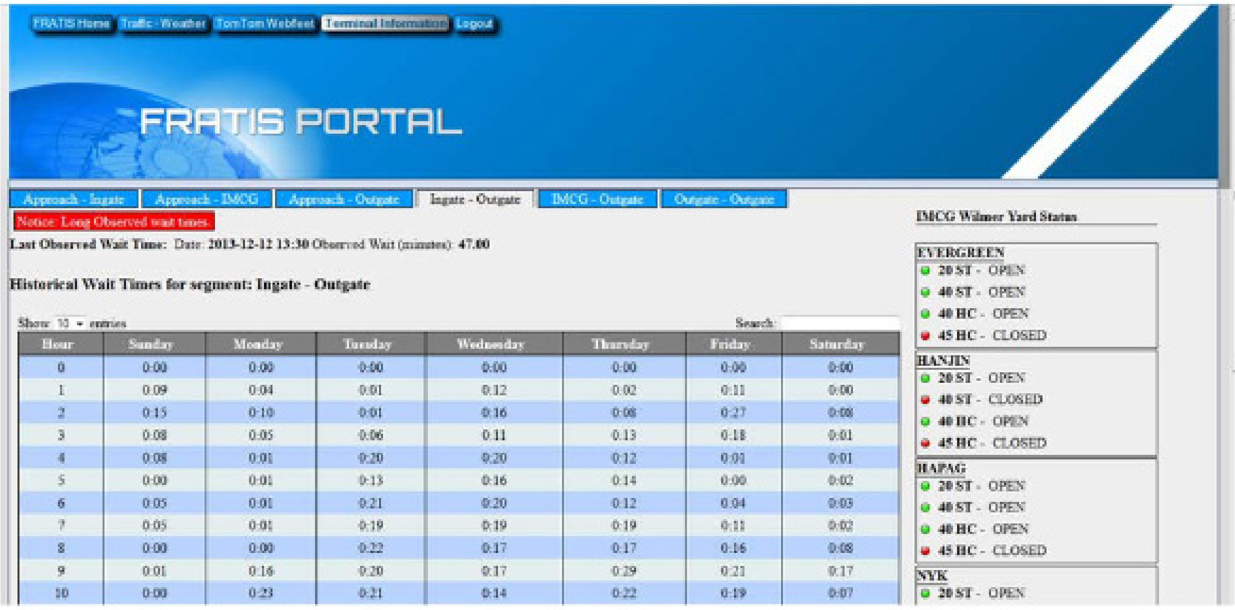
Dallas/Fort Worth Freight Advanced Traveler Information Systems Project

The Dallas/Fort Worth FRATIS project centered on improving the efficiency of operations within two drayage companies to incorporate integrated corridor management capabilities of the two FRATIS applications. The system included:

- A drayage optimization component, which sought to reduce bobtails and minimize miles traveled, while reducing dispatcher workload
- A terminal queue time component intended to provide insight regarding the current and predicted wait time at the intermodal facility
- Advance notice to terminals component, which provided drayage traffic information regarding trucks destined for their facility each day
- A routing, navigation, traffic, and weather component intended to provide real-time dynamic routing to each driver in conjunction with each work order, with traffic and weather overlays to the route

This pilot also produced a web portal that provided separate, secure access to these applications to the primary stakeholders (figure 3.2).[36]

Figure 3.2. Dallas/Fort Worth Portal Showing Gate Wait Times.



Source: United States Department of Transportation Intelligent Transportation Systems Joint Program Office.

South Florida Freight Advanced Traveler Information Systems Project

The South Florida FRATIS project added an emergency response capability to realign the purpose of freight transportation to bring in supplies during an emergency, such as a hurricane.[37] The three FRATIS tests found that the use of traffic data and enhanced dynamic routing allows trucks to make routing decisions that decrease the likelihood of crashes. While the FRATIS tests did not quantify trip time reductions or fuel consumption decreases, participants agreed that improved management of trucking operations does reduce fuel consumption and decreases air pollution in the areas around terminals and ports.[38]

ELECTRONIC CREDENTIALING AND PERMITTING

Description

Electronic credentialing and permitting systems to allow motor carriers to electronically apply for, pay for, and receive oversized/overweight permits, International Registration Plan (IRP), and International Fuel Tax Agreement (IFTA) credentials. By conducting credentialing and permitting via the Internet, these systems can be available 24 hours a day and reduce costs and time associated with paper-based systems.

E-credential and permit data are shared with roadside operations and jurisdictions outside the State as a key component of the Commercial Vehicle Information Systems and Networks (CVISN) infrastructure. A national CVISN architecture was defined by the Federal Motor Carrier Safety Administration (FMCSA), working with the States and the transportation research and motor carrier communities to maximize the mutual use of data (or "interoperability") among the participating jurisdictions. Safety and Fitness Electronic Records (SAFER) is a data-sharing system that facilitates the interoperability of several Federal and State information systems managed by FMCSA, including State information systems operating under the CVISN program, roadside applications operated by law enforcement officers, and other Federal information systems.[2] This safety information exchange allows electronic collection and exchange of safety performance information among States, Federal agencies, and motor carriers.

Where To Apply This Solution

When coupled with roadside electronic screening, electronic credentialing and permitting systems can identify trucks at highway speeds. This allows legal trucks to bypass weigh stations, providing inspectors with real-time data to decide whether to call in vehicles and control the volume of traffic through and around weigh stations.

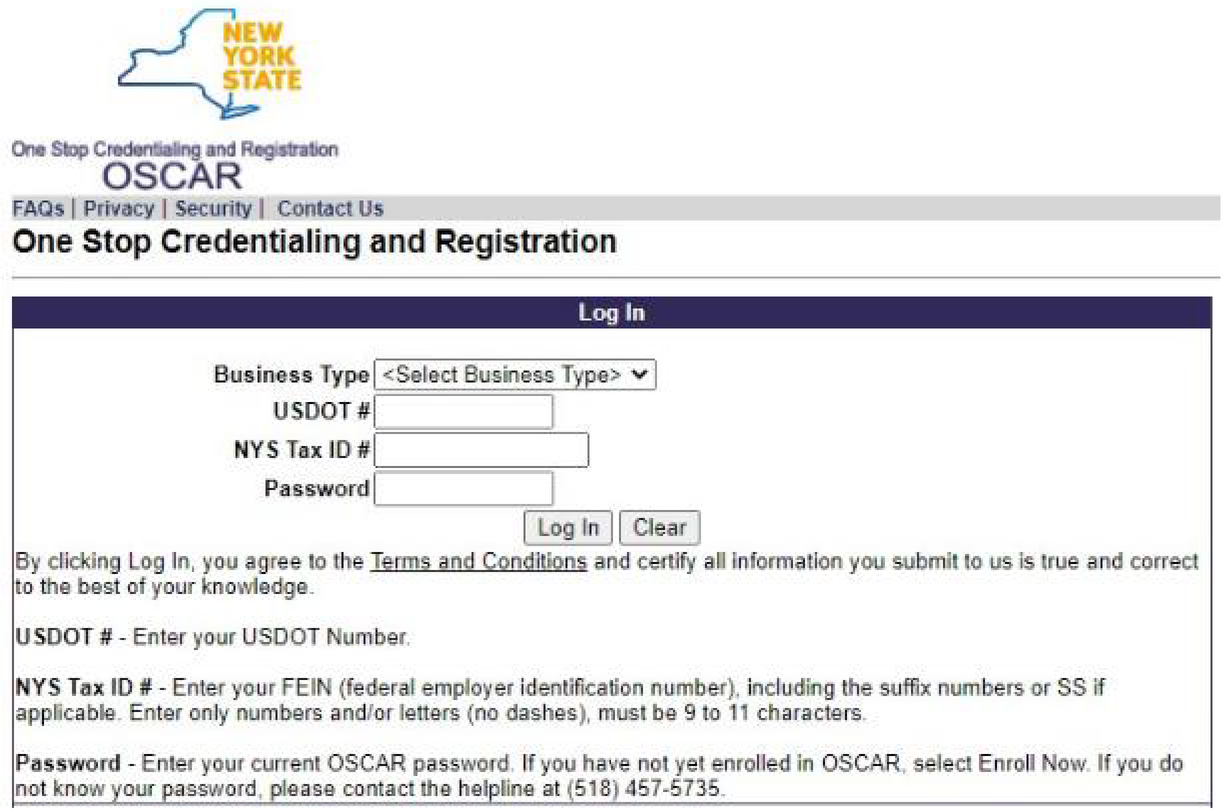
Examples

New York State One-Stop Credentialing and Registration (OSCAR) System

OSCAR is a web-based single point of contact for motor carriers to apply online, pay for, and receive credentials for certain IRP transactions, Highway Use Tax (HUT), IFTA, and certain New York State DOT Oversize/Overweight Permits online (figure 3.3). It replaces a prior system that required carriers to interact with as many as four different State agencies to acquire all required credentials, eliminating the need for multiple forms, multiple visits or contacts, and duplication of effort.[39]

[2]USDOT. n.d. "PIA—Safety and Fitness Electronic Records (SAFER)" (web page), last accessed March 4, 2023.

Figure 3.3. New York State's One-Stop Credentialing and Registration (OSCAR) electronic credentialing portal.



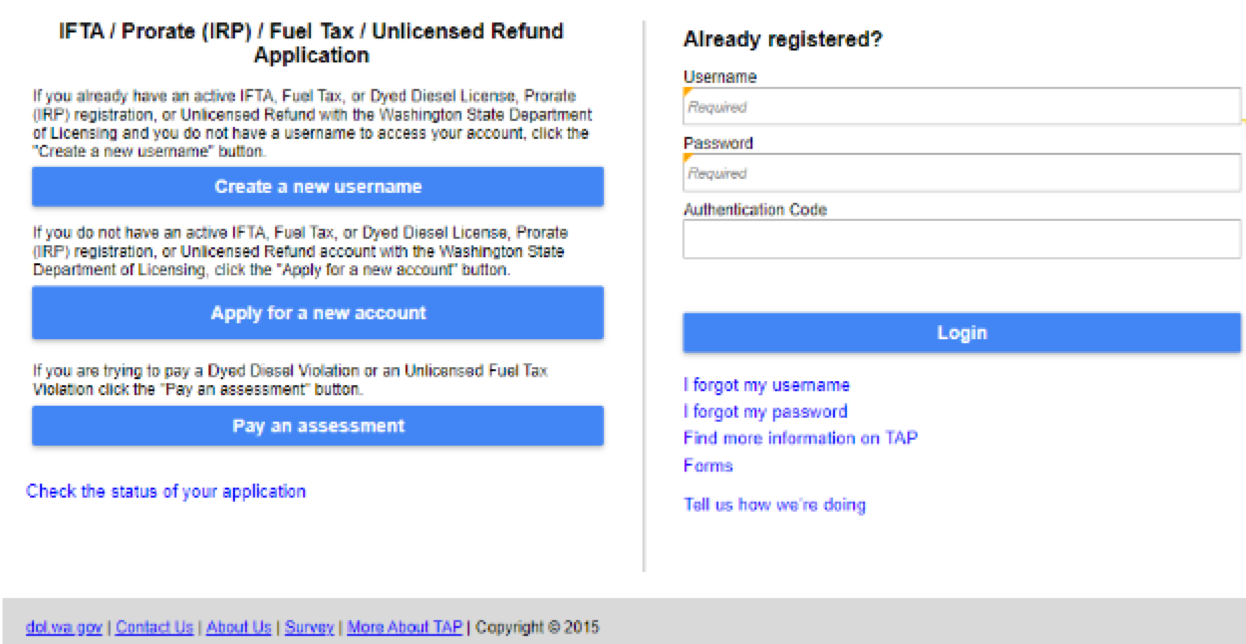
Source: New York State One Stop Credentialing and Registration.

Washington State Taxpayer Access Point (TAP)

The Washington State Department of Licensing's TAP online system can be used by motor carriers to file and pay IFTA, fuel taxes, and dyed diesel tax returns and amended returns; file fuel tax refund claims; file and pay IRP registrations and supplements; and view and print IRP information and temporary authority, tax returns and refund claims, account balances, and correspondence related to one's account (figure 3.4). Oversize or overweight permits can be accessed online through the Washington State Department of Transportation's Electronic System Network for Oversize and Overweight Information (eSNOOPI).

The predecessor of Washington State's TAP system had its basis in a 2004 case study. The electronic credentialing (e-credentialing) system was described as "a computer interface that allows selected motor carriers and private service bureaus to apply for and print commercial vehicle administrative documents (e.g., invoices, temporary operating authorizations, and credentials) in their own offices." Eighteen motor carriers and eight service bureaus took advantage of the e-credentialing system, which was found to save the commercial trucking firms money in reduced shipping and handling expenses and cost efficiencies in turning around credentialing forms, which were formerly cycled from the State to the motor carrier and back. In addition, State inspectors benefited from electronic access to real-time credentialing, safety, and WIM data, which saved time in deciding which vehicles to call in for a closer look and which to return to the roadway. The State also found that the system resulted in safer highways by controlling the volume of traffic flow through and around weigh stations.[40]

Figure 3.4. Washington State's Taxpayer Access Point electronic credentialing portal.



Source: Washington State Department of Licensing.

SMART ROADSIDE COMMERCIAL MOTOR VEHICLE MONITORING

Description

This toolbox solution refers to programs that use roadside technologies to collect information on trucks traveling at highway speeds. This includes:

- Automated USDOT recognition systems and license plate readers for commercial motor vehicle screening
- Thermal inspection systems that can scan axle sets to identify unsafe equipment like inoperative brakes or underinflated tires
- Light detection and ranging (LiDAR) sensors that scan vehicle and load length, width, and height to confirm the vehicles are within size limits

Where To Apply This Solution

This toolbox solution can be applied by transportation, law enforcement, and permitting agencies who share an interest in improving motor carrier safety, security, operational efficiency, and freight mobility. Resources will need to be invested in hardware and software to gather, store, analyze, and share data from moving commercial vehicles, law enforcement, highway facilities, and other transportation facilities. These resources will be of greatest benefit if they include or leverage interoperable technologies; information sharing among in-vehicle, on-the-road, and freight facility systems; and current technology investments that augment existing programs and support new activities.[3]

Like WIM systems, smart roadside monitoring systems do not require vehicles to slow down, providing additional benefits, including automating truck inspection tools, reduced infrastructure damage caused by overloading, safer highway operations, lower overall highway-based vehicle emissions, reduced driver costs, and enhanced global competitiveness, and substantially decreased time between inspections.[4]

Examples

Illinois Department of Transportation (IDOT) Pilot Oversize Vehicle Measurement System

IDOT has implemented a pilot oversize vehicle measurement system at the Maryville weigh station on Interstate 70 (I–70). Trucks are scanned in realtime by LiDAR scanners and high-resolution cameras as trucks approach the scale. Cameras photograph the vehicle and read the license plate. LiDAR sensors scan the truck to measure the length, width, and height. The measurement data is checked against the permit to identify any excessive height, width, or length. The system also counts axles to determine axle spacing and vehicle type. The system is designed to measure and classify vehicles during normal traffic flow. If all of the information gathered is consistent with the permit, the driver is allowed to continue on without stopping.[5]

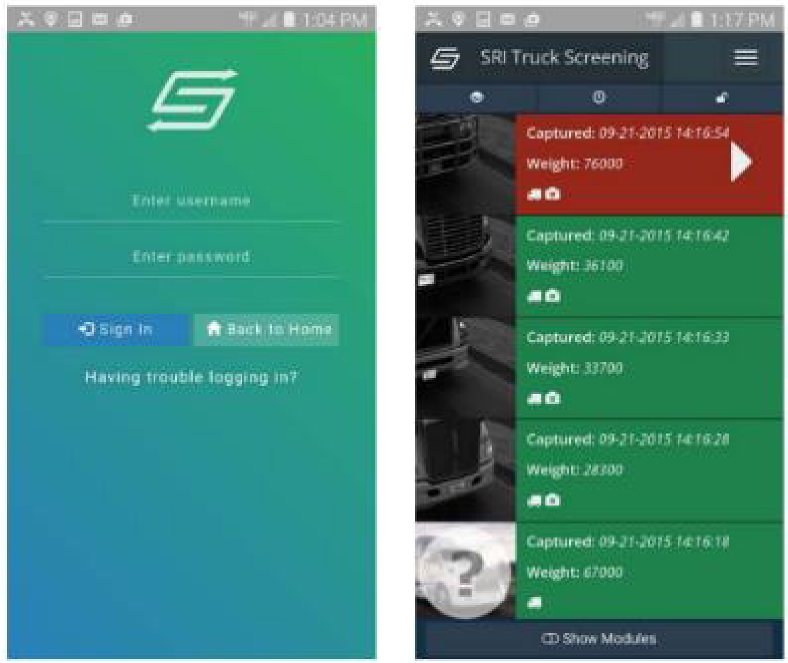
[3]FMCSA. n.d. "Smart Roadside Initiative" (web page), last accessed March 4, 2023.

[4]Schaefer, R., D. Newton, J. Cassaday, C. Black, R. Roth, and D. Stock. 2015. Smart Roadside Initiative Final Report. Report No. FHWA-JPO-16-258. Washington, DC: FHWA. Last accessed March 4, 2023.

[5]IDOT, *IDOT Telegram*, March 2021.

Smart Roadside Initiative (SRI)

Figure 3.5. Smart Roadside Initiative mobile website for law enforcement.



Source: FHWA.

In 2009, FHWA partnered with the FMCSA on the SRI to enhance the collection of information on commercial vehicles by gathering data using roadside technologies while trucks traveled at highway speeds.[41] The SRI system involved the development of a prototype system that was deployed at weigh stations in Michigan and Maryland. It was designed to:

- Extend truck inspection capabilities away from traditional fixed sites to the roadside not by replacing products currently on the market but by providing the means to integrate existing technologies into one user interface
- Streamline how information is located and accessed and improve the accuracy of decisionmaking processes
- Provide a means to electronically identify commercial vehicles at highway speeds and manage the exchange of information between vehicles and infrastructure-based systems
- Enable the delivery of mobile applications that enhance safety and mobility

The pilot projects used the data collected from the roadside systems to develop a mobile website for law enforcement, as well as a mobile application for truck drivers to be notified of whether to pull into or bypass a weigh station up ahead. The mobile website (figure 3.5, left) provided law enforcement officers the ability to use the Smart Roadside truck screening tool from any mobile device, which allowed officers to view weigh station activity without having to be at the weigh station. The mobile application (figure 3.5, right) provided truck drivers with audio and visual cues that notified them to either pull into the weigh station for further inspection or bypass the static scale. Drivers could also access the Truck Smart Parking System to locate available truck parking spaces using the mobile application. The mobile application provided a mechanism for drivers to enter their license number, vehicle identification number (VIN), USDOT number, license plate number, and a photo of their vehicle. It also communicated weigh station instructions back to the driver.[42]

WEIGH-IN-MOTION (WIM)

Description

WIM systems use electronic sensors to measure the features of vehicles as they continue to move at highway speeds. In the freight context, WIM systems can collect data on a truck's weight, height, and speed. WIM systems can also track the time and date of a vehicle's travel, vehicle axle count, axle spacing, axle weight, gross vehicle weight, weight violations, vehicle classification, and overall length.

WIM systems are useful to transportation and enforcement agencies. Data generated from WIM systems are used in pavement and bridge design, truck size and weight enforcement, and the development of transportation policy and projects.[43] WIM data are also useful to law enforcement agencies because they provide real-time information on the weight, speed, and height of passing commercial motor vehicles. This allows officers to prescreen trucks as they enter weigh stations.

When used as an enforcement strategy, WIM is also a solution for improving freight highway performance and reliability. WIM systems can expedite underweight vehicles through the weigh station. This reduces the number of trucks that need to be weighed by static scales. By measuring vehicles while they are moving, WIM systems help reduce congestion and keep freight moving.

Reducing the number of overweight trucks on roadways results in a pavement that suffers less deterioration. Taking overweight trucks off the road leads to less congestion due to bridge and overpass strike incidents. In addition, WIM provides an alternative to fixed roadside weigh stations, which are expensive to construct and can be bypassed by using alternate routes. This can lead to infrastructure deterioration and congestion on those routes.

Where To Apply This Solution

WIM applications can take the following forms:

- Bypass WIM systems installed upstream of weigh stations
- In-station WIM systems used to pre-screen trucks
- WIM used in conjunction with vehicle screening systems
- Mainline data WIM systems used for data collection

Through WIM, transportation and law enforcement agencies can continuously measure trucks traveling on the highway without diverting or stopping them. An example of a WIM system is shown in figure 3.6.

Figure 3.6. Example of a weigh-in-motion system.

Source: WeighingReview.

Examples

Maryland Department of Transportation (MDOT) "Virtual" Weigh Stations

MDOT's virtual weighs stations have been implemented, consisting of an inductive loop, two pairs of WIM sensors, a camera, an overweight detector, and associated information technology systems. The MDOT State Highway Administration (MDOT SHA) selected sites located several miles before fixed weigh stations or along known bypasses to fixed weigh stations. Law enforcement uses a secure, web-based user interface to monitor data on truck size and weight with images of vehicles indicating potential size or weight violations. Law enforcement can target particular trucks for inspection using this information. Law enforcement can also target their enforcement in areas where the data show high frequencies of noncompliant vehicles. In addition, MDOT SHA uses the WIM data to support freight and congestion planning.[44]

New York Truck Weigh-in-Motion System

In other jurisdictions, WIM is not legally authorized to be used for enforcement purposes but can serve data collection and analysis functions. In New York, the New York City Department of Transportation (NYCDOT) partnered with the New York State Department of Transportation (NYSDOT) and the Port Authority of New York and New Jersey to install truck WIM sites between 2013 and 2016 to collect and analyze truck weight data. NYCDOT is using data related to the number of overweight trucks to assess the resulting impact of those trucks on bridges.

NYCDOT is also using the WIM data to manage its truck routes. Similarly, California's WIM sites collect data that are essential for pavement studies, highway monitoring and capacity studies, and crash rate calculations.[45]

California Department of Transportation (Caltrans) Truck Activity Monitoring System (TAMS)

The Caltrans TAMS was initially developed by the University of California, Irvine's Institute of Transportation Studies and sponsored by the California Air Resources Board (CARB) and subsequently was expanded and enhanced in a followup study funded by the Caltrans to over 90 locations in the State of California. TAMS was developed to provide inductive signature-based truck body classification models from WIM and inductive loop detector (ILD) sites. By incorporating data from inductive vehicle signatures, the classification models developed through this research are now able to distinguish over 60 and 40 truck configurations at WIM and ILD sites, respectively. TAMS has been deployed at over 90 locations along major truck routes in California, encompassing State borders, regional cordons, and major metropolitan areas. The web portal for TAMS has an interactive GIS-based interface that provides detailed truck data collected from these sites.[46] Potential future applications for TAMS include estimations of truck movements, empty truck movements, travel behavior of trucks by industry, long- and short-haul trips along major and restricted truck corridors, and other truck travel patterns and behavior data.[47]

TRUCK QUEUE MANAGEMENT AND APPOINTMENT SYSTEMS AT PORTS

Description

Using a truck appointment system at ports allows cargo owners and trucking companies to make appointments to carry out marine terminal transactions within given time windows. Also known as a truck reservation system (TRS), appointment systems have twin purposes: (1) allow drayage firms to make efficient dispatching plans with reduced driver queue times; and (2) let marine terminals control workloads, which reduces drayage congestion and delay.[6]

Where To Apply This Solution

TRS is intended to improve overall cargo efficiency by managing flow in and out of gates using hardware and technology infrastructure to spread out truck volumes across the day. As such, TRS can be useful for port authorities and agencies seeking to reduce driver queue times and port congestion and thereby enhance dispatching and terminal productivity. Truck appointment systems can also benefit transportation and highway agency efforts at alleviating freight congestion on roadways used for drayage purposes.

A caveat to be mindful of regarding TRS is that the variability of traffic mobility and reliability places a limit on the precision of appointment systems. On one extreme, 4-hour windows do not structure or regulate the flow of trucks. Maersk adopted an appointment system at its terminals in Virginia and Mobile, AL, that used 4-hour appointment windows. The system serves primarily as a planning tool for the terminal operators because a driver can make multiple trips in a 4-hour

[6] USDOT Intelligent Transportation Systems Joint Program Office. 2019. "ITS ePrimer Module 15: Port Operations" (web page), last accessed March 4, 2023.

period. At the other extreme, 15-minute windows could not be maintained in ordinary operations due to the inherent variability of both drayage and terminal operations.[7]

Examples

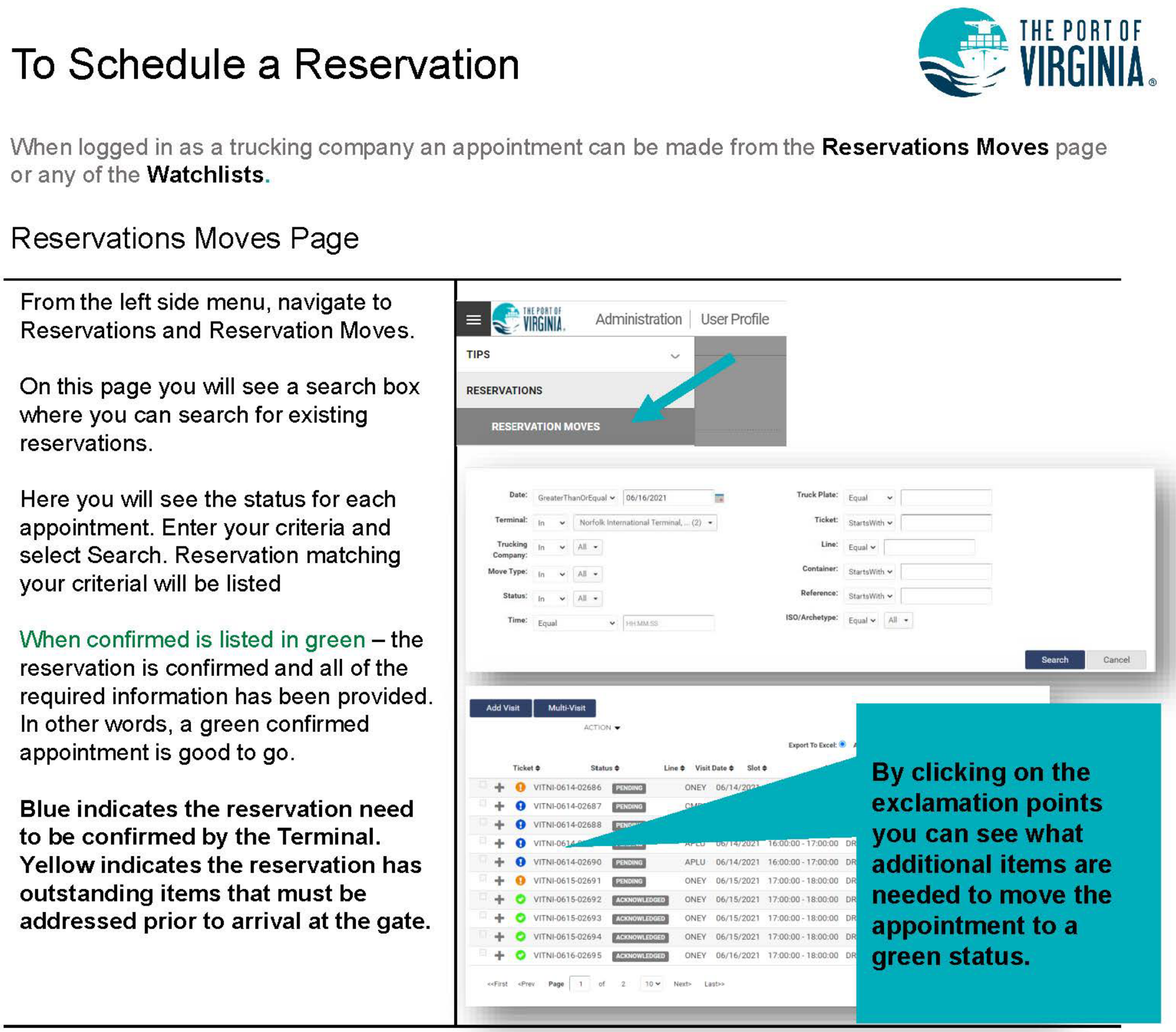
Port of Virginia PRO-PASS®

The Port of Virginia's PRO-PASS® Truck Reservation System moves drivers in and out of terminal gates up to 32 percent quicker than before.

In 2018, the Port of Virginia launched the first phase of its new motor carrier appointment system, the PRO-PASS Trucker Reservation System. The port's Norfolk International Terminal and Virginia International Gateway require motor carriers to have a reservation (figure 3.7).[48] The Port of Virginia's TRS has improved productivity at its Norfolk International Terminal and Virginia International Gateway by reducing truck turn times (a measure of time calculated from the point a truck enters the gate to the point it leaves the gate) up to 32 percent.[49]

[7]National Academies of Sciences, Engineering, and Medicine (NASEM). 2020. Truck Drayage Productivity Guide. Washington, DC: NASEM.

Figure 3.7. Instructions for scheduling appointment reservations at the Port of Virginia through the PRO-PASS Trucker Reservation System.



Source: Port of Virginia, PRO-PASS Portal Guide.

TRUCK PARKING INFORMATION MANAGEMENT SYSTEMS

Description

Truck parking is one of the most critical freight transportation issues in the Nation right now due to the scarcity of parking and the safety and economic challenges that are created when parking is not available. High demand for truck parking and a short supply are intensifying with economic and institutional growth, which increases the number of trucks on the road and truckers needing rest.

Truck parking information management systems disseminate real-time parking information and maximize the use of existing truck parking sites. These systems involve technologies for detecting, estimating, and disseminating truck parking information.

A variety of sensing technologies—including video, in-ground sensors or “pucks,” infrared sensors, above-ground radar, and side laser scanners—provide space occupancy, entrance/exit counts, or area-wide truck identification. Predictive algorithms are used to take the data and estimate utilization by time and day. The data are then disseminated through roadside dynamic message signs (figure 3.8), in-vehicle technologies, mobile apps, and 511 websites.

Figure 3.8. Example dynamic parking capacity sign.

Source: Mid America Association of State Transportation Officials.

Providing truck parking information to commercial drivers has the potential to reduce the searching time for parking and provide safe truck parking alternatives. State DOTs can deploy truck parking information systems that collect and broadcast real-time parking availability to drivers so that drivers may proactively plan their routes and make safer smarter parking decisions.

Where To Apply This Solution

Many State DOTs have completed truck parking studies identifying specific gaps in public and private parking capacity and demand for overnight parking and parking for staging for urban deliveries. These studies have recommended truck parking availability information management and dissemination systems to provide real-time parking information to truckers and maximize the use of existing sites.

It may not be feasible to collect and disseminate truck parking information for every available truck parking location in a given area. However, State DOTs have the ability to track and communicate the availability of truck parking, such as rest areas, and priority locations, such as those located at or near freight generators. Conveying truck parking information in relation to major freight origins and destinations is beneficial in that these locations, and the roadways leading to them, are often congested with commercial vehicles waiting to load or unload but pose mobility and safety challenges to others using the roadway.

State DOTs have a range of strategies to consider in developing and implementing a truck parking information system:

- *Implementation scale*: Even if the State DOT wants to develop a truck parking information system that includes both public and private spaces, the system should be developed and tested at public parking facilities first, while integration and information collection at private facilities are decided.

- *Ownership/management considerations*: Deciding who owns what information, how information is best aggregated and communicated, and whether this information is managed independently from other State DOT information functions will be important no matter the pace and scale of implementation.

- *Stakeholder involvement*: Given the number of actors and entities in the truck parking equation, State DOTs need a robust process for involving stakeholders (e.g., different classes of carriers and drivers, law enforcement at the State and local levels, truck stop operators, mobile application owners/developers, State DOT asset managers).[50]

Examples

Mid America Association of State Transportation Officials (MAASTO) Truck Parking Information Management System (TPIMS)

A number of States are actively pursuing truck parking information systems. On behalf of MAASTO, the Kansas Department of Transportation (KDOT) administered the development of a TPIMS that includes public and private parking spaces in eight States in the MAASTO region. Deployed in 2018, the TPIMS project provides real-time parking availability information to truck drivers through dynamic message signs, mobile applications, traveler information websites, and other communication methods. KDOT installed signs providing the number of available truck parking spaces at 18 rest areas along I–70. Each sign shows parking spaces available for two or three rest areas to give trucks advance notice of how full parking areas are. The system uses cameras to build 3D images of the parking areas, so available spaces can be automatically detected. Most rest areas have two camera poles installed near the truck parking area, and each pole has three cameras mounted on it to produce the 3D image.[51,52] Information on the MAASTO TPIMS is available at https://trucksparkhere.com.

Texas Department of Transportation (TxDOT) Truck Parking Availability System (TPAS)

TxDOT is in the beginning stages of planning for the implementation of its federally funded TPAS for 37 public safety rest areas along I–10 in the 4 States between Los Angeles, CA, and Beaumont, TX. TPAS will use two key systems to determine truck parking space utilization and availability: (1) a site volume approach using in-ground loop sensors to measure truck volume entering and leaving a site, and (2) a vehicle occupancy detection approach using in-ground magnetic sensors to detect if a space is occupied. The choice of deployment between these two technologies at each truck parking site will be determined through subsequent studies. Information on the number of available spaces will be disseminated using dynamic parking capacity signs (DPCS) and mobile or web-based applications.

BORDER WAIT TIME INFORMATION

Description

Delays at border crossings affect freight movement and reliability, posing problems that transportation agencies address through measuring and communicating border wait time information. Transportation agencies can measure border wait time data to improve mobility at border crossings for freight destined for or arriving from Mexico or Canada. Technologies are available to automate the measurement of crossing times and delays at border crossings. Once collected, the border delay and crossing time data can be used to improve mobility. Estimated wait times can be calculated and published through websites, mobile applications, text message and email alerts, and other traditional and social media platforms. In this way, anyone with online access can view the same information, which improves regional communication and decisionmaking. Border wait time data can also be used with ITS technologies, such as variable toll pricing, advanced traveler information systems, and electronic screening, to improve safety and mobility, reduce emissions, and improve security at border crossings.

Where To Apply This Solution

This toolbox solution can be useful to transportation agencies seeking to address freight congestion caused by the unpredictability of border crossing delays. By publishing border delays and wait times, travelers can make more informed decisions as to where and when to cross the border. By coupling border wait time data with ITS applications, travelers can benefit from additional processing and decision-making advantages.

Examples

Federal Highway Administration Research and Guidance

From 2001 through 2011, FHWA conducted research on technologies to automate the measurement of crossing times and delays at northern and southern border crossings. FHWA and State DOT partners implemented projects that deployed radio frequency identification (RFID) technology at land border crossings between Texas and Mexico. The key reason RFID technology was selected to measure crossing times (and later, wait times) was due to the relatively high percentage of commercial vehicles crossing at those locations that already had RFID transponders.

FHWA's research on measuring border delay and crossing times at the United States–Mexico border, summarized in *Measuring Border Delay and Crossing Times at the U.S.–Mexico Border–Part II: Guidebook for Analysis and Dissemination of Border Crossing Time and Wait Time Data*, provides guidance to local, regional, and State agencies regarding how to deploy similar RFID-based border crossing time and wait time measurement systems at the United States–Mexico border. As part of this work, FHWA also produced a prototype web tool to serve as a centralized repository of border wait times and crossing time data from multiple ports of entry (POE) and a platform to archive, process, and disseminate traveler information (current wait times and crossing times of commercial vehicles), as well as archived data related to the performance of POEs.[53]

Niagara International Transportation Technology Coalition (NITTEC)

The NITTEC compiles regional border wait time data and publishes estimated wait times through its website (figure 3.9), a mobile application, text messages, and email alerts. Bluetooth/Wi-Fi-enabled border wait time measuring equipment along border crossing bridges and approaching roadways capture the speed and travel time data to calculate:

- *Actual Delay*: The difference between travel time and the known free-flow travel time
- *Current Delay*: A smoothed delay measure of several data reads, which is the measure that is reported to the public

Figure 3.9. Niagara International Transportation Technology Coalition border wait time dashboard.

Source: Niagara International Transportation Technology Coalition.

Anyone with online access can view the same information, which is intended to improve regional communication and decisionmaking. Along with the Bluetooth readers, the border wait time technology deployments involve license plate recognition (LPR) technology that collects data about the number of Free and Secure Trade–cleared trucks crossing at the bridge and software supporting the compiling, analyzing, and distribution of real-time travel data to the public and other stakeholders.

NITTEC's publicly accessible online travel information clearinghouse has produced freight benefits. Congestion has decreased as travelers make more informed decisions about where and when to cross the border. During severe snow events, local police use NITTEC's clearinghouse to direct truck drivers to temporary parking areas, improving road safety and mobility. Through this initiative, NITTEC was able to develop performance metrics and benchmarks for how often vehicles can cross the border without delay (defined as 30 minutes or more), regularly assessing benchmark progress and sharing results with partners.[54]

Otay Mesa East (OME) Border Crossing

Border wait time data can also be used as part of an Intelligent and Efficient Border Crossing program, where ITS applications are leveraged to improve safety and mobility, reduce emissions, and improve security at border crossings. At the OME border crossing, FHWA and FMCSA are working with Federal, State, and local entities to develop a plan for a tolling system that can accommodate dynamic pricing at the border. The ITS components include:

- Electronic toll collection systems
- Border wait time monitoring systems
- Variable pricing of tolls to reduce wait times
- Enhanced border security systems
- Advanced traveler information systems

International Border Crossing Electronic Screening System (IBC e-Screening)

At a United States–Canadian border site, USDOT is supporting the development of the IBC e-screening for trucks, motor coaches, and buses. IBC e-screening is an alert-based system providing an automated, data-driven approach to the selection of vehicles for inspection at the border.[55]

TRUCK SAFETY WARNING SYSTEMS

Description

Trucks traveling at unsafe speeds or in slippery conditions are at higher risk of crashes. To counter this risk, transportation agencies have taken advantage of sensors and warning systems that detect potential safety issues, inform commercial vehicle drivers of them, and prompt safe driving. Truck safety warning systems typically take the form of dynamic roadway signs but are now being piloted with in-cab applications. Truck safety warning systems include:

- *Truck rollover warning systems*—These systems typically use WIM to measure a truck's weight, axle spacing, and vehicle classification to determine its safe speed. Some also use road surface sensors to detect pavement temperature, wet pavement, ice, and snow buildup, which increase the probability of rollover events. The data measured by the sensors are then processed and disseminated through dynamic message signs (DMS) that warn truck drivers to slow down.

- *Dynamic truck downhill speed warning system*—These systems use WIM sensor information to calculate maximum safe descent speeds for trucks. The safe speeds are then posted on DMS to alert drivers as they approach. Similar systems can notify truck operators driving too fast for safe descents of their speed and warn them to slow down.

- *Bridge and tunnel strike mitigation*—These may take the form of overheight warning systems that detect over-height trucks and activate signs, sirens, or beacons to warn the truck driver to exit the roadway before a strike occurs. Other initiatives include driver education, improved routing, and guidance systems, enforcement technology, in-cab warning systems, and other vehicle-based technologies to monitor loads.

- *In-cab alerts*—These systems provide warnings in realtime of traffic congestion or sharp curves ahead, reducing hard-braking incidents and giving truck drivers time to reduce their speeds safely.

Where To Apply This Solution

This toolbox solution can be applied to roadway segments that have been the site of truck crashes or near-misses due to a lack of warning of bottleneck congestion ahead, rollovers, unsafe downhill speeds, or bridge or tunnel strikes. Such systems may be considered a less costly alternative to capital projects involving road, bridge, interchange, or other highway redesign and reconstruction that increase capacity, raise bridge or tunnel heights, or change ramp geometry or grade.

Examples

Minnesota Department of Transportation (MnDOT) Truck Rollover Warning System (TROWS)

MnDOT implemented a TROWS project in 2015 at the ramp from southbound I–694 to eastbound I–94. This location was selected due to the number of large truck rollovers that occurred there, experiencing the second most truck rollovers in the State. The warning system uses both WIM and road surface detection technologies, incorporating truck rollover and road condition warnings into a single site. Along with the WIM sensors, a two-message blank-out sign display was also installed, displaying LED Truck Rollover (W1-13) and a Slippery When Wet (W8-5) signs. A secondary sign displays an advisory speed for trucks approaching an unsafe speed on the ramp (figure 3.10).[56]

Figure 3.10. Minnesota Department of Transportation (MnDOT) Truck Rollover Warning System sign.

Source: MnDOT.

Washington Beltway (I–495) TROWS

A truck rollover warning system was also installed at three curved exit ramps on I–495 in Virginia and Maryland in 1993. On-site sensors and computers detected truck speeds, weight, and height classification and then calculated the probability a truck would roll over as it approached. If a truck was at risk, a roadside warning sign was activated to alert drivers to slow down. A study of the system found that no crashes were reported at the sites during the 3-year postdeployment test period.[57]

Colorado Department of Transportation (CDOT) Downhill Speed Warning System (DSWS)

CDOT implemented a dynamic truck DSWS on I–70 in 1993. WIM sensor information was gathered to calculate maximum safe descent speeds for trucks, which were posted on DMS to alert drivers as they approached. A study found that installation of the system resulted in a 13-percent decrease in the number of crashes and a 24-percent reduction in the use of truck runaway ramps in the area during the 2-year period following deployment.[58]

New Jersey Department of Transportation (NJDOT) In-Cab Alert System

In January 2022, NJDOT announced the launch of a new real-time in-cab traffic alert system to warn truck drivers of congestion ahead. The system, developed by Intelligent Imaging Systems and INRIX, provides safety notices to all carriers and drivers using the Drivewyze PreClear software. Through electronic logging devices and other in-cab devices, truck drivers can be alerted to congestion through in-cab traffic alerts provided by the NJDOT on State highways, including the New Jersey Turnpike, Garden State Parkway, and Atlantic City Expressway. The alerts warn of slow-moving traffic several miles ahead, giving drivers additional time to slow down (figure 3.11). By warning them of congestion that is miles ahead, drivers of large commercial vehicles will have the extra time needed to safely slow down.[59]

Figure 3.11. In-cab safety alert.

Source: Drivewyze

Case Study: Georgia High-Risk Commercial Motor Vehicle Notification Project

In 2020, the Georgia Department of Transportation (GDOT) partnered with the electronic logging device (ELD) service provider Drivewyze to conduct a High-Risk CMV Notification Program Pilot Project in metropolitan Atlanta that would evaluate whether safety messages to commercial vehicle drivers would reduce the number of hard-braking events. The ultimate goal of the project was to improve safety for commercial vehicles, which have a high rate of fatalities and serious injury due to rear-end collisions. Rear-end collisions are a leading factor in commercial vehicle fatalities and incidents, so the project sought to reduce the number of hard-braking events to make roadways safer for commercial vehicles.

GDOT determined project locations following an evaluation of high-risk areas using crash data. The analysis narrowed locations down by selecting areas where crashes involving commercial motor vehicles occurred that were challenged by roadway geometry and relatively high AADT and truck percentages.

The pilot project used two groups within Drivewyze's commercial truck population to observe during a 30-day period. Commercial drivers who were enrolled in Drivewyze's Safety Notification Program received succinct safety messages through their electronic logging device (ELD), while commercial drivers who were not enrolled in the program did not receive the safety message. The safety messages were intended to not be distracting, displaying the following:

The differences in how the two groups reacted to safety incidents, slowdowns, and congestion were then compared, most notably the differences in hard-braking events.

The pilot found that safety messages appeared to show a mild to moderate impact on hard-braking events. The results indicated that providing safety messages through ELDs reduced the number of hard-braking events by almost 20 percent at some of the test locations. Commercial drivers appeared to drive more safely and respond to the safety message in the test locations.

The High-Risk CMV Notification Program Pilot Project was extended for another year, and GDOT nominated the project for the American Association of State Highway and Transportation Officials (AASHTO) Innovation Initiative in September 2021. GDOT's potential next steps are to expand the project to additional static locations and to dynamic messaging.

For more information, see the detailed case studies in Appendix A.

WORK ZONE MANAGEMENT FOR TRUCKS

Description

Work zones are necessary to maintain transportation network operations while maintaining and upgrading the highway system but can pose mobility and safety risks for passengers, drivers, and construction workers. In and around work zones, traffic patterns can change, speed limits may be reduced, rights-of-way can narrow, construction workers could be present, and work vehicles could be entering or leaving the construction area. These conditions give rise to slower moving traffic and work zone crashes and fatalities, which have been increasingly impacting more people, including commercial vehicle operators.[8]

The FMCSA reports that, in 2019, 33 percent of work zone fatal crashes and 14 percent of work zone injury crashes involved at least one large truck.[9] This is up from 2017, when 30 percent of work zone fatal crashes and 12 percent of work zone injury crashes involved at least one large truck.[10] In addition to safety concerns, work zones are responsible for almost one-quarter of all non-recurring freeway delays.

Improving large truck safety in work zones can be implemented through work zone design practices to better accommodate large trucks and/or assist drivers of large trucks to better negotiate work zones. Work zone design practices for trucks include:

- Considering the effect of large trucks on capacity and operations in work zone traffic impact analyses
- Providing at least one 12-foot lane for trucks in construction projects or a truck-only lane during construction
- Providing an additional 1-foot buffer if a barrier is used
- Designating detour routes around work zones for oversize/overweight trucks
- Encouraging the use of alternate routes (and designating them as detour routes) for large trucks around work zones if the alternate routes can accommodate them
- Establishing a truck-only lane through the work zone and diverting automobiles to a detour route around the work zone
- Avoiding large design-speed reductions for lane shifts, crossovers, or other critical geometric features in work zones of more than 10 miles per hour below the normal speed limit
- Avoiding using rest area truck parking lots for staging construction equipment and materials

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[8]Paracha, J., and R. Ostroff. 2018. "Improving Work Zones Every Day, in Every Way." *Public Roads* 82, no.2, last accessed March 4, 2023.

[9]FMCSA. n.d. "Large Truck and Bus Crash Facts 2019" (web page), last accessed March 4, 2023.

[10]FMCSA. n.d. "Large Trucks and Buses by the Numbers" (web page), last accessed March 4, 2023.

- Using high-performance sheeting on signs and channelizing devices for greater nighttime visibility for truck drivers
- Incorporating minimum reflectivity specifications for signs and channelizing devices into bid documents to maintain sufficient nighttime visibility
- Incorporating regular cleaning of signs and channelizing devices into bid documents to maintain sufficient nighttime visibility for truck drivers
- Considering the addition of a construction delivery work zone speed limit compliance requirement into bid documents
- Avoiding the creation of traffic queues
- Avoiding short or no acceleration lane entrance ramps
- Providing proper work space ingress and egress design and warning
- Considering access issues for incident response on hazardous materials routes
- Considering the use of high-level crash attenuation devices for work zones (figure 3.12).[60]

Figure 3.12. Truck in Work Zone Equipped with Attenuator.

Source: Texas A&M Transportation Institute.

Strategies and technologies to help truck drivers better negotiate work zones include:

- Encouraging truck drivers to activate emergency flashers whenever stopped or slowed at a work zone
- Providing outreach information about work zones and work zone challenges at truck stops, rest areas, dispatching at major trucking companies, and other points of contact with the trucking community
- Deploying smart work zone queue warning and/or dynamic lane merge warning systems when and where traffic queues are expected
- Deploying temporary portable rumble strips and optional signs warning of their presence upstream of temporary lane closures
- Deploying sequential warning light systems on channelizing devices used in the taper of nighttime lane closures
- Using enforcement presence at least 0.25-mile from the end of the queue[61]

FHWA, through the Smarter Work Zones (SWZ) initiative, provides additional strategies, including:

- Traveler information systems that provide drivers with real-time travel conditions prior to and within a work zone, as well as alternative routes in the corridor, to divert drivers away from the work zone when congestion exists

- Dynamic lane merge systems that encourage motorists to merge at specific points as they approach a lane closure, depending on current operating conditions

- Incident management systems that enable agencies, contractors, and responders to detect incidents in the work zone faster, allowing quicker response and clearance

- Variable speed limit systems that harmonize speeds before and within the work zone, calming traffic flow and warning of slowed or stopped traffic ahead

- Automated speed enforcement systems that detect and capture images of speeding vehicles for enforcement purposes

- Entering/exiting vehicle notification systems that warn drivers of slow-moving construction vehicles that may be entering the travel lane

- Sequential warning lights on temporarily deployed cones or barrels that improve recognition of nighttime lane closures for work zones by clearly delineating the lane taper area

- Overdimension warnings that give compliance notifications of temporary minimal width or height clearances as large vehicles approach the work zone [62,63]

- Dynamic lane merge systems that encourage motorists to merge at specific points as they approach a lane closure depending on current operating conditions

- Incident management systems that enable agencies, contractors, and responders to detect incidents in the work zone faster, allowing quicker response and clearance

These strategies have been compiled in the National Work Zone Safety Information Clearinghouse and FHWA's Smarter Work Zones (SWZ) initiative. A part of Round 3 of FHWA's Every Day Counts (EDC) initiative, SWZ includes two strategies:

1. *Project coordination* to harmonize construction projects and reduce work zone impacts
2. *Technology applications* to dynamically control traffic in and around work zones

Project coordination is promoted by SWZ to encourage the synchronization of work zones within a corridor, network, or region across agency jurisdictions to minimize combined impacts on travelers and produce time and cost savings. Early identification of potential impacts enables agencies to improve the coordination of construction activities, resulting in a greater ability to reduce and manage traffic disruptions from road work, minimizing delays in freight movements through the region.

Project coordination strategies may be carried out through Transportation Management Plans (TMP) that incorporate truck considerations. TMPs lay out a set of coordinated transportation management strategies and describe how they will be used to manage the work zone impacts of a road project. Transportation management strategies for a work zone include temporary traffic control measures and devices and operational strategies such as travel demand management, signal retiming, and traffic incident management.[64]

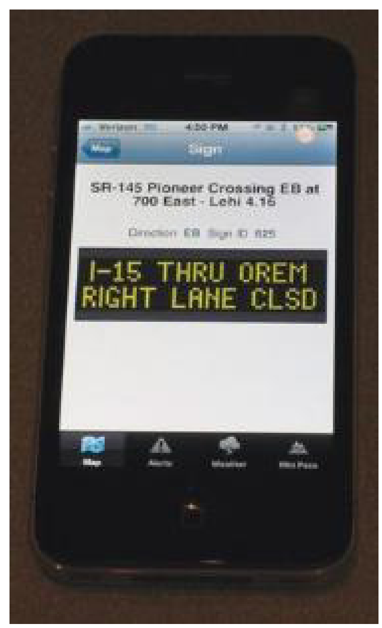
FHWA's Work Zone Management Program includes public information as "the best work zone impact mitigation strategy that may lead to significant traffic reductions."[65] As such, TMPs should include public information and outreach strategies to inform those affected by the project of expected work zone impacts and changing conditions. As part of this outreach, transportation agencies should target commercial vehicle operators as a key audience and provide truck driver-focused information, tailoring outreach to truck drivers.[66]

More information on work zone management can be found at: https://ops.fhwa.dot.gov/wz/.

Where To Apply This Solution

Large trucks must contend with unique challenges when driving through work zones. Longer stopping distance requirements, larger blind spots, reduced maneuverability due to narrower lanes, and reduced brightness or increased glare during nighttime operations create hazards that can lead to injuries and fatalities.

Figure 3.13. Mobile application showing real-time warning of work zone closure ahead.



Source: Federal Highway Administration.

Transportation agencies apply work zone management for trucks on freight corridors to maintain safety for both motorists and workers, minimize traffic delays, complete roadwork in a timely manner, and maintain access for businesses and residents. Work zone management strategies are available to address specific safety and mobility needs of trucks that keep workers and all travelers safe.[67,68] These strategies targeted at trucks can be incorporated into work zone transportation management plans and work zone traffic impact analyses.

A key component of work zone management for trucks is truck driver–focused information and outreach. Some States provide pretrip and en route traveler information to warn truck drivers of work zones ahead (figure 3.13). Some of these systems use up-to-date information about dynamic conditions occurring on roads, such as construction events, from USDOT's Work Zone Data Exchange (WZDx). FHWA established the WZDx to aid in the creation and adoption of a consistent language for communicating work zone activity data across jurisdictional and organizational boundaries. The WZDx specification enables infrastructure owners and operators to make harmonized work zone data available for third parties (including original equipment manufacturers (OEM) and navigation application developers) who will use the data to help automated driving systems (ADS) and human drivers navigate more safely.

Examples

Utah Department of Transportation (UDOT)

Work zone outreach specifically for truck drivers was conducted by UDOT as part of the I–15 CORE Project. UDOT developed a project website with tips for truck drivers and dispatchers.[11]

North Carolina Department of Transportation (NCDOT)

NCDOT informs the trucking industry of work zones, focusing on distribution channels that truckers use on a regular basis, including trucking industry and association print and online publications; truck/rest stops; and CB, satellite, and commercial radio.[12] NCDOT also piloted a new trucking alert system from 2021 to 2022 on I–95 and I–40 to reduce the risk of truck crashes and keep work zones on highways flowing smoothly. The system was developed in partnership with Intelligent Imaging Systems to provide in-truck messaging that alerts truck drivers in realtime of urgent road conditions. The goal was to help commercial drivers react more quickly before encountering dynamic message signs notifying drivers of stopped traffic or major slowdowns. The alerts displayed messages such as "Sudden Slowdown Ahead" and "Congestion Ahead" about two to three miles before commercial truck drivers encountered the slowed traffic or incident.[13]

Texas Department of Transportation (TxDOT)

TxDOT designed an innovative end-of-queue warning system as part of a project to widen I–35 through central Texas. The end-of-queue warning system was composed of:

- A portable work zone queue detection and warning system deployed upstream of the merging taper on each night that queues were expected and removed the next morning along with the taper
- Portable rumble strips deployed in the travel lanes upstream of the merging taper to provide tactile, audible, and visual alerts as the driver approached a lane closure (figure 3.14).

Due to this system, crashes were reduced by 18 to 45 percent compared with an estimate of what they would have been without the system. This resulted in savings of between $1.4 million and $1.8 million in societal crash costs and ongoing savings of societal crash costs of between $6,600 and $10,000 per night of deployment.[69]

BENEFITS OF TEXAS DEPARTMENT OF TRANSPORTATION END-OF-QUEUE WARNING SYSTEM

- 18- to 45-percent reduction in crashes
- $1.4 to $1.8 million in savings of societal crash costs
- $6,600 to $10,000 per night of deployment in ongoing savings of societal crash costs

[11]FHWA. n.d. "Project-Level Public Information and Outreach Examples" (web page), last accessed March 4, 2023.
[12]FHWA. n.d. "Communicating Work Zone Information To Truckers in North Carolina" (web page), last accessed March 4, 2023.
[13]NCDOT. n.d. "NCDOT Pilots New Commercial Trucking Alert System" (web page), last accessed May 20, 2021.

Figure 3.14. Texas Department of Transportation end-of-queue warning system consisting of (from left to right) portable rumble strips, speed sensor, and portable changeable message sign.

Source: Texas A&M Transportation Institute

CONNECTED AND AUTOMATED VEHICLES TECHNOLOGIES

Description

Over time, the supply chain will become increasingly automated, with trucks outfitted with automated vehicle (AV), connected vehicle (CV), and connected and autonomous vehicle (CAV) technologies. Automated vehicle technologies equip trucks with driving automation hardware and software that allow a safety-critical control function (e.g., steering, throttle, or braking) to occur without direct commercial driver input. Automated trucks could be autonomous, using only vehicle sensors, or connected, using communications systems that allow cars and roadside infrastructure to communicate wirelessly.[70]

Automated trucks have the potential to produce safety, mobility, and environmental benefits such as crash avoidance, reduced energy consumption and vehicle emissions, reduced travel times, improved travel time reliability and multimodal connectivity, and improved transportation system efficiency. Automated vehicle technology is being developed in almost every type and mode of surface and air freight transportation, including:

- Long-haul trucking
- Local freight delivery
- Package delivery vehicles using streets and sidewalks
- Terminal operations
- Unmanned aerial drones
- Autonomation in maritime, air cargo, and railroad operations

Automated vehicle technology can also provide a path to automated terminal equipment and autonomous freight delivery, with trucks interfacing with automated equipment and facilities at intermodal terminals, distribution centers, shippers, and receivers (figure 3.15). In addition, automated trucks equipped with CV technologies will display cooperative automation, which allows vehicles to communicate with others and infrastructure to coordinate movements and increase efficiency and safety. Examples of cooperative automation applications include vehicle platooning (i.e., platooning of linked vehicles that follow each other closely, with the vehicle at the front of the platoon acting as its leader so that vehicles behind the leader automatically react and adapt to changes in the lead truck's movement), speed harmonization, and cooperative lane change and merge functions to safely mitigate traffic.[71]

Figure 3.15. Automated commercial vehicle application to intermodal port facilities.

Source: United States Department of Transportation.

Where To Apply This Solution

For transportation agencies, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and infrastructure-to-vehicle (I2V) connectivity could improve the monitoring and reporting of road conditions. In fact, State DOTs are currently participating with the private sector and research institution partners in tests of heavy-duty CAVs within a V2I environment, where a bidirectional wireless exchange of data between vehicles and the road and roadside infrastructure can take place. V2I applications can potentially mitigate congestion and assist with lane management and signal operations. State DOTs are using this research to identify locations where V2I makes sense, including work zones and freight bottlenecks, where end-of-queue technology could be evaluated and where automation may be most practical, such as port drayage.[72]

Intermodal port facilities could benefit from applications of automation, enabling more seamless transfers of goods and a less strenuous experience for operators. The Maritime Administration (MARAD) and FMCSA are jointly exploring how truck automation might improve operations at intermodal port facilities, evaluating the regulatory and economic feasibility of using automated truck queueing as a technology solution to truck staging, access, and parking issues at ports. The study will investigate whether full or partial automation of queueing within ports could lead to increased productivity by altering the responsibilities and physical presence of drivers, potentially allowing them to be off-duty during the loading and unloading process.[73]

Examples

USDOT is supporting the advancement of CV technology with a pilot deployment program, awarding cooperative agreements to three pilot sites being led by the New York City Department of Transportation (NYCDOT), the Tampa Hillsborough Expressway Authority (THEA), and the Wyoming Department of Transportation (WYDOT).

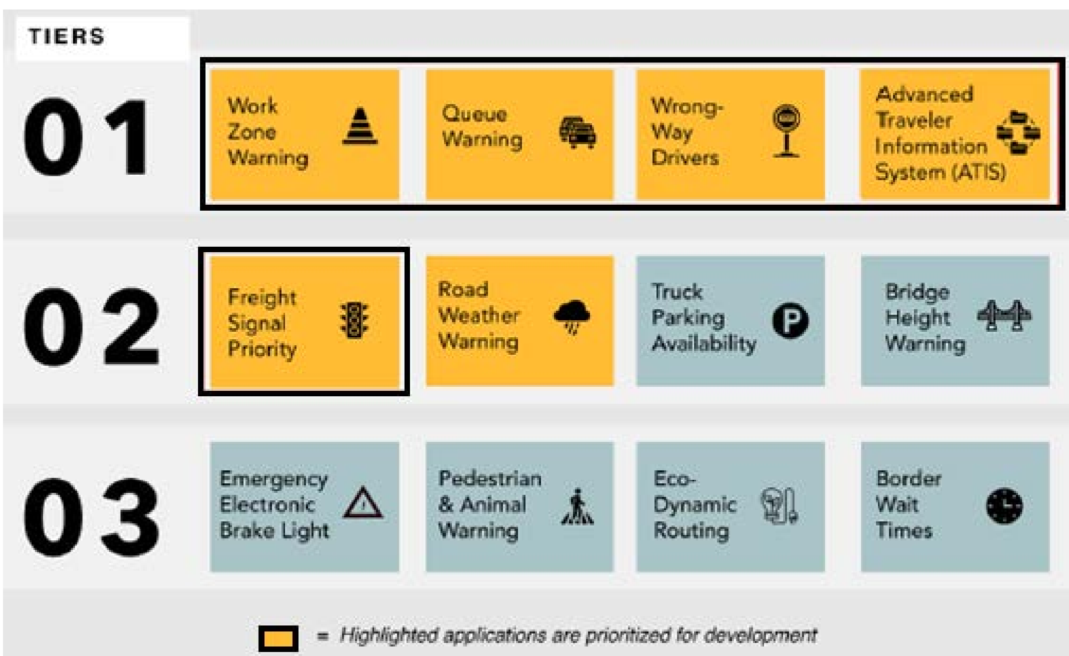
The WYDOT project deployed dedicated short-range communications (DSRC) for V2V and V2I communication along I–80, with 75 roadside units and 400 instrumented fleet vehicles to support a range of services from advisories, including roadside alerts, parking notifications, and dynamic travel guidance. WYDOT's CV pilot project is deploying forward-collision warnings, push notifications relaying roadway conditions, work zone warnings, spot weather impact warnings, and distress notifications to participating vehicles. Through this effort, the project will contribute to universal standards of connected vehicle technology and systems and determine how equipment should be placed in vehicles for best communication.

Case Study: Texas Connected Freight Corridors

Connected and automated vehicles (CAV) have the potential to improve safety and mobility for freight vehicles on the Nation's roadway network. Further, advancements in multimodal CAV could lead to a highly automated and technical logistics system linking modes in new ways and changing supply chain processes. To prepare for and facilitate CAV development and implementation, Texas is working to implement a freight CAV ecosystem through its Texas Connected Freight Corridors (TCFC) project. This federally funded project will develop the concept of operations, designs, and plans and then ultimately begin the implementation of the technological elements to support the safe and efficient adoption of CAV for freight.

The TCFC project's goal is to provide Texas' most significant deployment of CAV vehicle technology to improve freight travel and implement a sustainable CAV ecosystem along the Texas Triangle, 865 miles of a triangle of Interstates in Texas including I–35, I–45, and I–10. The ecosystem will include up to 12 vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) applications focused on freight safety and mobility. The project has a 4-year timeline and is currently underway.

The project has developed a concept of operations that outlines how technologies would support truck drivers and managers. This concept of operations includes scenario analysis to determine the types of incidents a truck driver encounters daily on the Triangle and a warning system for drivers. To date, the first few applications developed include queue warnings, work zone warnings, wrong-way driving alerts, and truck signal priority. Others to be developed include truck parking availability and border wait times, as shown below.



Source: Texas Department of Transportation.

For more information, see the detailed case studies in Appendix A.

ROAD WEATHER MANAGEMENT

Description

Weather is a major factor in travel time reliability, delays, and safety for freight movement that transportation agencies address through road weather management strategies. Weather events can vary in type and severity but pose safety and mobility challenges that transportation agencies must contend with through road weather management systems.

- Rain affects all vehicles, but especially commercial vehicles, by causing wet pavement, which reduces vehicle traction and maneuverability, as well as causing low visibility. Each year, 75 percent of weather-related vehicle crashes occur on wet pavement, and 47 percent happen during rainfall.

- Flooding reduces roadway capacity by limiting or preventing access to submerged lanes.[14]

- Snow and ice reduce pavement friction and vehicle maneuverability, causing slower speeds, reduced roadway capacity, and increased crash risk. Average arterial speeds decline by 30 to 40 percent on the snowy or slushy pavement. Freeway speeds are reduced by 3 to 13 percent in light snow and by 5 to 40 percent in heavy snow.[15]

- Hurricanes and tropical storms bring heavy rain and high winds to coastal areas and often cause inland flooding, which has typically been the greatest source of fatalities, and cause damage to roadway infrastructure.[16]

Also referred to as Weather Responsive Traffic Management (WRTM), road weather management promotes the use of road weather data from mobile and connected vehicle technologies to support traffic and maintenance management strategies during inclement weather. WRTM is an FHWA initiative under its Road Weather Management Program (RWMP). WRTM supports traffic management agencies and personnel as they implement three types of strategies to mitigate mobility and safety challenges due to adverse weather:

- *Advisory strategies* that provide information on prevailing and predicted conditions to both transportation managers and motorists

- *Control strategies* that alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity

- *Treatment strategies* that supply resources to roadways to minimize or eliminate weather impacts

WRTM is a set of such strategies that includes traffic advisories, alerts and warnings, speed management, vehicle restrictions, and signal timing, as well as improved incident management. WRTM strategies also promote the use of road weather data from mobile and connected vehicle

[14] FHWA. n.d. "Rain and Flooding" (web page), last accessed March 4, 2023.
[15] FHWA. n.d. "Snow and Ice" (web page), last accessed March 4, 2023.
[16] FHWA. n.d. "Hurricanes and Rain and Flooding" (web page), last accessed March 4, 2023.

technologies to support traffic and maintenance management strategies during inclement weather.[74]

WRTM strategies and technologies being deployed by State DOTs include:

- *Speed management systems*—Speed advisories and enforceable variable speed limits can be used to reduce speeds and speed variance during inclement weather conditions. Nonenforceable speed advisories can be issued in response to deteriorating weather conditions to achieve voluntary compliance with a recommended safe travel speed for prevailing conditions. Enforceable variable speed limits take the form of new speed limits or speed restrictions in direct response to weather conditions communicated via variable message signs (VMS) and/or variable speed signs (VSS).[75]

- *Low visibility and high wind warning systems*—Passive, active, pretrip, and en route warning systems can be used to provide travelers with advisories, alerts, and warnings before and during their travel and increase their awareness of current and impending weather conditions, including low visibility and high winds.[76]

- *Forward-collision warnings*—These systems provide advance warning of lane closures and slow or stopped traffic due to road conditions or incidents. Dynamic message signs and in-cab alerts (where systems are in place) can be used to notify downstream traffic of a lane closure or slow or stopped traffic ahead. By sequencing messages upstream of the closure, this signing strategy provides advance information to approaching motorists to encourage drivers to anticipate slowing or stopping or vacating closed lanes further upstream.[77]

- *Traveler information 511 sites*—A transportation and traffic information platform that can be accessed by telephone or any Internet-enabled device, 511 provides a means to provide pretrip and en route road and pavement condition information, weather alerts, and forecasts. Like VMS, 511 provides travelers with information about current and forecasted weather and pavement conditions before they initiate their trips in an attempt to influence their choice of travel mode, departure time, or route. While en route, 511 can provide real-time information and alerts about specific weather and pavement conditions currently existing or developing ahead.[78]

- *Maintenance Decision Support Systems (MDSS)*—These systems can help agencies make decisions about when and what kind of road weather management strategy to implement. This component would contain the rules and criteria for when and where to implement the various active signal management strategies. Measured weather, roadway surface, and traffic conditions can be compared to agency criteria established for each of the management strategies approved by the agency, with the outputs producing the recommended strategy.[79]

- *Transportation operations center*—Integration of weather and emergency systems and information into transportation operations centers coupled with effective deployment of ITS will improve performance and offer benefits in increased public mobility, safety, and security. Weather integration supports a TMC's ability to manage traffic, dispatch maintenance forces, and address weather-related emergencies. This is accomplished by providing TMC operators with accurate and timely weather and road condition information, effectively integrating weather and traffic information, and providing automated notifications and decision support. A potential benefit of integration is more efficient winter road maintenance operations by providing information, including ITS-generated traffic and road condition information, to support treatment strategies.[80]

- *Emergency truck parking*—During severe weather events, truck drivers need emergency parking areas as a safe haven until the storm passes and roads are safe to drive on. State DOTs can identify emergency lots for use during extreme weather events and make communication tools available to truck drivers to proactively alleviate future truck parking capacity issues.[81]

- *Connected vehicle-enabled weather responsive traffic management (CV-WRTM)*—This strategy takes advantage of the potential offered by CVs, leveraging vehicle connectivity to develop new WRTM tools.[82]

WRTM strategies and technologies are described in further detail in the following documents:

- FHWA, *Road Weather Management Program: Best Practices for Road Weather Management*

- FHWA, *Road Weather Management Program: Best Practices for Road Weather Management – Case Studies*

- Gopalakrishna et al., *Developments in Weather Responsive Traffic Management Strategies*, June 2011

Where To Apply This Solution

Road weather management strategies can be implemented by State DOTs wherever they have identified locations affected by the adverse consequences of rain, flooding, snow and ice, and hurricanes and tropical storms on truck traffic and safety. Successful deployment of WRTM strategies depends upon an agency's ability to collect and integrate traffic, weather, and road condition data to effectively analyze the impacts of weather conditions and deliver information back to drivers.[83]

Examples

Colorado Department of Transportation (CDOT) Variable Speed Management System

CDOT installed a Variable Speed Management System consisting of a road weather information system (RWIS) that used nonintrusive pavement weather sensor technology. The sensors monitored traction/friction conditions in shaded areas and allowed for alerts when conditions warrant. The system monitored wet conditions, wet conditions with traction loss as freezing begins, and snow and ice conditions. It communicated wirelessly to a single variable message sign (VMS) and a single variable speed sign (VSS) located nearly a mile in advance of this northbound section of Colorado State Highway 82 in Snowmass Canyon (figure 3.16). As a result of this system, the first winter of operation saw no winter weather-related crashes in this section of the highway.[84]

Figure 3.16. VMS Alerting Drivers of Wet Road Ahead on CO-82

Source: Federal Highway Administration.

Wyoming Department of Transportation (WYDOT) Variable Speed Limits (VSL)

WYDOT established regulatory electronic VSL along sections of highway based on traffic volumes, crash histories, and frequency of severe weather. WYDOT's Transportation Management Center (TMC) used the VSL to alternate speed limits when weather and road conditions deemed necessary, often reducing speeds to help prevent closure frequency caused by crashes. Since travel speed depends upon each driver, speeds can vary widely. This variance in speed can cause safety issues. These signs help to pull outliers into a pace speed and reduce closure-causing crashes. The VSL signs allow WYDOT to tailor the speed limit to match road conditions on highway sections as short as 2 miles in length. The posted speed limit can be changed almost immediately after a reduction is recommended by WYDOT maintenance personnel or Highway Patrol troopers in the area. In areas where signs are used, sensors are embedded in the pavement and installed alongside the road to help monitor traffic flow.

WYDOT Road Condition Reporting Application

WYDOT developed a new software application to improve the way maintenance personnel report road and weather conditions to their statewide TMC, recommend variable speed limit (VSL) changes, and report a number of different traffic incidents, including crashes and road hazards (figure 3.17). The primary goal of the WYDOT project was to improve maintenance staff road condition reporting. Specific objectives were to:

- Improve the efficiency of road condition reporting using a mobile application

Figure 3.17. Wyoming Department of Transportation (WYDOT) road condition reporting application

Source: WYDOT.

- Improve the efficiency of the TMC operations in taking actions based on the reported road conditions
- Improve the timeliness of updated traveler information
- Improve the situational awareness of maintenance staff in the field regarding road weather conditions

The road condition reporting application was built to run on a tablet computer installed in WYDOT plow trucks. It utilizes Wyoming's statewide communication system backbone, called WyoLink, to report road conditions to the TMC. The application is also used to share information with maintenance employees, including road conditions, variable speed limit information, weather information, messages posted on dynamic message signs, and map-based asset location information. The accuracy of information from the field was substantially improved for road condition reporting and incident reporting. Increased frequency of road condition reporting also improved the timeliness and accuracy of traveler information provided to the motorists.[85]

California Department of Transportation (Caltrans) Low Visibility Warning System

In 2009, Caltrans integrated a fog detection and warning system along a 13-mile section of the California Highway 99 corridor in the central part of the State. The system consists of visibility sensors, speed detectors, and cameras to detect congestion and visibility problems that could affect driver and passenger safety. It alerts motorists automatically of dangerous weather conditions and slow speeds by using changeable message signs (CMS), highway advisory radio (HAR), and the 511 web page and telephone system. Using the data collected from the sensors, the CMS and HAR warn drivers of the presence of fog downstream and instruct them to slow down when they are in dense fog. When slower speeds are detected downstream, the CMS warns drivers of the slower traffic ahead. If an incident has occurred, the CMS will warn drivers of slower traffic ahead in order to prevent chain-reaction collisions.[86]

Oregon Department of Transportation (ODOT) High Wind Alert Systems

ODOT used an active warning system to provide high wind warnings on a segment of U.S. 101 and the Yaquina Bay Bridge. With the U.S. 101 system, a local wind gauge was used to monitor wind speeds near Humbug Mountain. A controller continuously monitored wind speeds and activated flashing beacons attached to static warning signs located at either end of the corridor. The signs read, "CAUTION HIGH WINDS NEXT 27 MILES WHEN FLASHING." The Yaquina Bay Bridge system used a similar architecture to activate flashers on static signs that read "Caution High Winds on Bridge When Flashing." Benefits from these systems were generated from personnel savings and delay reductions from not closing the roadway, as well as the favorable view that motorists in the corridor had of them.[87]

South Dakota Department of Transportation (SDDOT) Maintenance Decision Support System (MDSS)

SDDOT led a multi-State pooled fund study that developed and extensively deployed an MDSS to recommend sound, cost-effective winter maintenance strategies (e.g., treatments, application rates, and timing) and predict resulting road conditions. Components of the MDSS included an information system to assimilate weather and maintenance data and model pavement surface response, a desktop graphical user interface to provide detailed information on weather and road surface conditions and predictions, and on-vehicle data systems that informed the MDSS of weather conditions, road conditions, and applied maintenance treatments, as well as predicted conditions and maintenance recommendations.[88]

Maryland Department of Transportation (MDOT) Emergency Truck Parking

MDOT, in cooperation with the Maryland Motor Truck Association (MMTA) and the I–95 Corridor Coalition, developed and implemented a program for emergency truck parking throughout the State of Maryland. The program includes the use of six park and ride lots statewide during heavy snow events as a safe haven for truckers. The development of a mobile application and web-based mapping to communicate the locations of all public facilities open for truck parking during the emergency and nonemergency operations was also included as part of the program. The mobile application and web-based mapping tools provide the location of all-truck parking areas available to truck drivers and company dispatchers, which facilitates preparedness when traveling in (and through) the State of Maryland.[89]

Washington State Department of Transportation (WSDOT) Connected Vehicle-Enabled Weather Responsive Traffic Management (CV-WRTM)

WSDOT shared agency snowplow and specialty fleet data through an updated WSDOT traveler information application programming interface (API) to increase safety and create a more weather-aware driving public. WSDOT accomplished this by joining existing fleet telematics, private CV technologies, and connected third-party services such as mobile applications. As motorists traveled on a State highway and agency-owned snowplows were actively engaged in snow-fighting operations, motorists could receive real-time messaging via a mobile application or connected vehicle safety systems. These messages would warn drivers of adverse weather conditions and advise of nearby impactful work operations.[90]

Case Study: Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program

I–80 is a critical interstate corridor running 402 miles through southern Wyoming and provides an essential link for freight and passenger travel. It supports over 32 million tons per year of freight movement, with trucks making up 30 to 55 percent of total traffic per year. A challenge in this corridor is weather-related safety. Severe snow events produce icy roadways and poor visibility, resulting in crashes involving commercial and passenger vehicles and devastating impacts on lives, mobility, and reliability. To address this problem, the Wyoming Department of Transportation (WYDOT) is implementing the Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program to test mobile and roadside technologies and advance connected vehicle applications, including:

- Vehicle-to-vehicle (V2V) communications: forward-collision warnings and distress notifications
- Vehicle-to-infrastructure (V2I) communications: driver response and road weather warnings
- Infrastructure-to-vehicle (I2V) communications: traveler information messages and variable speed limits

The pilot program deployed 75 roadside units (RSUs) that receive and broadcast messages using dedicated short-range communication (DSRC) along I–80. To support testing of the applications, onboard units (OBUs) were installed on 400 fleet vehicles and commercial trucks that regularly use I–80. The OBUs broadcast basic safety messages (BSM) and include a human–machine interface to share alerts and advisories with drivers. The pilot is monitored through a connected vehicle monitor (CVM) that shows roadway conditions and the types of information passing through the RSU to vehicles.

The pilot's applications provide drivers notice of crashes ahead, slow-moving or stopped vehicles, work zones, variable speed limits, road conditions, parking, detours, and safe stopping. The system also provides plow operators their current location to a 1/10-mile, weather forecasts, current weather, state of DMS, and RWIS information. This information is important for freight mobility because freight users on Wyoming's stretch of I–80 have access to information that informs routing and en route decisionmaking. With this information, freight users may improve efficiency by traveling at less congested times, knowing where bottlenecks and weather slowdowns occur, and other details to help them make more efficient routing and travel decisions.

For more information, see the detailed case studies in Appendix A.

ARTERIAL MANAGEMENT AND TRAFFIC SIGNAL TIMING FOR TRUCKS

Description

Arterial management refers to a system of monitoring, analyzing, and managing traffic along arterial roadways by employing vehicle detectors, information communication technologies, and traffic signal systems. Arterial management systems use information from traffic surveillance and detection technologies to regulate traffic flow along major roadway corridors. This can be accomplished by disseminating important information about travel conditions to travelers via DMS, HAR, or mobile devices. However, the most prevalent arterial management strategy deals with traffic signal systems.[91]

Transportation agencies employ many different applications for traffic signals, including advanced systems, adaptive systems, and different types of preemption and priority. Three strategies related to traffic signal timing for trucks are available for agencies to consider:

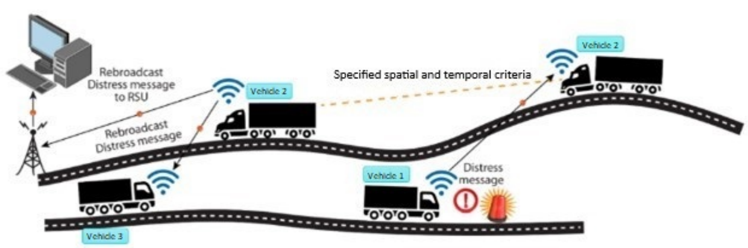
- *Truck signal priority* extends green time at intersections with high truck volumes to allow more trucks to make it through an intersection without stopping. Giving trucks extra green time can enhance safety by reducing the likelihood that a truck would run a red light and cause a crash. It can also reduce delays and congestion caused by the longer acceleration times that trucks need to reach posted speed limits.[92]

- *Signal priority at port gates* is timed to control flow through the port, channeling queues and preventing blockages at signalized intersections.[93]

- *Freight vehicle priority* takes truck signal priority a step farther, with dedicated routing lanes that channel truck flow and avoid mixing of trucks with nonport traffic.[94]

- *Eco-freight signal priority* takes into consideration a vehicle's location, speed, type, and weight, basing signal priority on real-time traffic and emissions data to produce the least amount of emissions (figure 3.18).[95]

Figure 3.18. Illustration of eco-freight signal priority.



Source: Wyoming Department of Transportation.

To provide truck signal priority, transportation agencies will need to invest in roadside infrastructure and intersection detection technologies that can identify an approaching truck and determine its speed. Freight operators may also need to equip their trucks with connected vehicle technologies. Thus, this strategy may need to be considered for the longer term on corridors projected to experience heavy freight traffic.

Truck signal priority systems can provide a number of benefits, including:

- Increased vehicular capacity of intersections and reduced congestion and delays from the extra time provided to slower moving trucks, which take longer to accelerate

- Reduced truck red-light running and crashes from safer phase termination for trucks (i.e., decision zone protection) that, due to their size and weight, are unable to stop after a light turns yellow

- Reduced truck emissions from trucks waiting at red lights and accelerating from a stop. Preliminary modeling results showed that eco-freight signal priority provides up to 4-percent fuel reduction benefits for freight vehicles.[17] With less delay at intersections, drivers can be better equipped to make on-time deliveries, with reductions in fuel consumption and emissions due to idling at intersections.

Where To Apply This Solution

Arterial management can be deployed whenever State DOTs or local transportation agencies seek to collaborate and share data, information, and other knowledge with other transportation agencies with the common goal of addressing safety and mobility challenges faced on arterial roadways. Transportation agencies can consider active management of signalized arterial roadways where crashes and congestion involving trucks are prevalent.

Freight signal priority systems are most helpful on corridors that serve as important freight routes used by a lot of trucks, and especially along designated truck routes near ports, industrial areas, warehouses, and distribution centers. They can also be installed on approaches to signals that are uphill, where the time to accelerate from a red light is longer, or downhill approaches to signals, where trucks have to brake harder to stop in time for a red light.[18]

More information on arterial management can be found at https://ops.fhwa.dot.gov/arterial_mgmt.

Examples

Arterial Management Planning

The Florida Department of Transportation (FDOT) TSMO Strategic Plan identified arterial management as a key focus area and established its Statewide Arterial Management Program (STAMP), which supports the implementation, management, operations, and maintenance of performance-based arterial networks. The STAMP focuses on active arterial management (AAM), integrated corridor management (ICM), and automated traffic signal performance measures (ATSPM), along with ITS infrastructure and communication needs, transportation management center (TMC) needs, and operations and maintenance needs.

FDOT's *2021 STAMP Action Plan* provides outcome-based actions intended to guide the agency's arterial management efforts. The plan's 5 focus areas and 25 action items are designed to guide the implementation process. Among the action items under the plan's emerging technologies focus, the area is for "[FDOT] Districts, local agencies, and transit authorities [to] implement transit and freight signal priority, emergency vehicle preemption, pedestrian, and bicycle systems" in the 2+-year timeframe.[96] To deliver on this action item, FDOT's CAV

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[17]Brewster, R., A. Giragosian, and D. Newton. 2015. *Integrated Corridor Management and Freight Opportunities*. Report No. FHWA-HOP-15-018. Washington, DC: FHWA.

[18]WSDOT TSMO. 2022. "Freight or Truck Signal Priority" (web page), last accessed March 4, 2023.

initiative has dozens of projects in planning, design, or operation, including CV applications that will facilitate freight signal priority systems.[97]

Truck Signal Priority

Truck signal priority systems have been deployed in rural and urban settings in the United States. One such system was developed and implemented at a rural, isolated, high-speed signalized intersection in Sullivan City, TX, to address high levels of truck traffic and resulting pavement damage, traffic delays, and safety problems by minimizing stopping trucks. Loop detectors and a classifier were used to identify trucks approaching the intersection. The before–after analysis of this system showed that it would pay for itself in less than 2 years.

Similar truck signal priority systems were deployed in high truck–density urban signalized intersections in Portland, OR. A study of the systems found that, due to the signal system, a significant number of trucks passed through the intersection at higher speeds with fewer stops. In addition, truck delays were reduced significantly. The analysis showed that truck priority through extended green signal time could ensure service reliability, reduce red-light running, and improve safety and smoother operations with little to no impact on other vehicular traffic. Signal priority for trucks also improved carbon emissions and reduced pavement damage by reducing the number of trucks needing to stop at the intersection.[98]

ACCESS MANAGEMENT AT MAJOR INTERCHANGES AND FREIGHT FACILITIES

Description

Access management along corridors leading to major interchanges and freight facilities is important to maintaining the capacity and safety of the corridor. Access management refers to techniques that transportation agencies can use to proactively control vehicular access points to land parcels adjacent to highways, major arterials, and other roadways.[99,100] Trucks are an important consideration in access management of roadways, especially at major interchanges and freight facilities, because they are substantially larger than passenger cars and have different operating characteristics (e.g., larger turn radius).[101]

Figure 3.19. Access spacing at a major interchange.

Source: Google Earth.

Access management techniques include (figure 3.19):

- **Access spacing**—increasing the distance of driveway spacing from intersections and interchanges

- **Driveway spacing**—limiting the number of driveways and increasing their spacing to ensure alignment of opposing driveways and encourage shared access and service roads

- **Safe turning lane**—providing dedicated left- and right-turn lanes, roundabouts, and innovative intersections to keep through traffic flowing

- **Median treatments**—limiting left turns and providing for directional crossovers to regulate the access and reduce crashes

- **Right-of-way management**—implementing access restrictions and reserving rights-of-way for future widenings, good sight distance, access location, and other access-related issues

- **Local planning and coordination**—implementing corridor planning and agency coordination on development site plans, subdivisions, and access permits

Implementing access management along freight corridors at major interchanges and freight facilities provides benefits to transportation systems, including maintaining roadway capacity, reducing crashes, improving the movement of traffic, and reducing vehicle conflicts.[19,20] However, implementing access management can be challenging because local businesses often have concerns with limiting direct access to individual businesses. Thus, it is important to demonstrate how well-planned access management helps maintain customer traffic while providing safe, efficient freight movement.[21] Partnering with local government is essential to managing access along major corridors through joint corridors plans, access standards, and coordination on development and access permits.

FHWA offers access management resources through its Access Management website, providing that effective access management is achieved through the application of planning, regulatory, and design strategies, including:

- Policies and guidelines issued by State and local agencies having permit authority on development and roadways

- Enforceable regulations, codes, and guidelines issued by State and local agencies

- Acquisition of access rights by States and local governments to protect transportation infrastructure interests

- Land development regulations by State and local governments that address property access

- Development review and impact assessments by State and local governments

- Good geometric design of transportation facilities

- Understanding of access implications by businesses and property owners[102]

[19]FHWA. n.d. "Access Management" (web page), last accessed March 4, 2023.
[20]FHWA. n.d. "What Is Access Management?" (web page), last accessed March 4, 2023.
[21]FHWA. n.d. "How Is Access Management Achieved?" (web page), last accessed March 4, 2023.

The TRB ACP60 Access Management Committee also includes resources on its website, including a State Access Management Library.

Where To Apply This Solution

Because freight-intensive land uses are often located near major highway interchanges, access management programs should focus on key freight corridors leading to interchanges to maintain capacity and safety. Access management techniques can relieve truck bottlenecks through the proactive regulation of vehicular access points to land along arterials, adjacent to major interchanges, and near freight facilities. Transportation agencies should consider the truck size and operational factors as part of their access management programs. However, in most cases, trucks must travel with other modes (passenger vehicles, bicyclists, pedestrians, and transit), so design and access management should accommodate trucks while also maintaining the safe operation of other modes.[22]

Examples

Louisiana Department of Transportation and Development (LaDOTD)

Figure 3.20. Replacement of closely spaced signalized intersections with roundabouts in Louisiana.

Source: National Academies of Sciences, Engineering, and Medicine.

Roundabouts can be used to improve intersection safety and operations by reducing the number of traffic conflict points and eliminating right angle or head-on crashes. LaDOTD replaced three closely spaced signalized intersections (two at the interchange with I–10 and one approximately 1,000 feet from the interchange) with roundabouts (figure 3.20). They also installed a raised median along this corridor, preventing left turns in and out of driveways. These treatments were intended to address operational and safety issues along the corridor due to the closely spaced signalized and unsignalized intersections and driveways in the vicinity of the I–10 interchange. High volumes of trucks, midblock left-turn movements, and closely spaced driveways and intersections contributed to congestion along the corridor. Long queues at signalized intersections contributed to congestion and delays at unsignalized access points. As a result of the roundabouts, traffic congestion has improved significantly, with trucks able to circulate around the roundabouts without issue, using the truck aprons (i.e., the part of the roundabout around the edge of the island in the middle that allows

[22]Ibid.

trucks to navigate the roundabout or turn without striking a fixed object or other motorists) as needed. In addition, the raised median has eliminated conflict points.

Michigan Department of Transportation (MDOT)

MDOT found that the space between crossroad ramp terminals at one interchange location was sufficient to store passenger cars making a direct left turn from one frontage road, but that large trucks turning left could not be stored in the space between the crossroad ramp terminals. Thus, MDOT implemented changes to the interchange's operations by allowing passenger cars to continue to make direct left turns but prohibiting trucks from making direct left turns. Instead, a U-turn roadway was constructed to provide an indirect left-turn routing for trucks (figure 3.21). This illustrates that separate turning paths can be used for passenger cars and trucks where appropriate.[103]

Figure 3.21. Alternative paths for passenger cars and trucks in Michigan.

Source: NASEM.

MDOT also has an Access Management Program where the State provides access management training to local government officials and assistance with local corridor access management planning. The MDOT *Access Management Guidebook* is a resource for use by elected and appointed local government officials, planners, and road authority personnel to promote access management through local, county, regional, and State cooperation. The guide identifies potential steps to prepare a local-access management plan and regulations and describes how MDOT, county road commissions, and local governments can coordinate on implementation. The MDOT *Access Management Guidebook* is available at https://www.michigan.gov/mdot/programs/highway-programs/roadside-property-management/access.

Off-Peak Deliveries

Description

Off-peak truck delivery programs are being piloted and implemented in cities, in part to alleviate freight congestion. Especially in urban areas, daytime commercial vehicle deliveries contribute to traffic congestion because of the lack of suitable parking for loading and unloading deliveries, which often results in double parking. This ultimately increases the price of goods and of doing business in cities.[23]

Off-peak delivery programs shift deliveries from daytime/peak periods to off-hours (i.e., overnight). In some cases, deliveries can be unattended by receivers, where drivers leave goods in a safe and secure location.

[23] Polimeni et al. 2005. "Off-Peak Freight Deliveries: Challenges and Stakeholders' Perceptions." *Transportation Research Record, Journal of the Transportation Research Board* 1906, no. 1:42–48.

Where To Apply This Solution

Off-hour delivery programs are applicable primarily in urban areas where commercial and delivery vehicles regularly disrupt smooth traffic flow by double parking or occupying available parking spaces when and where parking is in high demand. Off-hour deliveries have been tested and deployed in New York City, specifically in Midtown and Lower Manhattan (south of 59th Street) and the downtown areas of Brooklyn and Jamaica, where there are high pedestrian volumes and limited curb space.[24]

Off-hour delivery programs will work where their benefits will outweigh the costs of implementation, administration, and business adoption. Benefits include increased business efficiency for suppliers and retailers, reduced fuel consumption and CO_2 emissions, and reduced traffic during peak hours.[25]

Off-hour delivery programs should be tested or deployed in areas where businesses would be willing to shift their delivery model to nighttime hours. In New York City, the pilot focused on four types of industrial partners with an interest in exploring off-hour deliveries, including a national footwear retailer, a logistics company, a wholesale restaurant food distributor and its customers, and a national grocery store chain and its vendors.[26]

For an effective off-hour delivery program, resources will likely need to be invested in incentivizing businesses to change their delivery practices. New York City found that focused outreach to businesses in target areas, tailored implementation guides, and a recognition program are helpful for companies to move to off-peak delivery.[27]

Another consideration for where to use off-peak delivery programs is the issue of noise and noise mitigation. Overnight deliveries are not suitable in areas where nearby residents are disrupted or woken up by noise from delivery trucks and drivers. An off-hour delivery program test in Stockholm, Sweden, found that the noise people complained about was caused mainly by unloading the truck, not driving, and was a problem only in quiet neighborhoods.[28] The New York City program has established a protocol for noise management and promotes noise mitigation best practices, including educating participants on quiet delivery equipment and behaviors during deliveries.[29]

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[24] NYCDOT. 2019. *Improving the Efficiency of Truck Deliveries in NYC*. New York, NY: NYCDOT, last accessed March 4, 2023

[25] KTH The Royal Institute of Technology. 2017. "Switching to Off-Peak Delivery Times Reduced City Congestion." *Science Daily*, last accessed March 4, 2023.

[26] Holguín-Veras, et al. 2010. *Integrative Freight Demand in the New York City Metropolitan Area: Final Report*, last accessed March 4, 2023.

[27] NYCDOT. 2019. *Improving the Efficiency of Truck Deliveries in NYC*, last accessed March 4, 2023.

[28] KTH The Royal Institute of Technology. 2017. "Switching to Off-Peak Delivery Times Reduced City Congestion." *Science Daily*, last accessed March 4, 2023.

[29] NYCDOT. 2019. *Improving the Efficiency of Truck Deliveries in NYC*, last accessed March 4, 2023.

Examples

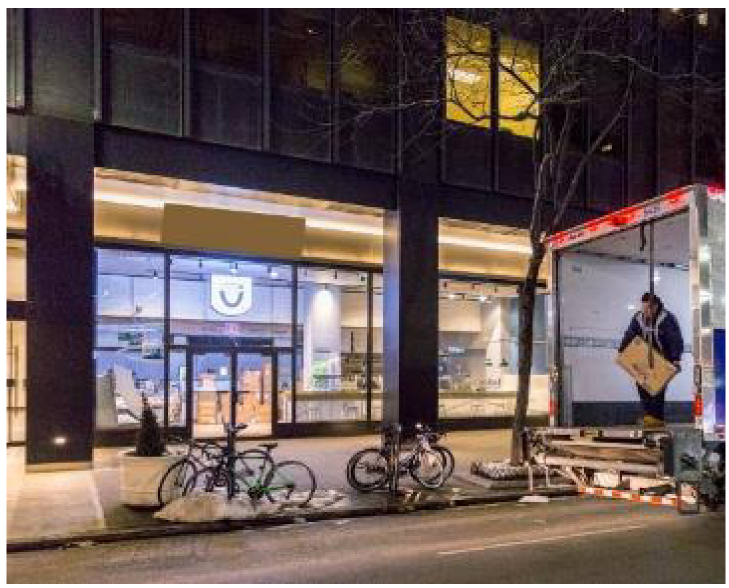
Sweden

In Sweden, a small-scale off-hour delivery program pilot project in Stockholm temporarily lifted a ban on freight deliveries between 10 p.m. and 6 a.m. for a national supermarket chain and a restaurant food supplier. The pilot reduced peak traffic volumes in the city and increased shipping efficiency by reducing the number of trucks making deliveries from several smaller vehicles to one larger truck. The study found that scaling up off-peak deliveries could increase business efficiencies for suppliers and retailers, reduce fuel consumption and CO_2 emissions, and make a positive impact on traffic volume during peak morning hours.[30]

New York City Off-Hour Delivery (OHD) Program

The OHD program was piloted from 2009 through 2010 and funded by USDOT. The pilot, which limits deliveries to between 7 p.m. and 6 a.m., found that truck travel speeds from the truck depot to the delivery drivers' first stop in Manhattan improved by up to 75 percent compared with travel speeds during the evening rush hour, while subsequent trips averaged travel speeds up to 50 percent faster. With less competition for parking spaces accessible to the delivery location, trucks spent only 30 minutes stopped at the curbside making deliveries instead of 100 minutes before the pilot. The pilot also found that 40 to 50 daily delivery tours switched to off-peak hours, for a total carrier savings of $2.25 million annually, and that 20 percent of truck traffic could be shifted to off-peak hours, with benefits of $150 to $200 million in travel time savings and productivity increases.

Figure 3.22. Transporter conducting delivery as part of New York City (NYC) off-hour truck delivery program.



Source: NYC Department of Transportation.

[30]KTH The Royal Institute of Technology. 2017. "Switching to Off-Peak Delivery Times Reduced City Congestion." *Science Daily*, last accessed March 4, 2023.

Due to the success of the pilot program, the New York City Department of Transportation (NYCDOT) is now expanding the Off-Hour Delivery Program, seeking additional transporters and receivers to rethink their delivery schedules and shift to off-hour deliveries (figure 3.22). The NYCDOT's goal with the program in 2021 was to expand it to 900 new food and nonfood retail locations. The steps they have taken to implement this expansion have involved:

New York City's Off-Hour Delivery Program found that 20 percent of truck traffic could be shifted to off-peak hours, resulting in $150 to $200 million in travel time savings and productivity increases.

- Development of a program brand and marketing strategy and focused outreach to businesses in target areas, including updated and tailored program implementation guides for receivers and transporters
- Establishment of a protocol for noise management and promoting noise mitigation best practices, including educating participants on quiet delivery equipment and behaviors during deliveries
- Development of a recognition program to foster behavior change by publicly spotlighting companies demonstrating Off-Hour Delivery Program best practices in safety, efficiency, and emissions.[104]

CURB LOADING ZONE MANAGEMENT

Description

Curb loading zone management programs use technology to allow online reservations of designated curb spaces for commercial deliveries. These programs are helpful to cities seeking relief from congestion and unsafe conditions imposed by double-parked delivery vehicles. They are also helpful to businesses looking for more timely deliveries and efficiencies from predictable scheduling.

Figure 3.23. Smart Loading Zone Sign and Marketing in Nashville, and App.

Source: Coord.

Where To Apply This Solution

Like off-peak delivery programs, curb loading zone management programs are applicable primarily in commercial corridors of urban areas where delivery vehicles regularly disrupt smooth traffic flow by double parking or occupying available parking spaces when and where parking is in high demand.

Off-hour deliveries have been tested and deployed in the District of Columbia; Columbus, OH; Omaha, NE; and other cities in corridors with a demand for loading zone reservations conducted online either on demand or in advance. All of the deployments have involved partnerships with private technology companies that provide a digital platform (i.e., mobile application) for those interested in using the reservation system. The mobile applications allow users to hold and pay for their curbside reservations. The cities provide dedicated curbside parking spaces, signage and markings, and marketing support (figure 3.23).

More information on loading zone management can be found at https://ops.fhwa.dot.gov/freight/technology/urban_goods.

Six Suggested Steps to Implement Curb Loading Zone Management

1. Map the curb space to identify where congestion and double parking by delivery vehicles are prevalent and learn what rules currently exist to regulate them
2. Define the curb management program objectives and desired uses of the curb space
3. Inventory potential users, needs, and value propositions
4. Develop technology tools (apps) in-house or through partnerships to allocate access, monitor use, collect fees, and enforce rules
5. Implement the pilot at key locations
6. Observe the pilot results and adjust or expand the program to meet the defined objectives from step 2.

Adapted from DeBow, C. and M. Drow. 2019. *Curbside Management: Managing Access to a Valuable Resource*. Fredricksburg, VA: International Parking and Mobility Institute, last accessed March 4, 2023.

Examples

District Department of Transportation (DDOT)

In the District of Columbia, DDOT partnered with CurbFlow on a 3-month pilot that removed curb parking at nine locations and required drivers to reserve loading zone times through a mobile website (figure 3.24). The 2019 pilot found that the curb loading zone management program reduced double parking by 64 percent, with participation from over 6,350 commercial drivers from more than 900 companies that made 15,000 reservations. The companies varied in size and delivery needs, achieving more timely delivery pickups and dropoffs and more-efficient schedules.[105]

Figure 3.24. Curb loading zone management pilot program signs in the District of Columbia.

Source: Southwest Business Improvement District.

City of Columbus, OH

In 2019–2020, the City of Columbus partnered with CurbFlow on a similar pilot project that offered drivers a native mobile application instead of a mobile website and expanded participation to taxis and transportation network companies (TNCs). The 6-month pilot found that the application was used to make loading zone reservations approximately 19,000 times by 2,400 commercial and on-demand delivery drivers. Participant driver satisfaction was "overwhelmingly high," with quicker pickups and dropoffs and reductions in double and illegal parking.[106]

City of Omaha, NE

In 2020, the City of Omaha partnered with Coord on a "smart zone" curb management pilot project. Similar to the District of Columbia and Columbus pilots, this project made use of a mobile application for drivers to reserve loading spaces. Delivery drivers use the mobile application to reserve curbside loading zone space along their routes. The pilot tested whether the program makes it possible for cities to monetize the curb through the generation of data on who is loading, for how long, and on what days and times. With these data, cities have the potential to create tools to better manage their curb space by incentivizing certain time windows.[107]

City of Pittsburgh, PA

In April 2022, the City of Pittsburgh and the Pittsburgh Parking Authority announced the launch of its "smart loading zone" program with their private partner, Automotus. Twenty loading zones are planned or in operation, identifiable by street signs and distinctive purple curbs. A mounted camera captures license plates of cars parked in the spaces so that those who park in the special zones and are not registered with the program will receive a bill and parking ticket in the mail. Delivery and other commercial drivers pay for parking by the minute with escalating rates for a vehicle that remains in the loading zone (figure 3.25). Several cities, including Pittsburgh and Omaha, are working with Automotus to develop a program that will deploy special delivery zones for larger commercial vehicles.[108]

Figure 3.25. City of Pittsburgh Smart Loading Zone Program reservation rates.

Smart Loading Zone details

Hours: Monday-Friday, 5 a.m.-10 p.m.
Pricing: pay by the minute.

TIME		RATE/MIN.	MAX PAYMENT
0-5 min.	=	$0.07	$0.35
5-15 min.	=	$0.14	$2.10
15-30 min.	=	$0.20	$6.00
30-60 min.	=	$0.27	$16.20

Source: Automotus Post-Gazette

Source: Pittsburgh Post-Gazette.

ACTIVE TRAFFIC AND DEMAND MANAGEMENT (ATDM)

Description

ATDM strategies are deployed by transportation agencies to improve travel time reliability, safety, and throughput by dynamically managing and controlling traffic demand and available capacity based on prevailing and anticipated conditions using real-time operational strategies.[31] ATDM leverages existing capabilities, assets, programs, and investments to actively manage freight traffic and demand through a variety of approaches.[32]

ATDM involves two concepts applicable to freight traffic to improve truck bottlenecks. The first is active traffic management (ATM), the dynamic management of recurring and nonrecurring congestion based on prevailing and predicted traffic conditions.[33] The other is active demand management (ADM), the dynamic management of travel demand by redistributing travel to less congested times of day or routes or reducing overall vehicle trips by influencing a mode choice.[34]

ATM approaches are increasingly making use of integrated systems with new technologies that automate the dynamic deployment of operational strategies in realtime. These strategies can be deployed without reliance on extra road capacity and include:

- *Dynamic lane use/shoulder control*—dynamically opening a shoulder lane to traffic or closing travel lanes on a temporary basis in response to increasing congestion or incidents

[31]FHWA. n.d. "About Active Transportation and Demand Management (ATDM)" (web page, last accessed March 4, 2023.

[32]FHWA. n.d. "About ATDM: Overview" (web page), last accessed March 4, 2023.

[33]FHWA, Active Traffic Management.

[34]Stateline. 2018. Variable Speed Limits: Improving Safety or Confusing Motorists?, last accessed March 4, 2023.

- *Dynamic or variable speed limits* (VSL)—dynamically changing speed limits based on traffic speed, volume, weather, and road condition information gathered from road sensors, which are transmitted to a traffic operations center and analyzed using an algorithm or a review by staffers who make decisions about what speed limits should be posted (figure 3.26).

Figure 3.26. Variable speed limits on I–5 approaching Seattle in Washington.

Source: Pew Charitable Trusts.

- *Queue warning*—dynamically displaying warning signs to alert drivers that congestion and queues are ahead

- *Adaptive ramp metering*—dynamically adjusting traffic signals at ramp entrances to proactively manage vehicle flow from local-access roads

- *Dynamic rerouting*—dynamically providing alternate route information in response to increasing congestion at bottlenecks/incidents

- *Dynamic junction control*—providing lane access based on highway traffic present and merging/diverging traffic to give priority to the facility's higher volume to minimize the impact of the merging/diverging movement

- *Adaptive traffic signal control*—optimizing signal timing plans based on prevailing conditions to increase throughput along an arterial[109]

ADM strategies seek to influence more fluid, daily travel choices. These strategies include:

- *Dynamic pricing*—dynamically changing tolls in response to changing congestion levels

- *Dynamic routing*—using variable destination messaging to disseminate information to make better use of roadway capacity by directing motorists to less-congested facilities

- *Predictive traveler information*—using a combination of real-time and historical transportation data to predict upcoming travel conditions and convey that information to travelers pretrip and en route[110]

Where To Apply This Solution

ATDM strategies can be applied to any corridor where truck travel time reliability, safety, and throughput are problematic. ATDM is relatively easy to implement since it builds upon existing capabilities, assets, programs, and investments. However, many ATDM strategies require investments in technology (hardware and software), operations centers, and infrastructure (e.g., DMS, markings, signs).

While active management can be applied to any part of the transportation system, it is most beneficial where the relationships and synergies to other parts of the system are considered and incorporated. For example, an agency could apply variable speed limits to improve truck safety along a corridor.[35]

Examples

Wyoming Department of Transportation

The Wyoming Department of Transportation started using VSLs in 2009 during winter storms or vehicle emergencies. The variable speed limits were posted on dynamic message signs and found to have made an immediate difference in reducing the number of large, multi-vehicle crashes in hotspots where the systems were deployed. A 2010 University of Wyoming study found road closures had dropped, and crashes were the lowest in 10 years in the year after the VSL signs were installed. The program's success led the State to expand it to other highways over the next 7 years.

Ohio Department of Transportation

In 2017, the Ohio State Legislature authorized the Ohio Department of Transportation to use VSLs in certain locations for inclement weather or congestion. During a November 2017 storm, the agency deployed VSLs on an interstate near Cleveland.[111]

RAMP MANAGEMENT AND METERING

Description

Ramp management and ramp metering are strategies that transportation agencies employ to address truck delays and safety, thereby enhancing the reliability of the freight network. Ramp management strategies are used to control access to selected ramps, limiting when vehicles may access the ramp. This can reduce the potential for collisions that occur because of traffic entering the ramp facility and ease the flow of traffic on segments of roadway where these collisions have occurred in the past.

Ramp management can also control the manner in which vehicles enter a freeway. Vehicles that enter the freeway in platoons introduce turbulence into the freeway system, which causes vehicles on both the mainline and ramp to slow down to safely merge, which often causes congestion.[112]

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[35]FHWA. n.d. "About Active Transportation and Demand Management (ATDM)" (web page), last accessed March 4, 2023.

A key ramp management strategy is ramp metering, where traffic signals are installed on on-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway. Vehicles traveling from an adjacent arterial onto the ramp form a queue behind the stop line. The vehicles are then individually released onto the mainline, often at a rate that is dependent on mainline traffic volume and speed at that time.

The most congested highway freight bottlenecks tend to be on interstates and expressways in major metropolitan areas.[113] Ramp metering can reduce congestion along these bottlenecks by managing the amount of traffic entering the freeway. It can also prevent traffic flow breakdowns, allow vehicles to merge more smoothly onto the mainline, and reduce the need for vehicles on the mainline to reduce speed. Ramp meters have been shown to reduce peak-hour lane occupancies (i.e., freeway density) and speed recovery from mainline breakdown back to or below the critical occupancy threshold. They have also been shown to reduce travel times and crash rates.[114]

Increasingly, ramp metering is being used on a temporary basis to mitigate nonrecurring congestion related to highway construction and work zones. These systems use temporary signal heads, wireless radar detectors mounted on portable trailers, and temporary signs.[115]

Where To Apply This Solution

Ramp metering should be deployed where operational issues are already affecting congestion and safety on a corridor. The issues that ramp metering could mitigate include:

- Recurring mainline congestion
- Safety issues at merge points and on the mainline
- Nonrecurring congestion or safety issues due to crashes, construction, or special events

Temporary ramp metering can be applied to control mainline access during construction activities, special events, or traffic incidents. The decision to deploy a temporary ramp metering system during highway construction will depend on the following considerations:

- Mainline congestion resulting from highway construction (i.e., temporary reductions in mainline capacity resulting from lane or shoulder closure)

- Safety issues at merge points and on the mainline (i.e., increases in crash risk within the construction zone related to merging volume conflicts)

- A temporary increase in volume caused by detoured traffic exceeding the capacity of through lanes[116]

Examples

California Department of Transportation (Caltrans)

Ramp metering (figure 3.27) is an integral part of the Caltrans Transportation Management System Master Plan, which outlines strategies to reduce congestion and increase safety on California's State Highway System. Caltrans uses ramp metering to maintain an efficient freeway system and protect the investment made in freeways by keeping them operating at or near capacity.[117]

Figure 3.27. Ramp metering in California.

Source: California Department of Transportation.

Minnesota Department of Transportation (MnDOT)

The Minneapolis-St. Paul region has more than 300 ramp meters with system control.[118] A study of the ramp meter system showed that, in their absence, freeway travel times were 22 percent higher, freeway speeds were 7 percent lower, reliability of freeway travel time was 91 percent lower, and crashes increased by 26 percent. As a result, MnDOT implemented a new system that added automated monitoring of wait times at meters so they could be adjusted as needed by MnDOT's traffic management center computers. The system provides real-time information about ramp delays and limits wait times based on ramp conditions as well as freeway conditions. The system has been designed so that ramp meter waits will be no more than four minutes on local ramps and no more than 2 minutes on freeway-to-freeway ramps, vehicles waiting at meters will not back up onto adjacent roadways, and meter operation will respond to congestion and only operate when needed.[119]

Figure 3.28. Ramp metering in Colorado.

Source: Colorado Department of Transportation.

Colorado Department of Transportation (CDOT)

CDOT's Smart 25 Pilot Project is deploying a coordinated ramp metering system on the I–25 corridor. The system uses a network of sensors supported by an algorithm to determine how many vehicles to release at each ramp based on traffic flow. Through the pilot project, CDOT is testing this new ramp metering system with the goal of reducing congestion and improving travel times. Sensors gather information on the number of vehicles, speed of vehicles, and length of the line of vehicles entering the highway for 18 arterial ramps along the corridor. This information is used to control the timing of the ramp meter lights to better control the flow of traffic onto the highway and reduce stop-and-go traffic on the mainline. The right shoulder lanes can be used on some of the ramps when the meters are on (figure 3.28). The goal of the project, the first of its kind in Colorado and North America, is to reduce congestion, improve travel time reliability, reduce crashes, and reduce emissions.[120]

INTEGRATED CORRIDOR MANAGEMENT

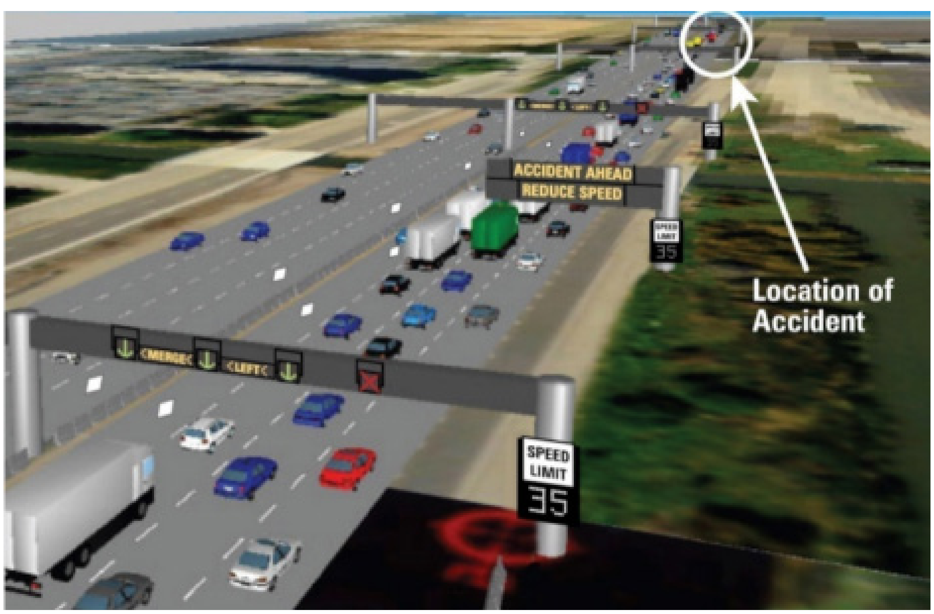
Description

Freight transportation corridors often contain underused capacity in the form of parallel roadways, single-occupant vehicles, and multimodal alternatives that could be better leveraged to improve truck travel time reliability and freight bottlenecks. The vision of Integrated Corridor Management (ICM) is that transportation networks will realize significant improvements in the efficient movement of people and goods through institutional collaboration and aggressive, proactive integration of existing infrastructure along major corridors.

An ICM approach helps transportation agencies manage corridors as a multimodal system and make operational decisions for the benefit of the whole corridor.[121] This includes consideration of multimodal freight options, including rail and waterways, for major interstate corridors.

The ICM approach is based on a corridor-level focus on operations, agency integration, and active management of corridor assets and facilities. For example, ICM response plans can address congestion by advising travelers via DMS and other traveler information sources (e.g., 511) to take a parallel route where there is capacity and/or changing signal timing on a parallel route to manage detoured traffic.[122] An ICM response plan could also advise travelers via DMS to take measures, such

Figure 3.29. Illustration of integrated corridor management concept.



Source: DKS Associates.

as reducing speed and merging into other lanes, in response to safety incidents further down the corridor (figure 3.29).

Where To Apply This Solution

ICM can benefit freight by improving truck drivers' situational awareness of conditions along a corridor. In an ICM corridor, they can receive regular, validated information updates from managing agencies across the length of the corridor, including travel times, incidents, work zones, road closures, and suggested alternate routes. Armed with this information, truck drivers can select alternate routes, notify shippers and receivers of pickup and delivery times, and make informed choices about scheduling off-duty and rest periods to remain compliant with hours of service (HOS) rules. Avoiding congested routes could also help providers cut down on operational costs through fuel, driver, and equipment savings.

Another benefit of ICM is that it provides freight stakeholders with a forum for collaboration. Bringing freight stakeholders to the table gives them an opportunity to explain these challenges and help to design a system that could better meet their needs.[123]

Examples

Dallas, TX, and San Diego, CA, Demonstrations

USDOT selected two corridors—US 75 in Dallas and I–15 in San Diego—to demonstrate the Nation's first ICM systems. The demonstrations went into operation in 2013. Through this effort, USDOT explored and developed ICM concepts and approaches to advance the deployment of ICM systems throughout the country.[124]

Metro and Oregon Department of Transportation (ODOT)

Metro and ODOT applied a multimodal ICM framework to the I–84 corridor, developing an approach for maximizing the corridor's efficiency and safety by actively managing the corridor's multimodal transportation networks and services. The multimodal ICM approach provided freight solutions as part of a recommended operations alternative to "Establish a Multimodal Detour Policy Across Agencies." The strategy takes freight into consideration in that the regional partners will prepare freight-specific detour plans based on the regional freight network and protocols for communicating with freight drivers.[125]

The Eastern Transportation Coalition (TETC)

Multimodal ICM can also support solutions that provide multimodal freight options, including rail and waterways, for major interstate corridors. TETC, on behalf of the member and affiliate agencies, applied for and successfully received the designation of a Marine Highway Corridor paralleling the I–95 highway corridor under the USDOT's America's Marine Highway Program. The M–95 Marine Highway Corridor consists of a series of waterways, crossings, and connections within the I–95 corridor region. TETC works with regional partners and the USDOT Maritime Administration (MARAD) to advance the utilization of the coastal and inland waterways within the I–95 and M–95 corridor region and identify potential freight and passenger markets where water could serve as a transportation mode to address mobility needs.[126]

TRAFFIC INCIDENT MANAGEMENT

Description

Traffic incident management (TIM) is the planned and coordinated multidisciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible. Commercial vehicle crashes pose additional challenges to TIM programs, creating longer delays because of the larger, heavier vehicles involved, damaged trailers, spilled cargo (including hazardous materials), and a higher likelihood of injuries and fatalities.

Effective TIM strategies reduce the duration and impacts of traffic incidents, improve safety for motorists, crash victims, and emergency responders, and lower the frequency of secondary crashes.[36] TIM programs that consider truck-involved crashes include strategies that make sure specialized equipment is on hand to respond to these major incidents.

A TIM program could include the following elements:

- Unified policies, procedures, operations, and communication systems among TIM responders
- Advanced technologies to improve traffic incident detection, response, and clearance
- Safety service patrols and pre-positioning of TIM equipment
- Interdisciplinary training in traffic control
- Improved and incentivized towing procedures and practices
- Traveler information

Where To Apply This Solution

TIM programs can be established as part of a transportation agency's traffic operations program in locations where there is a need to reduce traffic delay and congestion, improve responder and traveler safety, and improve mobility, reliability, and air quality.[37] TIM strategies are typically deployed by TIM responders who work together safely and quickly as a team to coordinate the clearance of travel lanes and improve interagency communications between firefighters, law enforcement officers, EMS responders, transportation/safety service patrols, maintenance crews, towing and recovery, and 911/dispatch.[38] TIM programs may also include contractors with specialized equipment and trained operators required to remove truck-involved wreckage from the roadway.

Examples

Maryland Department of Transportation (MDOT) Coordinated Highways Action Response Team (CHART)

MDOT's CHART program involves a comprehensive traffic management system enhanced by a state-of-the-art Statewide Operations Center (SOC), the "hub" of the CHART system. The SOC

[36] FHWA. n.d. "Welcome to Traffic Incident Management" (web page), last accessed March 4, 2023.
[37] National Operations Center of Excellence. 2022. "Traffic Incident Management" (web page), last accessed March 4, 2023.
[38] FHWA. 2012. "Traffic Incident Management" (presentation), last accessed March 4, 2023.

functions 24 hours a day, 7 days a week, with 3 satellite Traffic Operations Centers (TOCs) spread across the State to handle peak-period traffic. The CHART program has become a multijurisdictional and multidisciplinary program with a CHART Board, representing State and local transportation and enforcement agencies, that directs the program.

Figure 3.30. Maryland DOT (MDOT) CHART response technician.

Source: MDOT.

CHART is comprised of a number of subsystems, including incident management. Advanced cameras were installed on all 74 CHART emergency response technician (figure 3.30) vehicles and can be controlled remotely from the SOC and TOCs. Through CHART, MDOT has been able to prevent 225 to 250 secondary incidents a year, saving the public $1.5 million annually in fuel and delay costs.[127]

Florida Department of Transportation (FDOT) Rapid Incident Scene Clearance (RISC)

FDOT's RISC program supports Florida's Open Roads Policy goal of safely clearing major highway incidents and truck crashes in 90 minutes or less. RISC is a contractual, incentive-based program that requires specialized equipment and trained operators to quickly remove wreckage from the roadway, where major crashes close most lanes or cause significant travel delays (figure 3.31). The RISC contractor is responsible for responding to incidents within 60 minutes of a request. Once on scene and provided a Notice to Proceed by the lead official there, the vendor will have 90 minutes to open the travel lanes for traffic. The RISC contract requires the vendor to have specified extra equipment on hand or available 24 hours a day, 7 days a week, to respond to major incidents.[128]

Figure 3.31. Florida Department of Transportation (FDOT) Rapid Incident Scene Clearance contractor clearing an incident.

Source: FDOT.

Washington State Department of Transportation (WSDOT) and Washington State Patrol (WSP) Major Incident Tow (MIT)

In 2022, WSDOT and WSP established a mutual goal of safely clearing highway traffic incidents within 90 minutes to enhance motorist and responder safety and minimize congestion. WSDOT and WSP established and are jointly implementing the MIT program along the I–5 corridor and in the Puget Sound area to reduce congestion by clearing heavy truck-involved incidents within 90 minutes or less. Similar to FDOT's RISC program, the MIT program operates under a contract where the vendor is eligible for performance fees. Under this contract, to qualify for the incentives, the contractor must be en route to the incident scene within a certain timeframe, have completed the removal and clearance of incidents and opened all travel lanes within 90 minutes.[129]

MANAGED LANES AND CONGESTION PRICING

Description

Transportation agencies can improve truck travel time reliability and freight bottlenecks by taking advantage of managed lanes and actively managing demand and available capacity on managed lane facilities by applying congestion pricing strategies.[39] Managed lanes are highway facilities or a set of lanes where operational strategies are proactively implemented and managed in response to changing conditions. The concept involves making the most effective and efficient use of an existing freeway facility.

Congestion pricing refers to strategies that harness the power of the market to reduce wasted time and money associated with traffic congestion. It recognizes that trips have different values at different times and places and for different individuals. Faced with premium charges during periods of peak demand, drivers are encouraged to eliminate lower valued trips, take them at a different time, or choose alternative routes or transport modes where available.[40] Thus, by shifting a portion of rush-hour highway travel to other transportation modes or to off-peak hours, congestion pricing can take advantage of the fact that the majority of rush-hour drivers on a typical urban highway are not commuters.

Congestion pricing can be applied to specific traffic lanes or to an entire highway facility, and users of the lanes or facilities have the option of paying to use congestion-free priced lanes or traveling on general-purpose lanes without paying a toll. Congestion pricing strategies involving tolls include high-occupancy toll (HOT) lanes and express toll lanes.[41]

Where To Apply This Solution

Managed lanes and congestion pricing can be considered by transportation agencies for freight bottleneck locations that are facing challenges related to growth and density. In these areas, agencies are challenged by recurring and nonrecurring congestion and limitations in their ability to expand highway capacity due to construction costs, right-of-way constraints, and environmental and societal impacts. The solutions available to these areas are often limited to a combination of limited-capacity expansion coupled with operational strategies that seek to manage travel demand.[42]

Congestion pricing can be applied as one such strategy to specific traffic lanes or an entire highway facility, giving users the option of using congestion-free tolled lanes or congested

[39]FHWA. n.d. "Managed Lanes" (web page), last accessed March 4, 2023.
[40]FHWA. n.d. "Welcome to the FHWA Congestion Pricing Web Site" (web page), last accessed March 4, 2023.
[41]FHWA. n.d. "What Is Congestion Pricing?" (web page), last accessed March 4, 2023.
[42]FHWA. n.d. "Managed Lanes" (web page), last accessed March 4, 2023.

general-purpose nontolled lanes. These systems often require agencies to be familiar with the latest in tolling technologies, as well as innovative project delivery, including public-private partnerships (P3).

By implementing managed lanes and congestion pricing, drivers and businesses will benefit from reduced delays, increased predictability of trip times, and more deliveries made on time. Government agencies will benefit from improved transportation services without tax increases or large capital expenditures, additional revenues for funding transportation, retention of businesses and expansion of the tax base, and shortened incident response times for emergency personnel.[43]

Examples

Washington State Department of Transportation (WSDOT)

WSDOT has deployed managed lane and congestion pricing strategies on its facilities, including open road tolling of all lanes that varies by time of day or travel direction. In 2011, WSDOT began full facility tolling on SR 520 as a congestion management and safety enhancement strategy (figure 3.32). WSDOT actively manages SR 520 with toll rates that vary on a schedule by the time of day. Higher tolls are charged during times of peak demand to maintain speed and throughput, thus minimizing congestion. Lower tolls are charged at off-peak times, offering an incentive for motorists to switch their road use from peak to lower demand times of the day. This has resulted in an overall decrease in traffic volume on SR 520 and increases on nearby I–90 and SR 522, suggesting that drivers are shifting their travel patterns onto alternate routes due to the toll. The resulting decline in traffic has produced cost savings for trucks, including savings in fuel, repair, and business costs.

Figure 3.32. Variable tolling on Washington State Department of Transportation (WSDOT)'s SR 520.

Source: WSDOT.

In 2019, WSDOT opened the SR 99 tunnel in Seattle with a similar variable tolling operation. The same innovative and proven toll technologies will be deployed on SR 509 and SR 167 as part of the Puget Sound Gateway program, which will benefit trucks serving the Ports of Tacoma and Seattle and all traffic accessing Sea-Tac Airport from the south.

[43]FHWA. n.d. "Benefits of Congestion Pricing" (web page), last accessed March 4, 2023.

Virginia Department of Transportation (VDOT)

VDOT's express lanes program currently includes high occupancy toll (HOT) lanes on I–495, I–95, and I–395 in northern Virginia. The 495 Express Lanes run 14 miles (figure 3.33), the 95 Express Lanes run 31 miles, and the 395 Express Lanes are an 8-mile extension of these lanes, taking drivers right up to Washington, DC. The projects were delivered as design-build-finance-operate-maintain (DBFOM) public-private partnerships (P3). The VDOT Express Lanes are intended to reduce congestion and improve travel reliability in an area that is one of the most congested travel areas in the Washington, DC, metropolitan region. Similar to WSDOT's SR 520 facility, the decline in traffic from VDOT's HOT lanes is anticipated to produce cost savings for trucks in terms of savings in fuel, repair, and business costs.

Figure 3.33. Variable Tolling on I–495 in Northern Virginia.

Source: Virginia Department of Transportation.

TRUCK LANES

Description

Truck lanes are a tool to channel commercial vehicles to certain highway lanes to enhance safety and stabilize traffic flow. They may take various forms, including:

- Separated truck-only lanes are lanes designated exclusively for the use of trucks. They separate trucks (using barriers or other grade-separated structures) from other mixed-flow traffic by requiring them to travel in the designated truck-only lanes.[130]
- Separated auto-only and mixed-flow lanes are nonexclusive mainline lanes that are not separated by barriers or other structures, where passenger vehicles are allowed to use all lanes and trucks are restricted to specified lanes.[131]
- Truck lane restrictions are regulatory State restrictions that prohibit trucks in specific travel lanes, leaving them specifically for automobile traffic.[132]
- Interchange by-passes for trucks are facilities that remove trucks from interchange merge areas where their presence could be potentially detrimental to interchange operations and exacerbate interchange safety.[133]
- S*hort connectors from major port facilities* are ramps that allow for expedited truck movements between port facilities and freight highway corridors.[134]

Where To Apply This Solution

Transportation agencies can consider specific truck lane improvements based on their freight movement goals and the specific issues contributing to freight bottlenecks:

- Separate truck-only lanes are appropriate treatments in corridors where congestion and safety issues are posed by relatively high current and projected percentages of trucks, steep grades, and inefficient operations.[135]
- Separated auto-only and mixed-flow lanes and truck lane restrictions are appropriate treatments in corridors where truck conflicts, weaving maneuvers during passing, and crashes involving trucks pose a greater safety issue than in other locations along a corridor.[136] Truck lane restrictions can also be imposed through highway work zones to ensure that at least one lane is used only by passenger vehicles. In this case, a restricted vehicle should be allowed to use any lane, including the restricted lane, to pass another vehicle and to enter and exit the highway.[137]
- Interchange bypasses for trucks are appropriate at interchanges that experience relatively high proportions of truck travel that pose safety issues in merge areas.[138]
- S*hort connectors from major port facilities* are appropriate for freight bottlenecks connecting port facilities and corridors with relatively high concentrations of warehouses, distribution facilities, and other freight generators.[139]

Examples

I–5 Truck Lanes in California

California has two truck-only lanes on I–5 in Los Angeles and Kern Counties. The truck lane on southbound I–5 in Kern County is 0.3 miles and was designed to place truck merges farther downstream of the merge at the I–5/SR 99 interchange. The truck lane in Los Angeles County is on northbound and southbound I–5 and has a total length of 2.426 miles in the northbound direction and 2.452 miles in the southbound direction (figure 3.34). The purpose of these lanes is to separate slower moving trucks from the faster general traffic on the steep grade.[140]

As part of the I–5 North County Enhancements Project, the truck-only lanes in Los Angeles County will be extended for approximately 3 to 4 miles in each direction. The project, currently under construction, will also extend the existing HOV lanes on I-5 by approximately 13 miles and add auxiliary lanes. The project is needed to accommodate truck traffic along this stretch of I–5 due to the relatively high percentage of truck traffic, which ranges from 9.4 to 20.8 percent of total traffic volume (compared with truck traffic on other freeway facilities, which generally

Figure 3.34. Truck-only lanes on I–5 in Los Angeles, CA.

Source: Google Earth.

averages between 5 and 8 percent). It is also needed because the topography in the project area is mountainous or hilly, which, when combined with the large volume of trucks and passenger vehicles, results in conflicts and inefficient operations along the project segment of I–5. Due to the grades within the project area, slow-moving trucks and vehicles must share existing travel lanes with other vehicles and can obstruct the flow of traffic, thereby increasing congestion and reducing mobility. Given the high percentage of trucks, steep grades, and current inefficient operations, separated truck-only lanes are needed to improve congestion and safety.[141]

Georgia Department of Transportation (GDOT) I–75 Commercial Vehicle Lanes

A truck-only lane project currently in development is GDOT's I–75 Commercial Vehicle Lanes project. The goal of the project is to improve mobility and safety for freight operators and passenger vehicles by constructing two barrier-separated commercial vehicle-only lanes northbound along I–75 for approximately 41 miles. The new lanes will be nontolled and will span across five counties.[142] The project is expected to reduce the delay by 12 percent for commercial vehicles and 6 percent in general-purpose lanes during peak periods. It is also anticipated to reduce maintenance costs on the general-purpose lanes due to the separation of freight and passenger vehicle traffic, accommodate growth in commercial vehicle traffic coming from Florida and the Port of Savannah, and reduce potential traffic incidents involving trucks.[143]

Florida Department of Transportation (FDOT) I–4/Selmon Expressway Crosstown Connector

FDOT's I–4/Selmon Expressway Crosstown Connector is an example of a short connector to a major port facility. It connects the Port of Tampa to I–4 with a new dedicated express truck lane and ramp (figure 3.35) that allows for expedited truck movements between the port and the Tampa Bay/Orlando I–4 corridor, home to Florida's largest concentration of distribution centers.[144] The Connector is a new, elevated north-south toll road that provides exclusive truck lanes for direct access to the Port of Tampa, which was intended to remove heavy truck traffic

Figure 3.35. Port of Tampa truck access road.

Source: Google Earth.

from Tampa's historic Ybor City area. The Connector was intended to address current and projected levels of truck traffic, which is anticipated to increase beyond the 11,000 truck moves the port sees on an average day.[145]

Florida Department of Transportation Truck Lane Restrictions

Florida's truck lane restrictions have been in place on I–95 in South Florida for 30 years and 20 years on I–75. The current truck lane restriction criterion in Florida allows the restrictions where there are six-lane interstate freeways primarily consisting of rural interstate sections. Trucks are restricted from the left or inside travel lanes, leaving them specifically for automobile traffic. Failure to follow truck lane restrictions is a violation of Florida State statute and subject to a fine and points.[146]

TRUCK CLIMBING LANES

Description

Truck climbing lanes are additional lanes used for short distances in certain areas to allow faster traffic to pass. They help facilitate the passing of trucks and slow-moving vehicles whose speed drops because of the sustained steep grades. Climbing lanes typically are marked with signage advising slower traffic to keep right. In this way, they help reduce collisions and backups by providing slower moving trucks and vehicles an additional, safe lane to travel in, which reduces conflicts between slower-moving trucks and passing vehicles.[147]

Figure 3.36. Truck climbing lane.

Source: Missouri Department of Transportation.

Where To Apply This Solution

Truck climbing lanes are generally applied as a spot improvement, most often on steep, sustained grades that cause heavy vehicles, particularly heavy trucks, to travel at slow speeds (figure 3.36). This has the effect of reducing capacity, creating platoons, increasing delay, and increasing the risk of crashes.

Truck climbing lanes are appropriate for roadway segments where the volume and percentage of heavy trucks justify the added cost of the climbing lane. They can be provided as an added lane for the upgrade direction of a two-lane highway where the grade, traffic volume, and heavy-vehicle volume, including recreational vehicles (RVs), combine to degrade traffic operations from those on the approach to the grade. Where climbing lanes are provided, there is often a high degree of compliance in their use by truck and RV drivers.

The following criteria, reflecting economic considerations, are examples that can be used to justify a climbing lane on a highway improvement project:

- Upgrade traffic flow rate exceeds 200 vehicles per hour
- Upgrade truck (and/or RV) flow rate exceeds 20 vehicles per hour
- A 10 mph or greater speed reduction is expected for a typical heavy truck; LOS E or F exists on the grade, or a reduction of two or more levels of service is experienced when moving from the approach segment to the grade[148]

Examples

Missouri Department of Transportation (MoDOT) Mineola Climbing Lanes Project

MoDOT's I–70 Rocheport Bridge and Mineola Climbing Lanes Project included the construction of 1.2 miles of east- and westbound truck climbing lanes near Mineola Hill to improve traffic flow. The overall project is intended to maintain and improve a vital freight corridor carrying Interstate traffic. The Mineola Hill climbing lanes, which are now operational, were constructed to generate safety and mobility benefits for both cars and trucks traveling at different speeds along I–70.

I–10 Truck Climbing Lane

The San Bernardino County Transportation Authority (SBCTA), in cooperation with the California Department of Transportation (Caltrans), is proposing to extend the eastbound (EB) truck climbing lane on I–10 from the existing EB off-ramp at Live Oak Canyon Road located on the City of Yucaipa, to just east of the existing County Line Road EB off-ramp at the Riverside County line in the City of Calimesa. The existing truck climbing lane will be extended for an additional 3 miles along a steep uphill portion of I–10. The project will improve traffic operations by separating trucks and other slow-moving vehicles from faster-moving passenger vehicles. This will also reduce conflicts between automobiles and slow-moving trucks and would reduce the frequency of truck-related crashes.[149]

INTERMODAL CONNECTORS

Description

Freight highway intermodal connectors are roads that provide the "last-mile" connection between major rail, port, airport, and intermodal freight facilities on the National Highway System (NHS). The officially designated network of NHS intermodal connectors accounts for less than 1 percent of total NHS mileage, but these roads are critical for the timely and reliable movement of freight. The NHS intermodal connectors inventory was completed in 1998 and approved by Congress as part of the Transportation Equity Act for the 21st Century (TEA-21) (Public Law 105-178); the inventory was later updated in 2017.

There are approximately 1,484 miles of designated NHS freight intermodal connectors. The most common type of intermodal connectors are roads to port facilities, representing 40 percent of all intermodal freight connectors. Rail, airport, and pipeline intermodal connectors represent 26, 26, and 7 percent of intermodal freight connectors, respectively.

Two primary types of roads have been designated as intermodal connectors: (1) short, low-volume connectors owned by municipalities, with poor pavement conditions; and (2) long, high-volume connectors owned by State highway agencies, with fair pavement conditions. Cities or municipal highway agencies own 54 percent of all designated connectors, which tend to be relatively short, with an average length of 0.68 miles. State highway agencies own 29 percent of intermodal connectors, which have the highest average length of all ownership categories, at 1.66 miles.

The vast majority of intermodal freight connectors are in need of capacity and state-of-good-repair improvements. Many have a relatively low capacity, with roughly half having just two lanes. Only 15 percent are in good or very good condition. Trucks are delayed approximately 4,237 hours every weekday (roughly 1,059,238 hours annually) on intermodal freight connectors.

Estimates for the cost to improve pavement conditions on intermodal freight connectors to the good-quality condition are approximately $2.2 billion, and to increase capacity on congested connectors and eliminate truck delays is roughly $3.2 billion.[44]

Where To Apply This Solution

State and local highway agencies can repair, rehabilitate, or reconstruct intermodal connectors to alleviate issues of poor pavement condition and truck delay that are commonly experienced on these roadways. Investments in highway intermodal connectors can boost the economic productivity of the supply chain that depends on reliable "last-mile" connections to major rail, port, airport, and intermodal freight facilities.

Local and State highway agencies have undertaken intermodal connector improvements such as:

- Adding auxiliary lanes, driving lanes, or turn lanes
- Upgrading exit ramps and access
- Resurfacing or reconstructing pavement
- Separating rail and highway modes through grade separation projects

States and local jurisdictions have funded intermodal connector improvement projects using a combination of Federal, State, local, and private or facility operator sources. Successful connector improvements often leverage multiple funding sources, including private-sector funding sources. These improvements can be funded through a variety of Federal and State funding programs for freight improvement projects. Some connector improvement projects have used private-sector funding sources for freight intermodal connector improvement projects as part of a larger investment package.[45]

Examples

Florida Department of Transportation (FDOT)

The Florida Department of Transportation (FDOT) is the only State DOT that has specific funded programs targeted toward intermodal freight connectors. As part of the Florida Statewide Intermodal System (SIS), FDOT deployed a "Quick Fix" initiative to provide improvements to connectors, including auxiliary lanes, exit ramp improvements, new travel lanes, turn lanes, and resurfacing of an intersection using concrete. In Florida's FY 2013/2014, the program funded portions of seven projects at the cost of just under $7 million. In Florida's FY 2014/2015, it funded portions of eight projects at the cost of just over $15 million.

FDOT also funds an Intermodal Access Program, which is used by FDOT districts to implement small-scale connector and terminal projects that do not qualify for funding through the SIS program. The program funds access improvements to intermodal facilities, airports, and seaports for freight and passengers. The Miami Intermodal Center and the Jacksonville Multimodal Terminal Center were partially funded under the program. Between Florida's FY

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[44]Ahanotu, D., and L. Grenzeback. 2017. FHWA, *Freight Intermodal Connectors Study*. Report No. FHWA-HOP-16-057. Washington, DC: FHWA, last accessed March 4, 2023.

[45]Ibid.

2014 and FY 2019, over $250 million of projects were planned to be partially funded through this program.

Chicago Area Consolidation Hub

The Chicago Area Consolidation Hub project (figure 3.37) provided access improvements to a UPS sorting facility in Chicago. The project included a new rail intermodal terminal, local road access improvements, a rail-highway grade separation, and interchange access from I–294 to the Chicago Area Consolidation Hub. The project, which cost a total of $97.6 million, was funded with private contributions (including from BNSF Railroad) and a public-private partnership that included the State of Illinois, UPS, BNSF, and the Village of Hodgkins.

Figure 3.37. Chicago Area Consolidation Hub.

Source: Bing Maps.

Freight Action Strategy Corridor

The Freight Action Strategy Corridor in the Puget Sound region of Washington provided a series of improvements to key truck and rail infrastructure in the Seattle-Tacoma area to facilitate efficient freight movement in the region. The project included intermodal connector projects, such as the Spokane Street Viaduct widening at the Port of Seattle, East Marine View Drive widening at the Port of Everett, East Marginal Way grade separation in Seattle, and South 228th Street-grade separation in Kent. Funding for the projects was acquired from multiple public and private sources, including Federal funds, State funds, local funds, and contributions from BNSF, the Port of Seattle, and the Washington Transportation Improvement Board.

Stockton Airport Freight Terminal

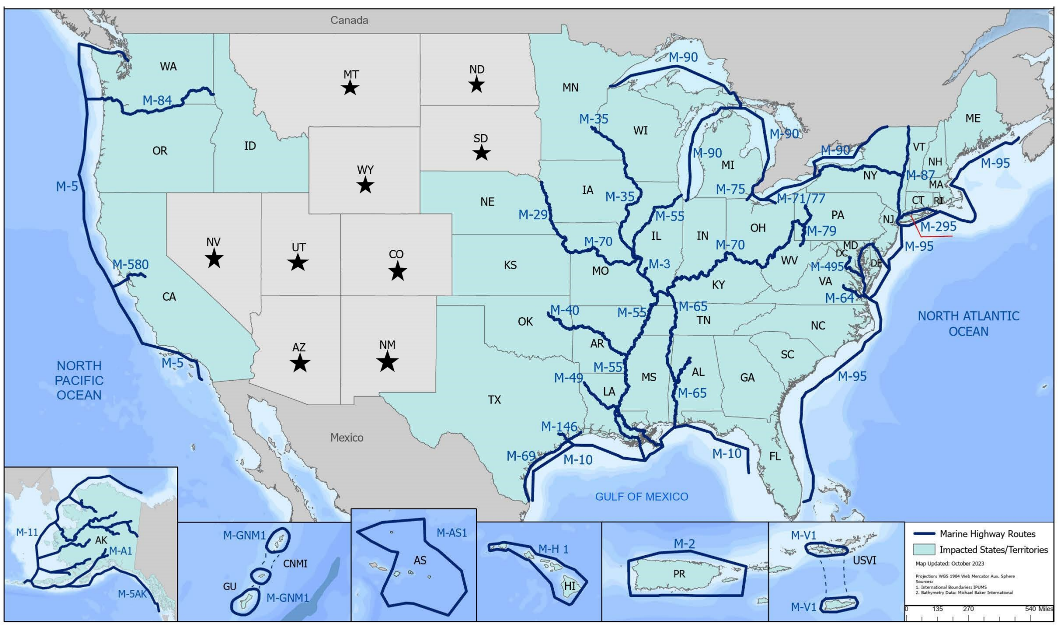
The Stockton Airport Freight Terminal in California constructed an air freight terminal at Stockton Airport, including cargo apron improvements, stream relocation, and access road shoulder improvements. The project cost a total of $1.7 million, which consisted of contributions from the Federal Aviation Administration, the State of California, the City of Stockton, and Farmington Fresh, a private company.[150]

MARINE HIGHWAY PROGRAM

Description

America's Marine Highway Program (AMHP) supports the increased use of the Nation's navigable waterways to relieve landside congestion, provide new and efficient transportation options, and increase the productivity of the surface transportation system. As of April 2022, the Marine Highway system includes 29 "Marine Highway Routes" under the AMHP. Each Marine Highway Route is a navigable waterway capable of transporting freight in the United States or its territories, serving as an extension of the surface transportation system (figure 3.38). Since its inception in 2014, the AMHP has designated 54 marine highway projects, which consist of a planned service or expansion of an existing service on a designated Marine Highway Route.[151]

Figure 3.38. America's Marine Highway Routes.



Note: Routes as shown are diagrammatic and may not depict all waterways and port connectors that are considered to be part of the U.S. Marine Highway System.

Source: United States Maritime Administration.

The Marine Highway program was established by the Energy Independence and Security Act of 2007 to reduce landside congestion. The Coast Guard and Maritime Transportation Act of 2012 further expanded the scope of the program to increase the utilization and efficiency of domestic freight or passenger transportation on Marine Highway Routes between United States ports. The The National Defense Authorization Act for Fiscal Year 2016 then expanded the definition of short sea shipping to include freight vehicles carried aboard commuter ferry boats and cargo shipped in discrete units.

The goal of the Marine Highway Program is to expand the use of America's navigable waters for the transportation of freight. The program staff works closely with public and private organizations to develop and expand marine highway service options and facilitate greater integration into the United States surface transportation system, especially where maritime transport is the most efficient, effective, and sustainable option. The program also seeks to promote waterways as a viable, and in some cases, a superior alternative to landside shipping and transportation options.

Public benefits of using marine highways include:

- Creating and maintaining jobs in United States vessels, ports, and shipyards
- Relieving landside congestion
- Improving state-of-good-repair on roads and bridges
- Improving the United States economic competitiveness by adding new cost-effective freight and passenger transportation capacities
- Driving mandatory use of emerging engine technologies
- Improving public safety and security by providing alternatives for the movement of hazardous materials outside heavily populated areas
- Improving environmental sustainability by using less energy and reducing air and greenhouse gas (GHG) emissions per passenger or ton-mile of freight moved
- Improving transportation system resiliency and redundancy by providing transportation alternatives during times of disaster or national emergency
- Improving national security by adding to the Nation's strategic sealift resources[152]

The types of Marine Highway projects that may be eligible for Federal assistance include specialized equipment, infrastructure, and vessel needs required for developing and expanding ports and terminals, such as:

- Incidental dredging to ensure sufficient berth depth outside the Federal channel
- Marine structures, such as piers, wharves, and fender systems
- Sufficient cargo storage area, cargo transfer equipment, and terminal handling equipment
- Gate operations infrastructure and equipment
- Landside access improvements, such as rail connections, rail loading/unloading tracks, and roadway improvements
- Specialized gantry cranes for smaller ports to efficiently load and unload marine container barges

- Modifications (e.g., wharf rehabilitation, berth improvements, paving, fencing, and staging area development) and additional shoreside equipment (e.g., specialized cranes, forklifts, hostlers, tractors, and top pick forklifts) to support the startup Marine Highway services at moderate-sized port facilities
- Special adaptations (e.g., increasing dock and yard capacity for loading and unloading smaller vessels and roll-on/roll-off vessels) at larger ports[153]

Where To Apply This Solution

State and local transportation agencies can take advantage of the AMHP where there are navigable waterways (e.g., rivers, bays, channels, coasts, the Great Lakes, open-ocean routes, and the Saint Lawrence Seaway System) that can provide relief to the landside highway and railway corridors suffering from congestion, excessive air emissions, or other environmental challenges. This includes areas with land-based congestion that public or private Marine Highway operators could serve through underused ocean, inland waterway, and lake access, particularly along the I–5, I–95, and I–10 highway corridors.[154],[155]

Examples

Tenn-Tom Freight Project

Figure 3.39. Barge at the Port of Itawamba.

Source: Mississippi Department of Transportation.

The Itawamba County Port Commission and Tennessee-Tombigbee Waterway Development Council in Mississippi sponsored the Tenn-Tom Freight Project on the M–65 Marine Highway corridor, which connects the M–10 corridor in Mobile, AL, and the M–55 corridor in Cairo, IL. The Tenn-Tom Freight Project received Marine Highway Program support to create a new container-on-barge service between the Port of Itawamba on the Tennessee-Tombigbee Waterway (figure 3.39) and the Port of Mobile, AL. The service now serves as the inland leg for new deep draft Gulf Coast container terminals. The project was intended to offset the approximately 3,150 daily truck trips on I–65 by moving containers on the M–65 Marine Highway instead. A significant proportion of intermodal traffic moving to the northeastern region of Mississippi had traveled by rail to and from ports in California to an intermodal hub in Memphis, TN, and then by truck to Mississippi. The service established by the project offers a nearly all-water route for this freight via the Panama Canal and the Tennessee-Tombigbee Waterway. In providing this service, the region has benefited from enhanced system resiliency, reduced emissions, and increased energy efficiency.[156]

Northeast Marine Highway Expansion Project

The Maine Department of Transportation's Northeast Marine Highway Expansion Project on the M–95 Marine Highway corridor expanded an existing container-on-barge service operating between Newark, NJ; Boston, MA; and Portland, ME. The project was intended to relieve the I–95 corridor of the trucks moving on it through the construction of an articulated tug and barge that rigidly connected the two vessels. This provided enhanced reliability because it could operate in rougher weather than traditional towed barges, which shippers indicated were needed to move their freight by waterway, as opposed to truck.

James River Container Expansion Project

The Virginia Port Authority's James River Container Expansion Project on the M–64 Marine Highway expanded an existing container-on-barge service between Hampton Roads and Richmond, VA, by increasing the frequency of service (figure 3.40). It also initiated a container shuttle service between four terminals in the Hampton Roads area, shifting the freight from local urban roads to the waterborne alternative. The project was intended to relieve truck traffic on the I–64 corridor, a major freight bottleneck causing up to 500,000 hours of vehicle delays annually. It was also beneficial to the environment, utilizing low-emission engines and ultra-low-sulfur fuel.[157] Recently, the Virginia Port Authority initiated a project to improve lighting within the perimeter of the Richmond Marine Terminal (RMT) through the installation of high-mast light poles with light-emitting diode (LED) fixtures and the retrofitting of existing light poles and LED fixtures. Expanding the operational capacity at the terminal with improved lighting within the facility will allow for barge operations beyond daylight hours.

Figure 3.40. Container-on-barge service on M–64 Marine Highway in Virginia.

Source: gCaptain.

M–3 Kaskaskia River Marine Highway Route Designation

In December 2021, USDOT announced the designation of a new Marine Highway route. The Marine Highway route designation was for M–3 Kaskaskia River in Illinois. The Kaskaskia River is the second-longest river in Illinois, originating in central Illinois around Champaign, IL, and terminating at its confluence with the Mississippi River—a distance of more than 300 miles. The Kaskaskia River has been predominately used to ship bulk commodities of coal, scrubber stone, slag, grain, and scrap metal since it was established as a navigable waterway. However, up to 50,000 tons of unitized coil steel are also moved on this waterway, with a new tenant expected to ship up to 1.2 million tons of coiled steel for processing and other uses once it constructs its processing plant. This route designation will include the existing freight traffic between the terminals on the Kaskaskia River and the Mississippi River, which will open new opportunities to leverage private investment through public and private partnerships and support supply chain resiliency efforts.[46]

[46]MARAD. 2021. "U.S. Transportation Secretary Pete Buttigieg Announces $12.6 Million in Grants for America's Marine Highways," last accessed March 4, 2023.

Case Study: Iowa Inland Waterways

Figure 3.41. River Barge

Source: Iowa Department of Transportation.

In Iowa, freight shippers have the convenience of multiple modal options for moving goods and materials. The State's 160,000-mile multimodal freight transportation system includes two bordering navigable waterways—the Missouri River and Mississippi River—which form Iowa's waterway system and are part of two USDOT-designated Marine Highway Routes: M–35, the Upper Mississippi River (312 miles in Iowa) on the west; and M–29, the Missouri River (179 miles in Iowa) on the east. Both Marine Highways connect to an extensive national inland waterway system and international deep-sea ocean port facilities on the Gulf Coast.

Waterways provide a lower cost–higher volume intermodal option to move grain and bulk materials to international markets. Transporting commodities via waterway is the most fuel-efficient and least costly option compared with truck and rail and can handle the largest volumes per trip. One barge can handle 1,750 dry tons of cargo, the equivalent of 70 trucks or more than 16 rail cars.

Freight moving via waterway in Iowa is primarily moving through facilities on the Mississippi River. A system of 11 locks and dams on the upper Mississippi River, operated by the United States Army Corps of Engineers (USACE), maintains adequate water levels for barge operations. The waterway's locks and dams are aging and deteriorating, creating a large backlog of maintenance and rehabilitation projects to bring the system into a state of good repair. The condition of the locks creates delays, unscheduled closures, and bottlenecks. In fact, all but one of Iowa's locks delay over 50 percent of vessels each time they try to lock through. Given the overall condition, size, and average delay of the locks bordering Iowa, all are considered freight bottlenecks in the Draft 2022 Iowa State Freight Plan, which also provides prioritized implementation strategies for Iowa's inland waterways.

To address performance, reliability, and bottlenecks in its waterway system, Iowa DOT has taken deliberate planning, partnering, and project delivery steps. The Iowa State Freight Plan prioritizes waterway improvement strategies. The State DOT is partnering with USACE to support their priority project lists for improving the M–29 and M–35 waterways. They are working with USACE to construct a new mooring cell near LeClaire, Iowa, at Lock 14. They also worked with regional partners to establish a new Port Statistical Area (PSA) to attract more investment and funding for the USACE to improve the performance and reliability of the waterway system. In addition, Iowa DOT worked with private partners to open a new barge terminal on the Missouri River as a more attractive and cost-effective alternative to shipping dry bulk and farm commodities.

For more information, see the detailed case studies in Appendix A.

INLAND PORTS

Description

Inland ports have emerged as an important component in the global supply chain due to common challenges with seaport locations. Many major seaports are located in urban areas where land for expansion is scarce and expensive, and congested roadways hinder truck access to the port. Inland ports allow containers to be moved by rail from seaports to intermodal yards located in less densely populated areas with available land and less traffic congestion.

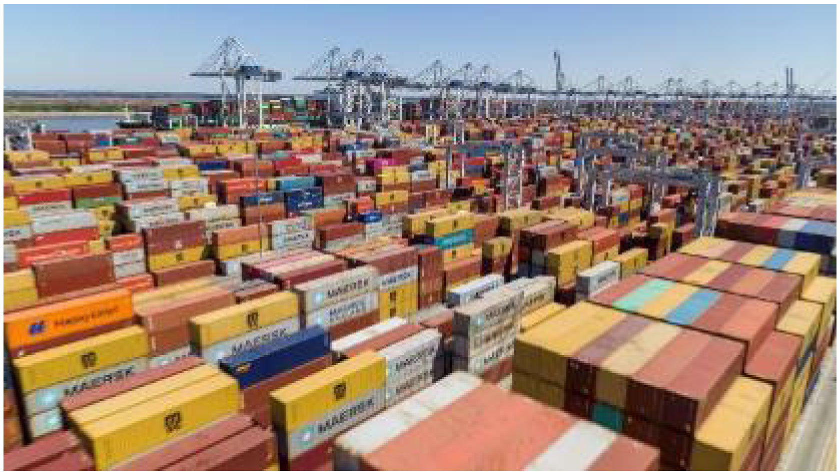
Inland ports can expand marine port capacity by moving functions that would otherwise be performed at the port the inland port.[158] Inland ports can place freight in locations more accessible to markets while relieving highway congestion, which is particularly impactful if containers would otherwise be trucked through congested areas. These logistics centers can also support economic development, such as nearby warehousing and distribution centers.

Today, inland ports can take the form of temporary "popup" ports or more permanent "dry" ports. "Popup" ports are quickly implemented, flexible intermodal terminals that are directly connected to seaports by rail or road. They expand the capacity of seaports by moving functions that would otherwise be performed dockside, like container storage, to more inland locations with adequate access and size.

"Dry" ports operate as inland intermodal terminals directly connected to seaports by rail or road. Cargo is transferred from an ocean vessel to railcars and then transported to an inland location, away from the more congested port itself, for further processing and distribution. Cargo also moves the other way from outbound cargo, offering inland manufacturers an efficient means of exporting their goods through seaports. In this way, dry ports provide flexibility and control to manufacturers running tight production lines and retailers in need of velocity and reliability in their supply chain.

Where To Apply This Solution

Figure 3.42. Container storage at the Port of Savannah.



Source: Georgia Ports Authority.

Inland ports provide a viable solution to limited capacity at seaports and dockside congestion (figure 3.42), which have become major bottlenecks in the global supply chain. They can be deployed where there is a need for an inland distribution point from a congested seaport to an inland destination.[159] Inland ports require large tracks of industrially zoned land that is away from more congested urban areas. By locating inland ports outside of congested urban areas, they can improve access for trucks collecting or dropping off containers, improving the movement of freight to manufacturing, warehousing, and other regional population centers.[160] Inland ports can also be used to shift the sorting and handling of imports and exports farther inland, away from the congested seaport.

The benefits of providing an alternative to moving freight by truck from an inland port can include:

- Reduced empty miles, higher truck productivity, and lower chassis/per diem/detention charges
- Enhanced flexibility with the ability to terminate and source empties closer to the origin/destination
- Increased competitiveness with round-trip all-motor on a one-way basis
- Reduced trucking risks due to variable fuel costs, driver availability, hours of service rules, and other factors
- Reduced emissions from fewer truck/empty miles

Examples

Table 3-2 shows examples of inland ports for the South Carolina Ports Authority (SCPA), Virginia Ports Authority, and Georgia Ports Authority.

Table 3-2. Example highway and rail access to and from dry ports.

Inland ("Dry") Port	Sea Port Served	Port Authority	Rail Access	Highway Access
Inland Port Dillon	Port of Charleston	South Carolina Ports Authority (SCPA)	CSX	I–95
Inland Port Greer	Port of Charleston	South Carolina Ports Authority	Norfolk Southern	I–85
Virginia Inland Port	Port of Virginia	Virginia Ports Authority (VPA)	Virginia Inland Port	I–66, I–81
Appalachian Regional Port	Port of Savanah	Georgia Ports Authority	CSX	I–75
Northeast Georgia Inland Port	Port of Savanah	Georgia Ports Authority	Norfolk Southern	I–85

Source: SCPA, VPA.

The SCPA has two dry ports in operation: Inland Port Greer, which opened in 2013, and Inland Port Dillon, which opened in 2018. In its fiscal year 2021, SCPA's inland ports set cargo records with a combined 192,829 rail moves. This represented a record year-over-year level of growth of 11.71 percent.[161]

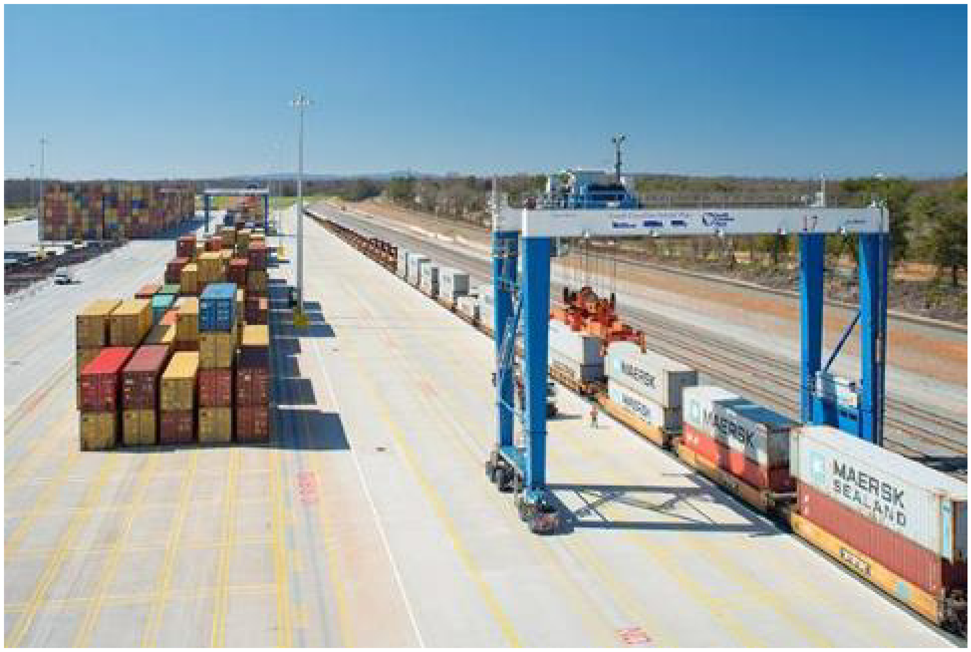
South Carolina Ports Authority Inland Port Greer

Inland Port Greer is located along I–85 between Charlotte and Atlanta, extending the Port of Charleston's reach 212 miles for shippers and producers. With 94 million consumers living within 500 miles of the facility, it is close to population centers and key import/export clients. Inland Port Greer has 24/7 gates and next-day availability of containers where import loads discharged in the Port of Charleston in the morning can be taken to the local Norfolk Southern (NS) intermodal ramp and be available in Greer by 8 a.m. the next morning, 6 days per week. In this way, Inland Port Greer offers flexibility and control, providing manufacturers and retailers the velocity and reliability they need in their supply chains.

A major motor vehicle manufacturer is one of the largest users of Inland Port Greer (figure 3.43). The inland port has allowed the company to expand production at its Spartanburg, SC, plant through the next-day service to and from the Port of Charleston.[162]

South Carolina Ports Authority Inland Port Dillon

Figure 3.43. Inland Port Greer.



Source: South Carolina Ports Authority.

The more recently developed Inland Port Dillon is located within a 3,400-acre industrial site and in close proximity to I–95 near the South Carolina/North Carolina border. The facility uses CSX rail that can move goods to and from the Dillon market and the Port of Charleston (table 3-2). This gives cargo owners the ability to control costs with flexibility and minimal inland truck miles, which is attractive to exporters in the region as it provides a low-cost platform from which empty containers can be sourced and returned loaded for export in the fastest possible turn time.[163]

Inland Port Dillon provides exporters one Dillon-origin rate from their ocean carrier that includes all terminal fees in Dillon, CSX rail transit to the Port of Charleston, delivery to the container terminal, plus international shipping to the destination. Importers receive one rate from their ocean carrier that includes shipping to Charleston, SCPA-provided dray to the CSX intermodal ramp within 24 hours of becoming available, rail transit to Dillon, and SCPA handling and facilitation fees in Dillon.[164]

The Dillon Inland Port also allows regional shippers to have greater access to empty containers to fill for export and import, lowering their costs by giving them the ability to terminate and source empties at Dillon, closer to the origin or destination. In addition, other shipper risks associated with trucking (e.g., higher fuel costs, driver availability, and hours of service rules) are lowered by moving to rail.[165]

By extending the reach of the Port of Charleston, Inland Port Dillon is anticipated to remove 35,000 to 56,000 truck movements from congested highways between the two facilities over the first 5 years of operation. The rail service to the Port of Charleston saves costs to shippers compared to trucks by maximizing tonnage moved per gallon of fuel. The inland port benefits shippers in the region because they pay the lower transportation costs of a one-way container move by rail instead of the costs of a roundtrip truck move (i.e., one trip with an empty container, one trip with a loaded container).

Virginia Port Authority's Virginia Inland Port (VIP)

A third dry port example is the Virginia Port Authority's VIP in Front Royal, Virginia (figure 3.44). As shown in table 3-2, VIP has access to I–66, I–81, and NS freight rail. Located approximately 60 miles west of Washington, DC, VIP brings the Port of Virginia 220 miles closer to inland markets and enhances service to the Washington DC/Baltimore metropolitan regions by providing rail service to the terminals in Hampton Roads. The terminal is serviced by nearly 18,000 feet of rail track that runs adjacent to NS's Crescent Corridor. Intermodal rail cars arrive at VIP and gain access via NS rail to Harrisburg, PA, and New York/New Jersey region. Containerized rail service is provided five days a week to VIP from both Norfolk International Terminal and Virginia International Gateway in Portsmouth.

A number of companies have opened distribution centers in the Front Royal area to use VIP. The facility is a United States Customs-designated port of entry and offers customers a full range of services, including an onsite log-stuffing operation, onsite chassis/container repair vendor, secure container storage, and shore power for refrigerated units.

Figure 3.44. Virginia Inland Port.

Source: Virginia Business.

Case Study: Georgia's Inland Ports

For the Georgia Ports Authority (GPA), the inland port model has proven valuable in terms of reduced highway and seaport congestion, as well as local economic development. Containers can be trucked for shorter distances and staged at the inland port intermodal yard, where they are loaded onto trains moving hundreds of containers in a single trip. This extends GPA's reach and capacity to meet growing demands, stages cargo closer to population centers, extends port gates, saves millions of truck miles, and attracts new businesses.

Appalachian Regional Port (ARP): ARP is GPA's dry port in Murray County at the Tennessee border (see image). It opened in August 2018 at a cost of $27 million as a joint effort of the State of Georgia, Murray County, GPA, and CSX Transportation. ARP provides manufacturers and shippers in target markets in the Midsouth region an alternative to all-truck drays to/from the Port of Savannah. ARP provides an inland gateway to global markets, with highway access to I–75 and US 411 and exclusive CSX freight rail service on a direct 388-mile route to/from the Port of Savannah's Garden City Terminal. Located in a rural area, the facility offers customers proximity to key highway connections away from the inefficiencies of urban congestion. Each round-trip container moved via ARP offsets 710 truck miles on Georgia highways and results in savings on the costs of fuel, congestion, safety, and state-of-good repair that would otherwise be incurred from truck traffic.

Northeast Georgia Inland Port: Planned to enter construction in fall 2022, GPA's new 104-acre dry port will provide a direct link to the Port of Savannah via Norfolk Southern rail service from northeast Georgia. With a top capacity of 150,000 container lifts per year, the facility will offset 600 roundtrip highway miles for every container moved by rail. Along with NS rail access, the dry port will have highway access to the I–985 corridor and is located close to I–85.

PopUp Ports: Recently, when American port terminals were inundated with import containers, GPA worked with Norfolk Southern, CSX, USDOT, and other entities to establish six temporary, popup container yards near manufacturing and distribution centers in Atlanta, Savannah, Statesboro, and Murray County in northwest Georgia, as well as Huntsville, AL, and Rocky Mount, NC. Those yards have served as a pressure relief valve to combat dockside congestion at the Port of Savannah's Garden City Terminal. The six popup yards provide inland and off-dock storage for long-dwell import containers. The use of these sites has not only eased the movement of cargo across the terminal, but also expedited vessel service by opening up space for offloaded containers. GPA has the ability to expand the popup sites depending on demand, bringing the total annual capacity for the off-port locations to 500,000 20-foot equivalent container units (TEUs) or the equivalent of 27 mega container ships.

For more information, see the detailed case studies in Appendix A.

RAIL INTERMODAL CORRIDORS

Description

Like marine highways and inland ports, rail intermodal provides a means of shifting freight to nonhighway modes to alleviate highway congestion and truck bottlenecks. Similar to inland ports, rail intermodal involves long-haul movement of shipping containers and truck trailers by rail combined with a truck or water movement at one or both ends. An advantage that rail intermodal offers is "double stacking" of containers that sharply increases productivity and keeps intermodal economical (figure 3.45).

Figure 3.45. Double-stack containers on a Norfolk Southern railroad.

Source: Norfolk Southern.

Private freight rail companies have partnered with transportation agencies to establish rail intermodal corridors that provide service to inland markets from major United States ports. These corridors need sufficient line haul and terminal capacity to keep trains moving and to avoid congestion or delay. Corridor initiatives include three in the eastern United States focused on upgrading trackage and clearances for double-stack rail cars to provide service to inland markets from major east coast ports:

- NS's Heartland Corridor
- CSX's National Gateway Corridor
- NS's Crescent Corridor

Where To Apply This Solution

Rail intermodal corridors can be applied where transportation agency interests are generally aligned with those of private freight rail companies operating in their jurisdiction. Investments in funding and staff resources are often required to establish rail intermodal corridors. NS's Heartland Corridor and Crescent Corridor, and CSX's National Gateway Corridor have required cooperation between public and private sponsors whose investments in infrastructure and equipment have included:

- Adding track capacity and advanced signaling to allow faster, more frequent trains
- New or expanded inland intermodal terminals to facilitate the transfer of containers and trailers between rail and truck, and new near-dock intermodal terminals to facilitate ship-to-rail container transfers
- Raising height clearances along rail routes to accommodate the additional height required for double-stack trains
- Introducing new intermodal car types and modernizing the locomotive fleet to enhance customer reliability

State and local agencies can benefits from rail intermodal through:

- Reduced air emissions—On average, railroads are three to four times more fuel efficient than trucks. Moving freight by rail instead of truck reduces greenhouse gas emissions by up to 75 percent on average.
- Reduced highway congestion—One intermodal train can carry up to several hundred containers and trailers, which removes that many trucks off the road, reducing highway congestion and wear on highways.

Examples

Three major intermodal rail corridor development projects in the eastern United States have been developed to upgrade trackage and clearances for double-stack rail cars and provide service to inland markets from major the United States East Coast ports.

Norfolk Southern Heartland Corridor

The Heartland Corridor is a 530-mile railway line that became operational in September 2010. It carries double-stack container freight trains between Hampton Roads, VA; and Chicago. The initiative was a partnership between NS, USDOT, the States of Ohio and West Virginia, and the Commonwealth of Virginia. It improved the NS rail line by clearing double-stack rail overhead restrictions through the corridor—raising the height of 28 tunnels and removing overhead obstacles on the main lines. The initiative also included the development of rail-truck container transfer terminals along the route, such as the Intermodal Terminal in Columbus, OH. The initiative ultimately reduced each container move by approximately 250 route miles and decreased transit times by a day.

CSX National Gateway Corridor

The National Gateway Corridor initiative is a package of rail infrastructure and intermodal terminal projects designed to improve the cargo flow along three major freight rail corridors owned and operated by CSX. The initiative includes increasing 40 height clearances in 4 States to accommodate double-stack container cars through the Midwest and along the Atlantic Coast. The project parallels the I–95 corridor, connecting North Carolina with Baltimore, MD, and travels east along the I–70/I–76 corridor between Washington, DC, and northwest Ohio via Pittsburgh, PA. As part of Phase I of the project, new intermodal terminals in Chambersburg, PA, and northwest Ohio have been completed and are operational.

Norfolk Southern Crescent Corridor

The Crescent Corridor initiative centered on the continued development of NS's rail intermodal route from the Gulf Coast (Memphis and beyond to New Orleans) to the mid-Atlantic region (New Jersey). The program improves rail infrastructure to create a high-capacity 2,500-mile intermodal route through 13 States. The initiative involves developing intermodal terminals in Tennessee, Alabama, and Pennsylvania and expanding 2 others; constructing 300 miles of double track and 10 passing sidings; straightening curves; and adding signals.[47]

SHORT LINE RAIL

Description

Figure 3.46. Short line railroad in Oregon (Portland and Western Railroad).

Source: Union Pacific.

Short line railroads play an important part in the United States supply chain, providing shippers a critical connection to the Nation's rail network and allowing them to ship by rail, which can be a more economical shipping solution than truck. Altogether, short line railroads operate on 50,000 miles of track, or nearly 40 percent of the national railroad network.

American short lines operate in 49 of the 50 States, concentrated in small-town and rural America. They run shorter distances than the Class I freight rail providers, handling the first mile and last mile of the freight rail network and serving as a distribution and feeder system for the overall freight rail network (figure 3.46).

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[47]MARAD. 2013. *Panama Canal Expansion Study Phase I Report: Developments in Trade and National and Global Economies*, last accessed March 5, 2023.

Short lines typically serve manufacturing, agricultural, and industrial customers in locations that might not otherwise have access to freight rail. Because they connect to Class I railroads, short lines often provide rail service to customers in areas that are not directly served by the larger railroads.[166]

Where To Apply This Solution

Freight rail service in general, and short lines in particular, offer significant opportunities to mitigate truck bottlenecks in metropolitan areas and reduce environmental degradation and capital infrastructure requirements for highways. Each year, short line railroads transport 11 million cars of cargo each year, hauling enough carloads to divert 26 million trucks from the Nation's highways. It is estimated this reduction in highway traffic lowers pavement damage costs by $1.2 billion annually.[167]

Short line railroad infrastructure is an underused asset that offers opportunities for future growth. Within metropolitan areas, transportation agencies could promote the use of short lines as part of a comprehensive solution to supply chain problems. Agencies can partner with short line railroads to improve their infrastructure and attract customers that would switch from truck to rail, providing first- and last-mile rail access that can bypass congested areas and keep their freight moving.

Examples

Genesee and Wyoming Railroad Portland and Western Railroad (PNWR)

The PNWR is a 516-mile short line serving central and western Oregon. PNWR trains primarily carry commodities including chemicals, forest products, grain, and steel. A primary customer of PNWR's is Georgia-Pacific, which recently relied on PNWR's services to meet demand in 2020 for paper-product packaging for ecommerce home deliveries. PNWR played a vital role in supplying raw materials to Georgia-Pacific manufacturing facilities by carrying inbound wood pulp that had been shipped by rail from Texas to Georgia-Pacific mills in Oregon. The materials were used at the Georgia-Pacific mills to make products for personal paper-product producers who finish, package, and distribute goods to the consumer market. At the same time, PNWR hauled inbound wood chips from California and outbound containerboard to the western United States for another Georgia-Pacific plant in Oregon (figure 3.47). PNWR was able to meet this demand by adding days of service for inbound raw materials, ensuring receipt of a sufficient supply of empty railcars for loading finished goods, and adding additional locomotive power to pull the increased outbound loads to warehouses and customer sites.[168]

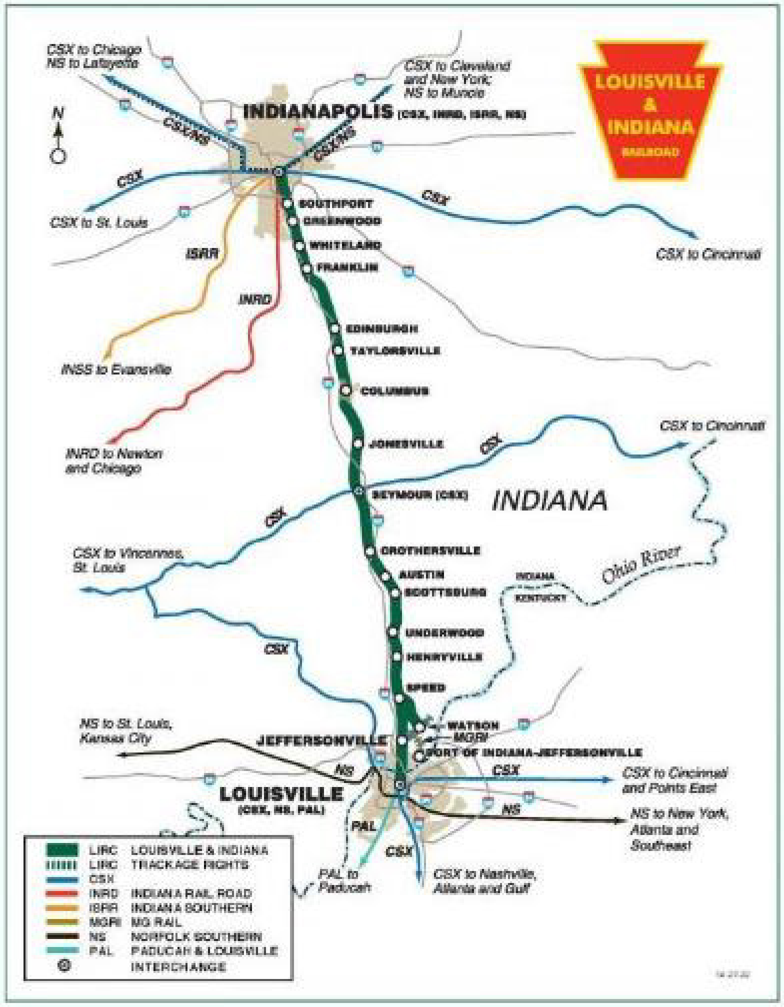
Figure 3.47. Portland and Western Railroad short line railroad network serving Georgia-Pacific facilities in Oregon.

Source: Genesee and Wyoming Railroad

The Louisville and Indiana Railroad (LIRC)

In Indiana, the LIRC is a short line that operates over 106 miles of rail line between Indianapolis, IN; and Louisville, KY (figure 3.48). LIRC's railroad connects to larger systems, including CSX, NS, the Indiana Railroad, and the Paducah and Louisville Railroad. LIRC's line also serves major companies and a Ports of Indiana inland port facility in Jeffersonville, IN. Every year, LIRC carries 20,000 carloads of cargo, including lumber, plastics, steel, alcohol, cement, grain, chemicals, copper, and paper products.[169]

Figure 3.48. Louisville and Indiana Railroad system.



Source: Anacostia Rail Holdings.

ORGANIZATION AND PLANNING FOR OPERATIONS TO INCLUDE FREIGHT STAKEHOLDERS

Description

This toolbox solution encompasses the involvement of freight stakeholders who are internal and external to transportation agencies to advance solutions for addressing freight bottlenecks and mobility. It is foundational to applying any of the other toolbox solutions described in this report, underlying how agencies should approach those other tools to support freight planning and project development.

Effective freight transportation solutions take advantage of freight information collection, management, and utilization. To support freight planning and project development, agencies use stakeholder engagement that harnesses input from freight stakeholders representing diverse interests.

Organizing and planning for operations involve addressing freight bottlenecks and mobility as a central part of an agency's mission and institutional structure. This is accomplished by advancing freight solutions within the agency through internal freight stakeholders to inform planning and other business processes, performance measurement, cultural understanding, acceptance, and championship of freight's relevance, organizational structure and staff development, and effective external collaboration and partnerships.

FHWA has developed specific guidance to help transportation agencies improve the effectiveness of their TSMO activities. The framework, the "Operations Capability Improvement Process," is based on self-evaluation regarding the key process and institutional capabilities required from a transportation agency (or group of agencies) to achieve effective TSMO. This framework is adapted from a concept developed in the information technology (IT) industry called the "Capability Maturity Model," which has been tailored to the transportation community. It is based on self-evaluation regarding the key process and institutional capabilities required from a transportation agency (or group of agencies) to achieve effective TSMO. More information on this guidance can be found at https://ops.fhwa.dot.gov/plan4ops/focus_areas/organizing_for_op.htm.

Where To Apply This Solution

To gather important information and data from stakeholders, engagement could be accomplished through:

- Advisory groups (e.g., freight advisory councils or committees)
- Interviews
- Surveys
- Information sharing
- Feedback loops (e.g., reviews, updates)

States use State Freight Advisory Committees (SFACs) to provide input on freight planning and projects. Several options are available to transportation agencies for deciding who the freight stakeholders represent and how they are engaged. Key stakeholders involved in SFAC and other freight advisory functions can include representatives from:

- Ports
- Railroads
- Shippers and carriers
- Cargo owners
- Third-party logistics providers
- Modal representatives
- Freight operators
- Industrial real estate developers
- Industry associations
- Freight industry workforce
- MPOs
- Local governments
- State environmental agencies
- Community organizations
- Transportation authorities
- Economic development agencies

When considering freight stakeholders to include in a freight advisory group, transportation agencies should not only have private-sector freight representatives involved but also entities like

MPOs, educational/academic interests, planning agencies, labor groups, and others that can be important to engage in any organizational or planning process.

The composition and purpose of freight stakeholders are important because they can serve as freight champions and provide a face for freight to build trust with industry stakeholders and the public. They can also provide important information on the market, economic factors, industry practices, trends, and commodity movements on the network. This input can be useful in planning, transportation analyses, impact assessment, project selection, and managing operations.

Examples

Texas Department of Transportation (TxDOT) Freight Advisory Committee (FAC)

The TxDOT FAC provides industry support, buy-in, and project advancement, especially those advancing emerging technologies (e.g., CAVs). Its mission is to advise TxDOT on freight issues, priorities, projects, and funding needs for freight improvements and elevate freight transportation as a critical component of the State's economic vitality and competitiveness.[170] In this way, the TxDOT FAC serves as a forum for agency transportation decisions affecting Texas freight mobility. TxDOT FAC members represent a diverse range of interests, from educational institutions to public-sector agencies to private-sector companies.

The North Jersey Transportation Planning Authority (NJTPA)

The NJTPA has produced numerous resources to describe freight flows, which have helped the agency gain support from stakeholders. Its Freight Initiatives Committee supports the regional goods movement industry. Composed primarily of representatives from counties, cities, the New Jersey Department of Transportation, NJ Transit, and the Port Authority of New York and New Jersey, they provide recommendations on strategic transportation investments and policies to keep the region globally competitive. The committee serves as a forum for dialogue on freight issues between the public and private sectors.[171]

NJTPA's Goods Movement Strategies for Communities tool has facilitated discussions on trucking issues by helping stakeholders identify and clarify issues with moving goods by truck and offering strategies to address community concerns while preserving the critical function of trucks in the regional economy. The development of this application and its database of truck-related issues was guided by extensive stakeholder input from both the public and private sectors. The NJTPA Freight Division drafted a list of potential freight issues communities might face. Each issue is categorized by geographic area, truck operations, and related issues. Staff researched and identified 34 strategies for addressing these issues. A two-page summary was developed for each strategy, including a description, goal, implementer(s) and supportive stakeholders, action items, challenges, settings in which each should be used, and examples with links for further details.[172]

NJTPA also provides a Freight Activity Locator application that shows key freight data developed and gathered by NJTPA during the course of its freight planning activities. The application presents maps of the region's freight transportation network and major freight facilities, including the port, intermodal yards, and distribution centers.[173]

OPERATIONS AND FREIGHT PERFORMANCE MEASUREMENT AND MANAGEMENT

Description

Another tool to support freight planning and project development is the visualization of freight performance data. Like the prior toolbox solution, it is foundational to applying any of the other tools described in this report, underlying how agencies should approach those other strategies.

Transportation agencies are increasingly measuring and monitoring freight operations and performance and applying freight data to visual formats that a variety of audiences, from highly technical DOT staff to the public, can understand. Freight movement, connections, routes, and performance may be difficult to describe, especially when freight moves across multiple modes and jurisdictions. Visualization tools are available to help agencies convey freight performance at a glance.

Some existing performance measurement tools for freight data among State DOTs show measures across ranges of geographies. Many show freight bottlenecks, usually with some key statistics available such as hours of delay, cost of congestion, commodity value, and other measures of mobility and reliability that help tell a freight story. Another element of these tools is information that can be conveyed dynamically so that users can experience how performance changes over time.

Often, these tools will use GIS to conflate data on conditions and operations to paint a more vivid picture of freight performance. For example, bottleneck location mapping can be layered with data on freight generator locations, land uses, or areas with environmental sensitivities such as flood-prone locations. This can reveal the bottlenecks in relation to the locations freight serves or where delay might be caused by environmental or resiliency impacts.

Having good visualization of freight performance, especially when it allows people to interact and zoom in on parts of the system most important or impactful to them, helps engage public-sector decisionmakers. Decisionmakers can more easily see how businesses in their jurisdiction are impacted and understand the connection between bottlenecks and economic development, safety, and regional quality of life.

The use of spatial information such as showing freight bottlenecks in relation to mapped freight generators like ports and factories or in relation to traffic volumes and asset conditions adds to the understanding of what may be happening at a bottleneck. Not only can the visualization of freight performance show the bottlenecks, but it helps to identify possible causation by looking at traffic activity around locations of economic development or population growth.

Understanding where the bottlenecks are and seeing what the cause might be can assist decisionmakers and stakeholders in identifying solutions. The use of visualization supports ways to determine if capacity expansion is necessary or if operational and technological solutions might assist. An example is temporary rerouting or allowing for auxiliary truck lanes or prioritization at certain times of the day to improve freight flows when freight flows can be seen and absorbed at different times of the day.

Where To Apply This Solution

Freight performance visualization can be applied to any geography where there is available data. It is useful at microlevels, such as areas around ports, or at the State level to see the top segments with bottlenecks in the State.

In developing freight performance visualizations, there are considerations and steps for transportation agencies to consider:

1. First, consider the questions that need to be answered by the visualization. Freight performance visualizations should provide the information that users are most interested in. For example, visualizations could focus on mobility issues on specific corridors or a multistate regional transportation system depending on whether the visualization is intended to illuminate the need for and outcomes from targeted operational treatments versus major capital projects.
2. Second, consider what data are available. There are publicly available datasets and those that need to be purchased. Increasingly, big data and connected options such as probe data are available to fuel performance measures and to identify bottlenecks.
3. Third, a component in visualizing freight data is to align data to a State's transportation network. Doing so helps to view performance measures together with other roadway data. For example, if travel time data are conflated with the transportation network, a visual tool can be developed to show congestion in relation to pavement and bridge conditions, high crash locations, or any other element aligned to the network. It can be helpful to have one network with a consistent linear reference system to which data are aligned.

Examples

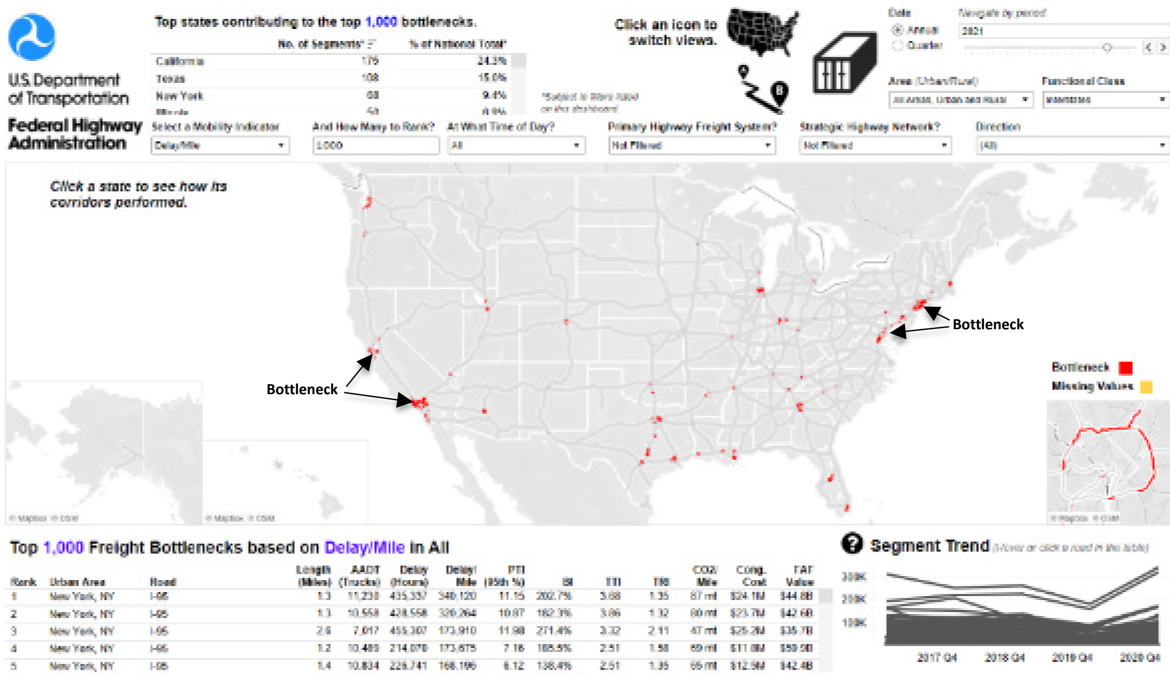
Federal Highway Administration Freight Mobility Trends Tool

FHWA's Freight Mobility Trends (FMT) tool shows freight performance across a range of locations in the United States. It uses NPMRDS truck data to present a suite of measures for delay, mobility, reliability, cost of congestion, commodity value, and emissions. It allows users to see bottlenecks at the national level, as well as State and MPO levels, to help tell the freight story (figure 3.50).

New York State Freight Web Transportation Atlas

The New York Department of Transportation's (NYSDOT) New York State Freight Transportation Plan website includes access to the Freight Web Transportation Atlas, which was developed to support the plan. The atlas (version 1.0) is an interactive, web-based map that includes various freight-related transportation facilities that were identified during the

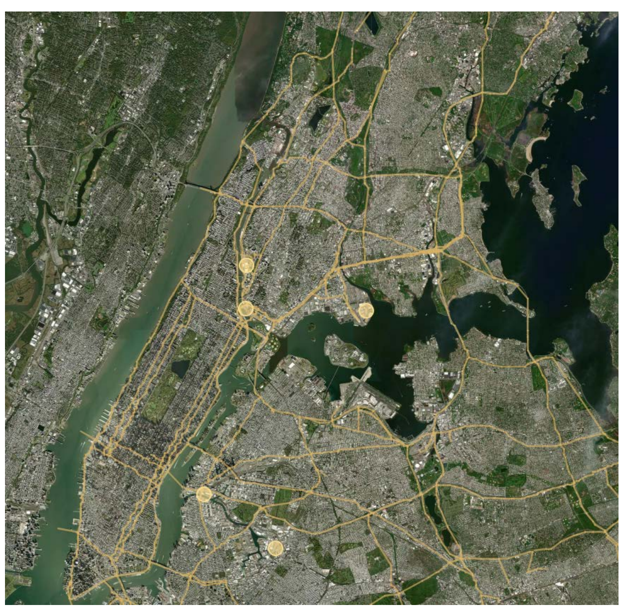
Figure 3.49. Federal Highway Administration (FHWA) Freight Mobility Trends Tool Showing Freight Bottlenecks.



Source: FHWA.

Freight Plan development process. In developing the Web Atlas, stakeholders were invited to review and comment to ensure that the most accurate information was being used and displayed. The Web Atlas includes several "layers" of map data (port, intermodal, interstate highway, rail,

Figure 3.50. New York State Freight Web Transportation Atlas.



Source: New York State Department of Transportation.

border crossing) to display a view of one or more categories of freight facilities. It also includes key statistics associated with the State's freight corridors (figure 3.51).

Case Study: Visualizing Freight Performance in Texas and Maryland

Visualizing freight performance through pictures, graphs, maps, and other means convey freight stories to diverse audiences and stakeholders in an easily understandable way. This is important because when someone can see what is happening, they may be more compelled to engage in proposed solutions.

The Texas Department of Transportation (TxDOT) and Maryland Department of Transportation (MDOT) have produced freight visualization tools that are improving decisionmaking by providing their leadership and stakeholders with compelling freight performance information. Their success is rooted in their ability to align mobility data with their HPMS network. This provides a more holistic understanding of where freight bottlenecks are and what other conditions exist, such as pavement or safety issues.

Texas' 100 Most Congested Road Sections: TxDOT's Texas' 100 Most Congested Road Sections tool identifies freight bottlenecks. It includes over 1,800 road sections as bottlenecks, providing a visual, interactive way for people to easily see the bottlenecks, know where the bottlenecks are located in the State, and have useful performance statistics all in one view that tells the freight performance story (see image). TxDOT produces Annual Truck Congestion Report Cards for each of the Top 100 Truck Congested Roadways and predefined regions and geographies, which quickly examine performance trends.

Truck Congestion Assessment Tool (TCAT): TxDOT's TCAT allows users to access freight mobility performance measures on most of the major roads in Texas beginning in the data year 2017. Through TCAT, users have access to the Top 100 Congested Roadways information, primarily focused on the top 100 truck congested roadways. TCAT can visualize TxDOT's transportation projects and access Annual Truck Congestion Report Cards for each of the Top 100 Truck Congested Roadways, as well as each of the predefined regions/geographies.

Maryland Roadway Performance Tool (MRPT): MDOT's MRPT conflates mobility data (all traffic and truck) to the HPMS network, which allows users to view congestion by HPMS segment and evaluate segments with other HPMS-level information such as asset condition (e.g., pavement condition), as well as with the Freight Analysis Framework (FAF) to provide a segment freight value. The MRPT links to MDOT's sophisticated geospatial data and mapping platform and pulls relevant GIS maps so that performance may be viewed in relation to important layers like freight generators, resiliency, and vulnerability, and land uses.

For more information, see the detailed case studies in Appendix A.

4. Next Steps to Consider for Implementation

This report reflects an assessment of how State DOTs are approaching freight performance and identification of bottlenecks, as well as a Toolbox of Solutions with strategies that can help improve freight mobility. States can use the information in this report to understand what their peers are doing and how they can approach freight mobility performance in their own organizations.

Specifically, the Toolbox of Solutions presented in chapter 3 provides a review of numerous State DOT methods for approaching freight mobility performance and how the solutions can be applied. The intention of the toolbox is to be a resource for agencies to mature their technological, operational, performance management, and capacity approaches to addressing freight performance, reliability, and bottlenecks.

It may be challenging for a State DOT to intuitively know when and where to apply these solutions. It may also prove challenging to increase the effectiveness of the solutions once they are deployed and advance them to a more programmatic level in the agency. The toolbox can serve as a resource for existing and new staff to guide the application of these strategies.

CAPABILITY MATURITY MODELS TO SUPPORT TOOLBOX DEPLOYMENT

To best make use of the Toolbox of Solutions, it may be best to start with a capability maturity framework. This section describes the capability maturity model (CMM) concept as it applies to TSMO and how it can similarly be adapted to the implementation of strategies in the Toolbox of Solutions. The CMM frameworks that are presented here are intended to serve as examples of how an agency can take the next step in implementing some or all of the strategies in the Toolbox of Solutions. This next step is determining where and how to start. The next step toward the implementation of toolbox solutions is assessing where an agency is and where the agency wants to be with regard to its freight planning, operations, and management capabilities. Because several approaches can be taken in conducting this self-assessment, staff within agencies may need to determine which method will work for them.

A CMM can be a helpful next step because it provides State DOTs the ability to:

- Develop consensus around needed agency improvements
- Identify their immediate priorities for improvements
- Identify concrete actions to continuously improve capabilities[174]

By using a CMM framework, agency staff have available to them a structured process to identify their current and desired levels of capability for improving freight mobility and reliability without being overwhelmed by the number of Toolbox options. CMM provides a starting point for agencies, as well as guidance in achieving desired performance goals and continued opportunities for improvement through regular reassessments. CMM typically provides a way to identify where an agency is in terms of mainstreaming freight planning and performance.[175] It allows agencies to either self-assess based on a scale that outlines different levels of program maturity or have an independent evaluation conducted based on specific improvement criteria.

FHWA, the Transportation Research Board (TRB), AASHTO, and others have made use of CMMs and maps (visual representations of improvement pathways) for many years, as these have been useful in helping agencies understand where they fall in terms of a level of implementation for a particular strategy or set of strategies such as implementing TSMO practices. CMMs help answer questions such as:

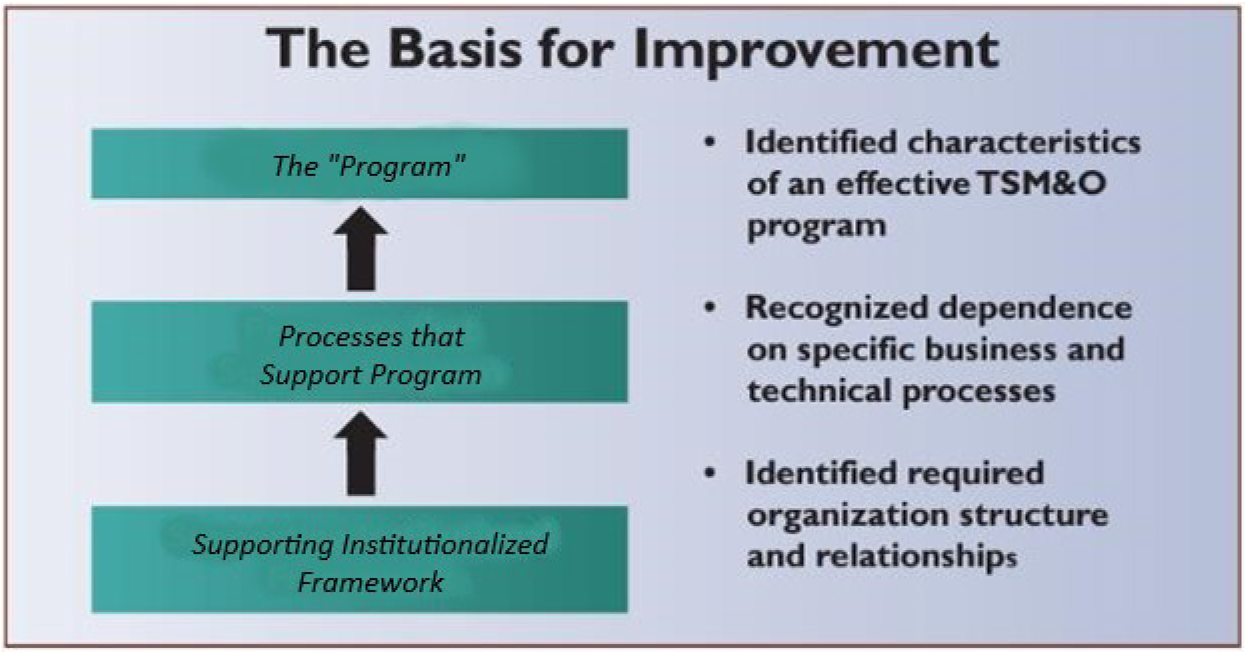
- Is an agency at the beginning, someplace in the middle, or are they mature in implementation?
- If in the middle, what has the agency done, and what have they not done?
- How can the agency mature?
- What strategies can the agency pursue to reach its goals and advance in maturity?
- Are there actions that the agency needs to take, such as acquiring new staff, reorganizing, or changing how and where funding is distributed?

The concept of using a CMM framework began with the Strategic Highway Research Program 2 (SHRP2) projects that promoted process-driven approaches to improve TSMO. It was adapted from the software development industry and incorporates three tenets as reported by FHWA:

- "Process matters: projects fail or do not achieve desired functionality for [a] variety of reasons unrelated to the technology;
- Prioritizing the right actions is important: is an agency ready, how do they know, and what should they do next;
- Focus on the weakest link: what is holding the agency back in becoming a leader in a particular area."[176]

The full potential of CMM for TSMO requires certain specific business and technical process dimensions and supporting institutional arrangements to be put in place and managed, as shown in figure 4.1. In this way, reaching capability maturity is just like the other formal core program of transportation agencies.[177]

Figure 4.1. Relationships among program and processes in an institutional capability maturity model framework.



Source: Federal Highway Administration.

In the context of TSMO, a CMM can be applied to specific TSMO strategies (e.g., traffic management, traffic incident management, road weather management, planned special events, work zone management, and traffic signal management). It could also be applied to the adoption and success of an overall TSMO program within an agency. In the same way, a CMM can be applied to a specific Toolbox of Solutions strategy, in addition to an overall TSMO program.

Typically, capabilities or maturity for agencies are grouped into the following six dimensions:

1. *Business processes*, which include formal scoping, planning, programming, and budgeting
2. *Systems and technology*, which includes the use of systems engineering, systems architecture standards, interoperability, and standardization
3. *Performance measurement*, which includes measures definition, data acquisition, and data utilization
4. *Organization and workforce*, which includes programmatic status, organizational structure, staff development, and recruitment and retention
5. *Culture*, which includes technical understanding, leadership, outreach, and programs legal authority
6. *Collaboration*, which includes relationships with public safety agencies, local governments, metropolitan planning organizations (MPOs), and the private sector

For each of the six dimensions, four levels of capability are used in the CMM framework adapted to TSMO. Level 1 represents a lower level of maturity or implementation of strategies to support TSMO, while level 4 represents an optimized, high-level maturity.

- A level 4 agency will have reached its maturity peak, having implemented various improvements or practices that make them advanced in an area. The capability has become a full, sustainable core DOT program priority, established on the basis of continuous improvement with top-level management status and formal partnerships.
- A level 3 agency will have implemented standardized strategy applications in priority contexts and managed for performance. It will also have developed technical and business processes that are documented and integrated into the agency and aligned partnerships.
- A level 2 agency will have understood basic strategy applications and have in development key processes that support identified requirements and key technology and core capacities but limited internal accountability and uneven alignment with external partners.
- A level 1 agency might just be undertaking activities and relationships in an ad hoc manner, substantially outside the mainstream of other agency activities, which may be sufficient for certain agencies.

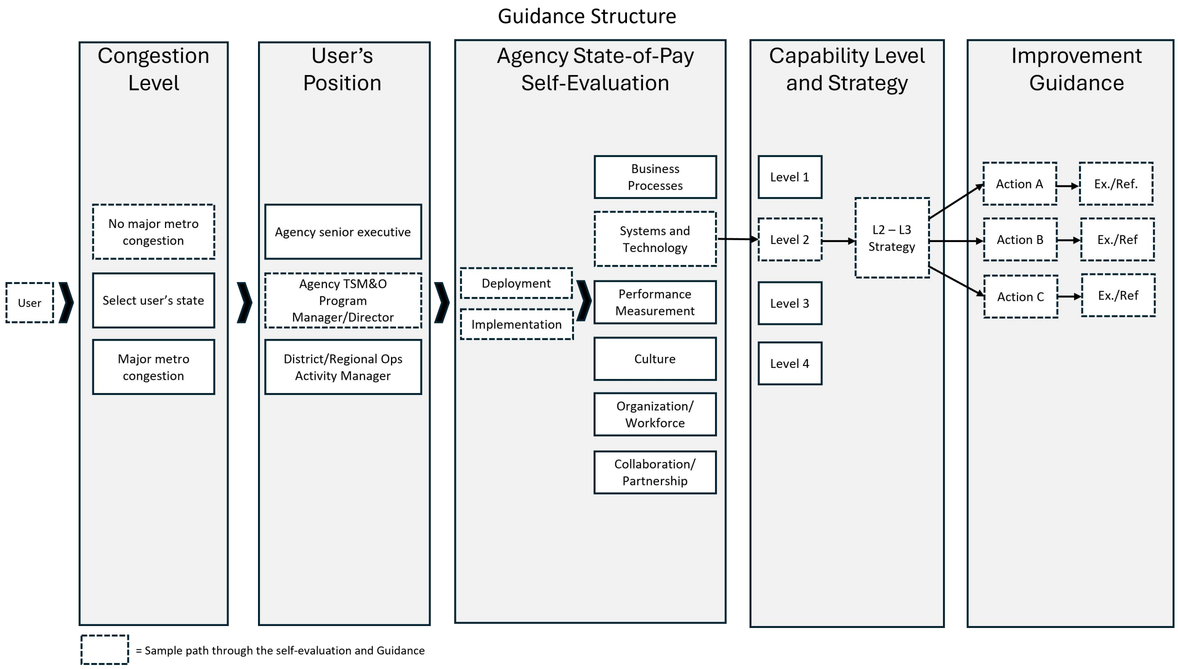
The Transportation Systems Management and Operations Example

AASHTO advanced the concept of CMMs developed in SHRP2 in its official TSMO guidance, the AASHTO Transportation Systems Management, and Operations Guidance that State transportation agencies can use in developing capabilities critical to supporting TSMO programs. It was designed for transportation agency managers to evaluate agency capabilities in key areas of process and institutional arrangements and to prepare a formal action plan.[178]

The AASHTO guidance recommends the use of a CMM as a management tool to guide improvement in the effectiveness of TSMO as a program. Using the matrix style supported by the SHRP2 work, it combines the key features of quality management, organizational development, and business process reengineering concepts into one framework an agency can use to assess its capabilities. It uses the six dimensions listed above and the four different levels of maturity.

AASHTO designed the TSMO CMM to be applied by agencies in a few different ways, depending on the level of detail desired in the assessment. Agencies can undertake a more detailed, customized self-evaluation tailored to their particular mobility and organizational issues. This custom-tailoring can be accomplished by linking the AASHTO guidance provided to the assessor's agency and managerial position context in terms of (1) significance of congestion level in the agency's general jurisdiction; (2) the assessor's position in the agency (span of control); and (3) the current state of the agency program in terms of the type and level of TSMO strategy implementation. The assessor's response to a set of questions in these three areas generates an evaluation of the level of maturity for the user agency in each of the six major dimensions of capability for TSMO. The assessor's levels are then directly linked to specific guidance in terms of actions to move to the next level of capability. Figure 4.2 provides a visualization of this process.

Figure 4.2. Customized self-evaluation process diagram.



Source: American Association of State Highway and Transportation Officials.

In advance of undertaking this customized self-evaluation, agencies can also use AAHSTO's One-Minute Guidance Evaluation to obtain a snapshot of which level they might fall in terms of their current TSMO program.[179] Figure 4.3 shows the six capability maturity dimensions and a description of the four capability levels for each. To conduct this brief self-evaluation, assessors should select the capability level box that most closely corresponds with their agency. Once complete, assessors should then view general guidance themes related to their evaluation choices.

Figure 4.3. One-minute guidance evaluation matrix that can be used to determine level of transportation systems management and operations (TSM&O) capability maturity.

Dimension	Level 1	Level 2	Level 3	Level 4
Business Processes (Planning, programming, budgeting, implementation)	Processes related to TSMO activities ad hoc and un-integrated	Multiyear statewide TSMO plan and program exists with deficiencies, evaluation, and strategies	Programming, budgeting, and project development for TSMO standardized and documented	Processes streamlined and subject to continuous improvement
Systems & Technology (Systems engineering, standards, and technology interoperability)	Ad hoc approaches outside systematic systems engineering	Systems engineering employed and consistently used for ConOps, architecture, and systems deployment	Systems and technology standardized, documented, and trained statewide, and new technology incorporated	Systems and technology routinely upgraded and utilized to improve efficiency performance
Performance Measurement (Measures, data & analytics, and utilization	No regular performance measurement related to TSMO	TSMO strategies measurement largely via outputs, with limited after-action analyses	Outcome measures identified and consistently used for TSMO strategies improvement	Mission-related outputs/outcomes data routinely utilized for management, reported internally and externally, and archived
Culture (Technical understanding, leadership, outreach, and program authority)	Value of TSMO not widely understood beyond champions	Agency-wide appreciation of the value and role of TSMO	TSMO accepted as a formal core program	Explicit agency commitment to TSMO as key strategy to achieve full range of mobility, safety, and livability/sustainability objectives.
Organization/Workforce (Organizational structure and workforce capability development)	Fragmented roles based on legacy organization and available skills	Relationship among roles and units rationalized and core staff capabilities identified	Top-level management position and core staff for TSMO established in central office and districts	Professionalization and certification of operations core capacity positions including performance incentives
Collaboration (Partnerships among levels of government and with public safety agencies and private sector)	Relationships on informal, infrequent, and personal basis	Regular collaboration at a regional level	Collaborative interagency adjustment of roles/ responsibilities by formal interagency agreements	High level of operations coordination institutionalized among key players (public and private)

Source: American Association of State Highway and Transportation Officials.

To summarize the self-evaluation process, figure 4.4 shows an example of the CMM matrix with the dimensions and levels, along with the steps for conducting a self-assessment. This CMM builds on the key activities of integrating and mainstreaming TSMO across a transportation agency by defining maturity using the level of activity in place.

Figure 4.4. Example of a Capability maturity model (CMM).

Dimensions of Process Areas	What is it	Level 1 Ad Hoc Low Level of Capability	Level 2 Managed, Medium Level of Capability	Level 3 Integrated, High Level of Capability	Level 4 Optimized, Highest Level of Capability
Business Process	Plans, Programs, Budgets	Statement of Capability			
Systems & Tech	Approach to Building Systems				
Performance Measurement	Use of Performance Measures	See Step 1 note below			
Workforce	Improving Capability of Workforce			See Step 2 note below	
Culture	Changing Culture and Building Champions			See Step 3 note below	
Collaboration	Improving Working Relationships				

Step 1: Self-assessment work with your stakeholders to assess where you are in terms of the capabilities in each area.
Step 2: Identify areas of improvement and the desired levels of capability to improve program effectiveness.
Step 3: Identify actions that you need to take to move the desired levels of capability.

Source: American Association of State Highway and Transportation Officials.

As a further resource, FHWA identifies mainstreaming TSMO in an agency through the following activities, visualized in figure 4.5:[180]

EXECUTIVE LEADERSHIP

- Endorse TSMO with strategic plans and communications
- Consider TSMO directives in agency activities
- Include TSMO measures in agency dashboards
- Budget for TSMO activities

HUMAN RESOURCES

- Provide TSMO training
- Develop job categories for new workforce requirements for TSMO
- Establish a career path for those involved in TSMO

PLANNING AND PROGRAMMING

- Consider TSMO solutions as alternatives to capacity expansion projects
- Incorporate travel time reliability, efficiency, and equity in performance goals and objectives
- Identify and prioritize operations needs and investments
- Evaluate TSMO strategies for programming
- Integrate TSMO into transportation plans

PROJECT DEVELOPMENT AND DESIGN

- Evaluate TSMO options to support performance-based practical design
- Include TSMO strategies in capacity projects to maximize investments
- Incorporate TSMO assets in infrastructure design
- Incorporate TSMO elements in design manuals

TRANSPORTATION MANAGEMENT

- Monitor travel conditions 24/7
- Coordinate with partners for traffic incident management
- Share operations data with planners

CONSTRUCTION

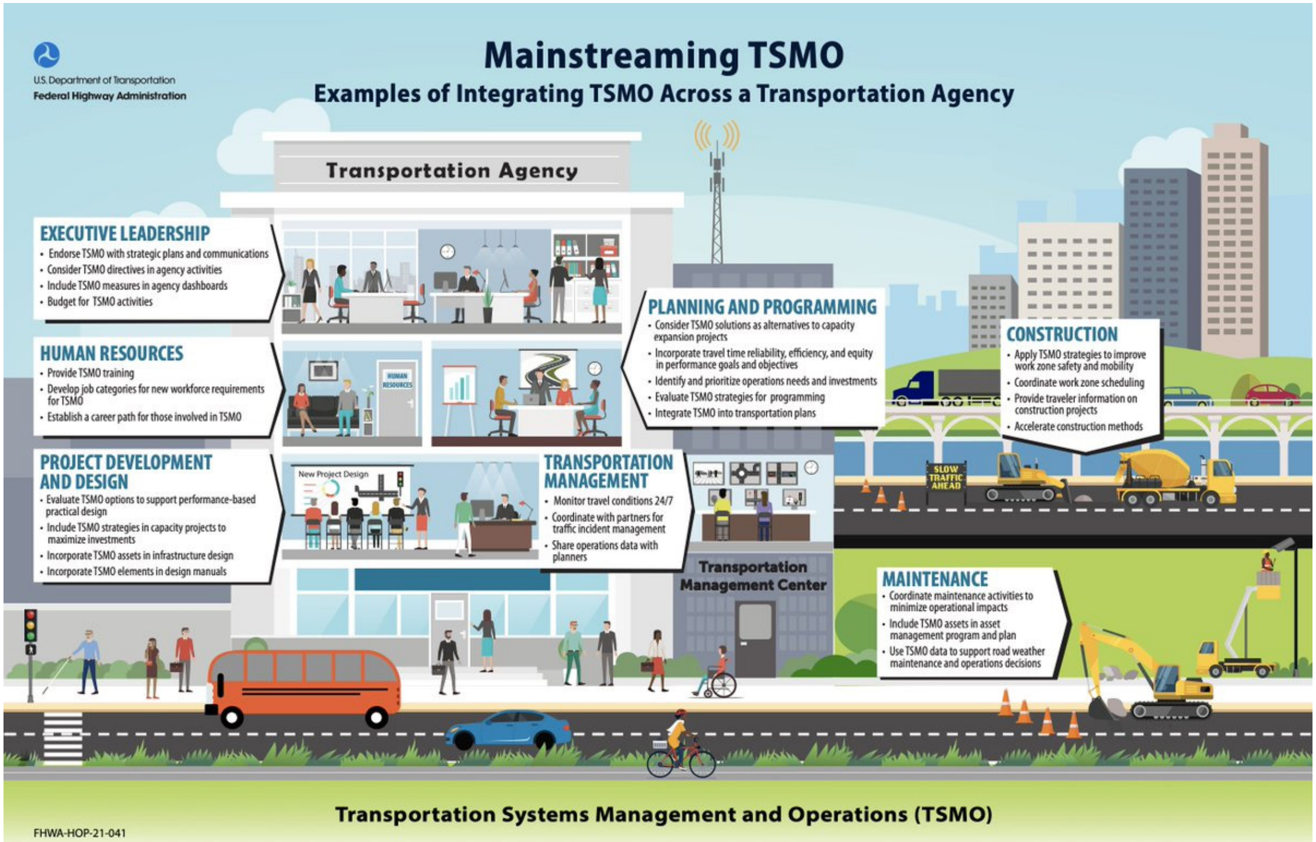
- Apply TSMO strategies to improve work zone safety and mobility
- Coordinate work zone scheduling
- Provide traveler information on construction projects
- Accelerate construction methods

MAINTENANCE

- Coordinate maintenance activities to minimize operational impacts
- Include TSMO assets in the asset management program and plan

- Use TSMO data to support road weather maintenance and operations decisions

Figure 4.5. Mainstreaming TSMO infographic.



Source: Federal Highway Administration.

These mainstreaming activities can then be visualized into a maturity map. As an example, a maturity map for improving winter operations is shown in figure 4.6. This could be adapted to apply to the deployment of the Toolbox of Solutions.

Figure 4.6. Maturity map example.

Source: Transportation Research Board.

Applying Capability Maturity Models for Freight Performance

The CMM used for TSMO can be adapted to help State DOTs self-assess their capability to support freight mobility and to identify the types of actions important to advance. For example, a State DOT might want to adapt the CMM as presented in table 4-1 for freight mobility performance.

The following freight-adapted CMM matrix and mainstreaming recommendations are intended as examples that an agency can use to tailor it to their freight mobility needs, assess their capabilities, and map a path forward that helps to mainstream freight mobility consideration in their agency functions. This can help to customize ways to use the toolbox strategies in the most targeted way that helps an agency grow in capabilities to improve freight mobility and reduce freight bottlenecks.

Table 4-1. Capability maturity model for freight mobility performance.

DIMENSION	LEVEL 1 AD HOC	LEVEL 2 MANAGED	LEVEL 3 INTEGRATED	LEVEL 4 ORGANIZED
Business Processes	Addressing freight mobility is project specific or ad hoc.	Agencies implement a nominally systematic approach to freight mobility to address immediate concerns.	Freight mobility processes are standardized and have a more system-wide approach that is well documented.	Development and deployment processes for freight mobility are streamlined throughout the agency, and agencies have a continuous improvement process for freight mobility.
Systems and Technology	Freight mobility systems or technology are used on an ad hoc basis.	Resources are consistently used to support freight mobility.	Agencies apply advanced technologies and resources to support freight mobility. These resources are well integrated within an agency's functions.	Automation of freight mobility processes is based on historical, current, and predicted data. New and emerging technologies are deployed on a continuous basis to improve freight efficiency.
Performance Measurement	Use of performance measurement processes for freight management is not undertaken on a regular basis.	Agencies employ performance measurement assessment of freight mobility and performance of strategies to improve mobility, primarily to analyze impacts post-deployment.	Agencies identify desired outcome measures and consistently use freight mobility performance measure analyses to improve strategy deployment and overall freight mobility.	Agency freight management goals and objectives are mapped to performance measures, which are regularly used to manage systems. Documentation of analyses results are distributed internally and externally and are archived for later use.

DIMENSION	LEVEL 1 AD HOC	LEVEL 2 MANAGED	LEVEL 3 INTEGRATED	LEVEL 4 ORGANIZED
Organization and Workforce	In-house personnel have limited freight mobility experience with no specialized experience in freight-related planning, traffic analysis, etc. Agency personnel roles are fragmented.	Core staff knowledge, skills, and abilities are identified within the freight mobility arena, and roles are linked across various responsible groups.	Freight-involved staff members and their related knowledge, skills, and abilities (KSAs) are identified and established on a broad basis and within individual groups.	A specific freight planning and or performance management program exists to engage in the advancement of performance for mobility. Formal and ongoing training on freight is offered and supported by the agency.
Culture	Freight mobility efforts are primarily an assortment of loosely related projects and strategies. Only a few champions lead the efforts.	Freight performance is recognized as valuable and a key role of the agency. Select agency managers lead efforts for freight mobility.	Freight mobility is recognized as a core program that coordinates with other programs on an ongoing basis.	Freight mobility is a program that is highly integrated with related core functions, such as planning, design, construction, maintenance, etc. All agency staff members, from leadership to rank and file, embrace the importance and value of freight mobility.
Collaboration	Relationships and collaboration between stakeholder organizations are informal and ad hoc.	Collaboration with stakeholders is more formal and related to specific freight mobility needs and projects.	Agencies collaborate on freight mobility at a high level via the engagement of regional stakeholders.	Agencies approach freight mobility at the regional level.

An important caveat to note is that a CMM specific to freight mobility should not take the place of the TSMO CMM or be seen as an alternative. Instead, agency staff responsible for freight mobility should collaborate with agency staff responsible for TSMO implementation, viewing TSMO and the Toolbox of Solutions as complementary. As provided in chapter 3, the toolbox represents a spectrum of solutions that agencies can use to improve the performance of freight movement in their State or region. Many of the toolbox solutions address multiple functions and overlap with TSMO approaches, so a CMM specific to freight mobility may overlap with the TSMO CMM, providing a more comprehensive approach to addressing congestion and freight mobility.

Once an agency has an understanding of its level of capability maturity related to freight mobility and reliability, it can design strategies using what is presented in the Toolbox of Solutions. Agencies can also create a maturity map by implementing some of the following elements in their agency functions (similar to the TSMO mainstreaming recommendations).

EXECUTIVE LEADERSHIP

- Include freight performance measures in strategic plans, performance programs, and capital programs
- Consider elements of freight mobility in directives or agency activities
- Include freight mobility (and other freight measures) in agency dashboards
- Budget for freight activities, especially for safety and efficiency improvements

HUMAN RESOURCES

- Provide freight awareness and performance training
- Develop freight-specific career paths, especially focused on mobility
- Provide job categories for new workforce requirements that support freight or incorporate freight mobility awareness

PLANNING AND PROGRAMMING

- Consider freight options in all projects, the impacts of freight, and how to incorporate freight if prudent
- Develop freight plans
- Develop freight performance-based planning and programming processes
- Integrate freight into nonfreight plans, illuminating the impacts or coordination with freight elements to ensure mobility
- Identify and prioritize freight operations needs and investments

PROJECT DEVELOPMENT AND DESIGN

- Consider freight movement at the planning stage to address and mitigate change orders and other unforeseen impacts during construction
- Evaluate freight options to support performance-based practical design
- Include freight strategies in capacity projects to maximize investments

- Incorporate freight mobility considerations in temporary and permanent infrastructure design
- Incorporate freight elements in design manuals that help improve mobility during and after construction

TRANSPORTATION MANAGEMENT

- Monitor freight flows 24/7; if data are not available, at least use historical data to monitor how well freight is moving
- Coordinate with operations partners to ensure freight mobility or reduced impacts on mobility if the system is compromised
- Share freight mobility data with planners and others that can use it to help with moving freight efficiently and reducing bottlenecks

CONSTRUCTION

- Support freight flows and critical goods movement in work zones and when diverting traffic to alternate roads
- Coordinate work zone scheduling with key freight entities or movers
- Coordinate freight detour routing to ensure continued mobility
- Provide advanced work zone information to freight organizations
- Promote accelerated construction methods to support freight mobility

MAINTENANCE

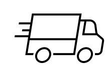
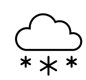
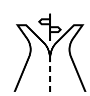
- Ensure maintenance staff understands key freight flows in their operating regions in order to minimize impacts on freight mobility
- Include freight mobility when assessing asset condition and the impact of assets on freight flows
- Use data to support road weather maintenance and operational decisions that best support freight mobility

5. CONCLUSION

This research provides an overview of how States are using the TTTR performance measure, reporting on bottlenecks, and implementing other measures to improve freight mobility. The findings in this report, especially in the ways States are mitigating freight mobility challenges, are intended to provide information and suggest solutions that other States, MPOs, and even local governments or corridor and regional organizations can deploy.

There are many ways States, MPOs, and local governments are working to measure and improve freight mobility, and these strategies show a range of efforts, from capacity expansion to more technologically driven TSMO solutions. The Toolbox of Solutions presented in this report summarizes these strategies. They represent a spectrum of solutions that agencies can use to address a variety of freight transportation challenges.

The table on the following pages provides a matrix that illustrates the risks or problems that each toolbox solution addresses. Each toolbox solution is described in terms of the issues that it can be applied to, including the following:

- **Technological & Analytical Inefficiencies**—solutions that address an agency's lack of integrated data, automation, and/or coordination with other data and analytical systems 
- **Safety**—solutions that reduce the risk of crashes involving commercial motor vehicles 
- **Lack of Reliability Due to Recurring Congestion**—solutions that target reliability problems associated with recurring congestion, including truck bottlenecks, signal systems, and access issues 
- **Lack of Reliability Due to Nonrecurring Congestion**—solutions that target reliability problems associated with nonrecurring congestion, including crashes, weather events, construction and work zones, and special events 
- **Lack of Highway Capacity**—solutions that expand highway capacity or provide alternatives to highway capacity expansion (e.g., by offering viable means of mode shift or managing highway demand) 
- **Pavement/Structural Deterioration**—solutions that provide a way to monitor and/or reduce the impact of freight traffic on roads and bridges 

It appears from the ways States are measuring and mitigating freight mobility that technology and increasingly big and connected data will play a leading role in performance analytics. This aligns with the FHWA efforts to support freight performance measurement and management efforts over the years. This also supports efforts to collaborate and develop data and supply chain analytics that can best tell the freight story and provide the information needed for the public and private sectors to work together to support United States businesses and their supply chains.

Toolbox Solution	Risks/Problems Addressed					
	Technological & Analytical Inefficiencies	*Safety*	*Lack of Reliability Due to Recurring Congestion*	*Lack of Reliability Due to Nonrecurring Congestion*	*Lack of Highway Capacity*	*Pavement or Structural Deterioration*
Freight Traveler Information Systems	X		X	X		
Electronic Credentialing and Permitting	X	X	X			X
Smart Roadside Commercial Motor Vehicle Monitoring	X	X	X			X
Weigh-in-Motion	X		X			X
Truck Queue Management and Appointment Systems at Ports	X		X			
Truck Parking Information Management Systems	X	X	X	X		
Border Wait Time Information	X	X	X	X		
Truck Safety Warning Systems	X	X		X		X
Work Zone Management for Trucks	X	X		X		X
Connected and Automated Vehicles	X	X	X	X		
Road Weather Management	X	X		X		

Toolbox Solution	Risks/Problems Addressed					
	Technological & Analytical Inefficiencies	*Safety*	*Lack of Reliability Due to Recurring Congestion*	*Lack of Reliability Due to Nonrecurring Congestion*	*Lack of Highway Capacity*	*Pavement or Structural Deterioration*
Arterial Management and Traffic Signal Timing for Trucks	X	X	X		X	
Access Management at Major Interchanges and Freight Facilities		X	X		X	
Off-Peak Deliveries		X	X		X	
Curb Loading Zone Management		X	X			
Active Traffic and Demand Management		X	X	X	X	
Ramp Management and Metering		X	X	X	X	
Integrated Corridor Management	X	X	X	X	X	
Traffic Incident Management	X	X		X		
Managed Lanes and Congestion Pricing			X	X	X	
Truck Lanes		X	X		X	X
Truck Climbing Lanes		X	X		X	
Intermodal Connectors		X	X		X	X
Marine Highway Program			X		X	X
Inland Ports			X		X	X

Toolbox Solution	Risks/Problems Addressed					
	Technological & Analytical Inefficiencies	*Safety*	*Lack of Reliability Due to Recurring Congestion*	*Lack of Reliability Due to Nonrecurring Congestion*	*Lack of Highway Capacity*	*Pavement or Structural Deterioration*
Rail Intermodal Corridors			X		X	X
Short Line Rail			X		X	X
Organization and Planning for Operations to Include Freight Stakeholders	X		X			
Operations and Freight Performance Measurement and Management	X	X	X	X		

APPENDIX A

DETAILED CASE STUDIES

- Georgia High-Risk Commercial Vehicle Notification Project
- Texas Connected Freight Corridors
- Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program
- Iowa Inland Waterways
- Georgia's Inland Ports
- Visualizing Freight Performance in Texas and Maryland

CASE STUDY: GEORGIA HIGH-RISK COMMERCIAL MOTOR VEHICLE NOTIFICATION PROJECT

Key Takeaways

In 2020, the Georgia Department of Transportation (GDOT) partnered with the electronic logging device (ELD) service provider Drivewyze to conduct a High-Risk CMV Notification Program pilot project in the Atlanta metropolitan area that would evaluate whether safety messages to commercial vehicle drivers would reduce the number of hard-braking events. The ultimate goal of the project was to improve safety for commercial vehicles, which have a high rate of fatalities and serious injuries due to rear-end collisions. Reducing the number of hard-braking events can make roadways safer for commercial vehicles. The High-Risk CMV Notification Program pilot project was extended for another year, and GDOT nominated the project for the AASHTO Innovation Initiative in September 2021.[48]

The pilot project used two groups within Drivewyze's commercial truck population to observe during a 30-day period. Commercial drivers who were enrolled in Drivewyze's Safety Notification Program received the safety message, while commercial drivers who were not enrolled in the program did not receive the safety message. The differences in how the two groups reacted to safety incidents, slowdowns, and congestion were then compared, most notably the differences in hard-braking events. The safety messages appeared to show a mild to moderate impact on hard-braking events. Any reduction in hard-braking events should be considered an improvement in commercial safety.

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[48]Georgia Department of Transportation. 2021. High Risk CMV Notification Program with Drivewyze. AASHTO Innovation Initiative: [Proposed] Nomination of Innovation Ready for Implementation, last accessed March 5, 2023.

Background

According to the High-Risk CMV Notification Program pilot project report prepared by Drivewyze,[49] in 2020, GDOT partnered with Drivewyze to pilot an innovative technology that can provide important safety messages to commercial drivers through an ELD. The intent of the project is to improve commercial vehicle safety and reduce the number of hard-braking incidents in test locations.

The purpose of this pilot project was to determine whether sending commercial drivers messages about safety incidents in specific locations through the in-cab ELD would reduce the number of commercial vehicle safety incidents. The pilot project was implemented around the Atlanta metropolitan area, but the risk of commercial safety incidents is not just a problem faced in Georgia, as commercial vehicle safety is a national concern. Many States could learn insights from the GDOT pilot project and partner with ELD operators to distribute safety messaging to drivers.

Historical crash data for 2019 indicated that there were 114 fatalities involving commercial vehicles on interstates throughout Georgia, with rear-end collisions being the primary cause of these fatalities. In the 2018 Statewide Strategic Transportation Plan, GDOT adopted the following goals, with an advanced mission to reduce the number of serious injuries and fatalities on Georgia roadways for both passenger and commercial vehicles:

- Enhance safety
- Maintain and protect the system
- Improve reliability
- Reduce congestion
- Increase freight and economic development
- Better the environment[50]

These types of systems alert drivers of upcoming changes in the roadway, such as speed-dangerous curves and turns and changing speed limits.[51] These alerts include:

- Risk Zone Alerts
- Proactive Speed Alerts
- Custom Zones
- Dynamic Parking Alerts
- High Rollover Alerts
- Low Bridge Alerts
- Mountain Corridor Alerts

This pilot project has increased the innovative ways that GDOT is attempting to improve commercial vehicle safety and provide important messaging to commercial drivers. The State required ELDs provide a way to communicate messages to drivers and eliminate some of the costs of implementing more dynamic message signs, which can be extremely costly for GDOT to

[49]Ibid.
[50]Ibid, p. 13.
[51]Ibid.

build and maintain. Another drawback of the dynamic message signs that this pilot addresses is that the message goes straight to the cab based on the vehicle's geolocation, so the messaging is available in the exact locations where they are needed most.

According to GDOT,[52] the investment for this project was minimal. The pilot project itself cost $164,320, and the yearly support and maintenance were estimated to cost $62,400. There was also the minimal effort required by GDOT after the locations were determined based on historical commercial vehicle safety information. GDOT partnered with Drivewyze on this pilot to manage the technical aspects and requirements of ELD communications. Expanding the program to include other third-party ELD service providers could reach more commercial drivers.

Methodology

The pilot project was completed first by identifying the test locations based on crash data, roadway geometry, AADT, and the percentage of trucks on the roadways. Table A-1 highlights the locations of the 10 test sites.

Table A-1. Safety message test locations.

Location #	Location Description	Safety Message
1	I–285 West at I–75 South	
2	I–285 East to I–75 North	
3	I–75 South to I–285 East	
4	I–75 North to I–285 West	
5	I–285 South to I–20 West	
6	I–675 South to I–75 South	
7	I–20 East to I–285 Merge	Merging Traffic Ahead: Right Lanes Use Caution
8	I–285 North to I-20 East	Merging Traffic Ahead: Right Lanes Use Caution
9	I–20 West at Thornton Rd	Slow Traffic: Thornton Rd Use Caution
10	I–75 South Near Morrow	Limited Visibility: Use Caution

Source: Georgia Department of Transportation.

Drivewyze applied geofences and collected speed and location data for more than 500,000 vehicles over a 45-day period. The research team used acceleration data and hard braking as indicators for potential crashes and other unsafe traffic conditions. The hard-braking events were calculated when braking exceeded $-2 m/s^2$. Consistent patterns of congestion were

[52] Ibid.

determined, and the fixed locations for the safety messages were finalized. The safety message would activate between 600 and 900 meters before the congested location. At this location, a commercial driver driving at highway speeds would have approximately 20 seconds to react to the alert.

The following data were collected and analyzed by the day of the week:

- Number of vehicles with hard-braking events per 100 vehicles
- Total number of hard-braking events
- The severity of braking in each group[53]

Results

The results of the data analysis showed that drivers who received the safety messages had a lower total number of hard-braking events, and the number of vehicles with hard-braking events per 100 vehicles was also lower. Based on weekday measurements, the drivers who received safety messages had a consistently lower number of total hard-braking events, resulting in a uniformly positive impact of safety messages on drivers. Table A-2 highlights the percentage of hard-braking behavior improvement for the drivers who were shown the safety message.

Table A-2. Improvement in hard-braking events for drivers shown safety message.

Location Description	Alternative Description Name	Safety Message	Percentage Change in Hard-Braking Events
I–285 West at I–75 South	Cobb Cloverleaf Southbound		+12.0%
I–285 East to I–75 North	Cobb Cloverleaf Westbound		+4.0
I–75 South to I–285 East	Cobb Cloverleaf Northbound		+50.0
I–75 North to I–285 West	Cobb Cloverleaf Eastbound		+4.0
I–285 South to I–20 West	Fairburn		–3.0
I–675 South to I–75 South	Stockbridge		+19.0
I–20 East to I–285 Merge	Westhaven Westbound	Merging Traffic Ahead: Right Lanes Use Caution	+10.0
I–285 North to I–20 East	Westhaven Northbound	Merging Traffic Ahead: Right Lanes Use Caution	+13.0

[53]Georgia Department of Transportation. 2021. High Risk CMV Notification Program with Drivewyze. AASHTO Innovation Initiative: [Proposed] Nomination of Innovation Ready for Implementation, pp. 16, last accessed March 6, 2023.

Location Description	Alternative Description Name	Safety Message	Percentage Change in Hard-Braking Events
I–20 West at Thornton Rd	Bridgeport	Slow Traffic: Thornton Rd Use Caution	–19.6
I–75 South Near Morrow	Jonesboro	Limited Visibility: Use Caution	+18.0

Source: Georgia Department of Transportation.

Conclusion

The purpose of this pilot project was to reduce hard-braking events and improve commercial vehicle safety by providing notifications to drivers of upcoming traffic conditions and congestion that could slow down traffic. Rear-end collisions are a leading factor in commercial vehicle fatalities and incidents, so it is imperative to reduce the number of hard-braking events whenever possible. This pilot project has produced results that indicate providing safety messages through ELDs reduces the number of hard-braking events by almost 20 percent in some of the test locations, and commercial drivers are appearing to drive more safely and respond to the safety message in these test locations.

The High-Risk CMV Notification Program Pilot Project report[181] indicated that future research could further be improved by the following actions:

- Observation of real-time congestion conditions, including the location of congestion onset and separation of driver visits into congested and noncongested groups
- Comparison of same-driver behavior in prealerted and post-training states after being exposed to several alerts at the same site
- Analysis of alert location versus typical onset of congestion for each site
    - Adjustment of alert location, forward or backward
- Investigation (possible site visit) to the Bridgeport site to investigate potential reasons for the negative correlation/outlier results that were seen
- Longitudinal study:
    - Desensitization over time
    - Training effect over time
    - Peak effect for drivers making the first visit
    - Metric to understand the value of the alerts
- Extraction of real-time congestion data from the GPS data collected in the study or from other available data sets.[182]

CASE STUDY: TEXAS CONNECTED FREIGHT CORRIDORS

Key Takeaways

Connected and automated vehicles (CAV) have the potential to improve safety and mobility for freight vehicles on the Nation's roadway network. Further, advancements in multimodal CAV could lead to a highly automated and technical logistics system linking modes in new ways and changing supply chain processes.

To prepare for and facilitate CAV development and implementation, State departments of transportation (DOTs) are planning and implementing technology ecosystems. These ecosystems will support the flow of data between vehicles (vehicle-to-vehicle, or V2V) and between vehicles and infrastructure (vehicle-to-infrastructure, or V2I) while also providing the type of environment from pavement improvements to technology that will allow CAVs to operate and evolve.

Texas is working to implement a freight CAV ecosystem through its Texas Connected Freight Corridors (TCFC) project. This federally funded project will develop the concept of operations, designs, and plans and ultimately begin the implementation of the technological elements to support the safe and efficient adoption of CAV for freight.

Background

The TCFC project's goal is to provide Texas' most significant deployment of CAV vehicle technology to improve freight travel. The project was funded by the Federal Highway Administration (FHWA) Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) initiative.[183]

Texas is home to over half of all United States freight tonnage flow. Thus, a strong relationship between freight operators and the State DOT system operators should exist to support goods movement.[184]

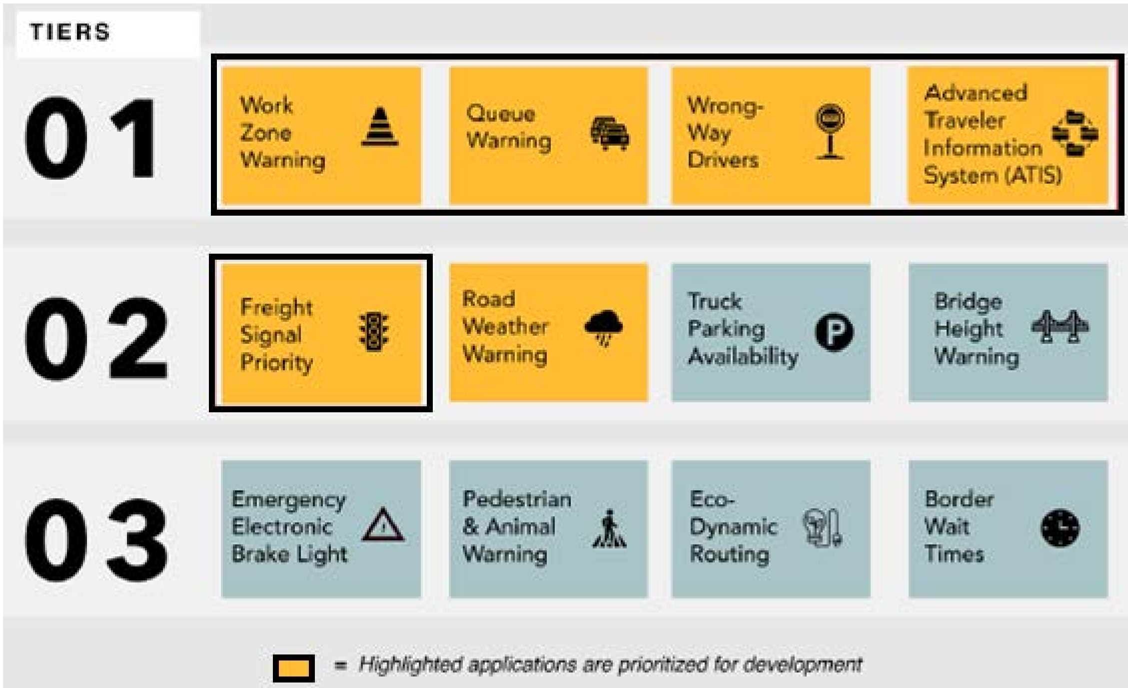
The TCFC aims to implement a sustainable CAV ecosystem along the Texas Triangle, 865 miles of a triangle of Interstates in Texas, including I–35 (as well as the extension into Laredo), I–45, and I–10. These Interstates link major cities of Austin, Dallas–Fort Worth, Houston, and San Antonio. Figure 0.1 shows the location of the TCFC.[185]

Figure 0.1. Texas Connected Freight triangle location.

Source: Texas A&M Transportation Institute (TTI)

The ecosystem will include up to 12 V2V and V2I applications focused on freight safety and mobility (figure 0.2).

Figure 0.2. Prioritized connected and automated vehicle applications.



Source: Texas Department of Transportation.

The project has a 4-year timeline and is currently underway.[186] The timeline is:

- Year 1: Conduct project planning, which includes stakeholder outreach, development of a concept of operations, and creation of other key support plans for design and deployment.

- Years 2 and 3: Undertake detailed design development, application development, and system integration and testing.

- Year 4: Implement system operation and maintenance, data collection, analysis, and performance measure reporting.

The project includes specific freight mobility and safety goals, including:

- Improve roadway safety for freight and passenger vehicles
- Increase mobility and efficiency of freight across the Texas Triangle
- Develop lessons learned for a broader rollout of CAV technology
- Evaluate communication methods for V2I applications
- Use crowd-sourced data to reduce emergency response time[187]

The TCFC builds on intelligent transportation system (ITS) technologies already implemented in Texas. For example, TxDOT already has an advanced traffic management system (ATMS) software platform in each of its districts that uses advanced traveler information system (ATIS) technologies to post travel times, incidents, work zone information, and weather messages on dynamic message signs throughout the State. The ATMS shares data with private-sector entities so that they can provide advanced traveler information to their clients.[188]

The specific activities for the TCFC are to:

- Deploy infrastructure condition monitoring technologies on TxDOT fleet vehicles to support maintenance activities.

- Implement CAV V2I and V2V technologies to support safety and mobility applications such as end-of-queue, work zones, road weather, and wrong-way driving warnings on interstate corridors.

- Deploy specific freight technologies such as truck parking systems, border crossing technologies, and other mechanisms to provide freight operators and drivers with better travel information and mobility support.

- Share CAV V2I and V2V data with truck platooning technologies to improve the safety and efficiency of their operations.

- Use telecommunication technology to support CAV applications with dedicated short-range communications (DSRC) for the I–35 corridor and cellular for rural areas of I–45 and I–10.[189]

- Year 1: Conduct project planning, which includes stakeholder outreach, development of a concept of operations, and creation of other key support plans for design and deployment.

- Years 2 and 3: Undertake detailed design development, application development, and system integration and testing.

- Year 4: Implement system operation and maintenance, data collection, analysis, and performance measure reporting.

The project includes specific freight mobility and safety goals, including:

- Improve roadway safety for freight and passenger vehicles
- Increase mobility and efficiency of freight across the Texas Triangle
- Develop lessons learned for a broader rollout of CAV technology
- Evaluate communication methods for V2I applications
- Use crowd-sourced data to reduce emergency response time[54]

The TCFC builds on intelligent transportation system (ITS) technologies already implemented in Texas. For example, TxDOT already has an advanced traffic management system (ATMS) software platform in each of its districts that uses advanced traveler information system (ATIS) technologies to post travel times, incidents, work zone information, and weather messages on

[54]Ibid.

dynamic message signs throughout the State. The ATMS shares data with private-sector entities so that they can provide advanced traveler information to their clients.[55]

The specific activities for the TCFC are to:

- Deploy infrastructure condition monitoring technologies on TxDOT fleet vehicles to support maintenance activities.
- Implement CAV V2I and V2V technologies to support safety and mobility applications such as end-of-queue, work zones, road weather, and wrong-way driving warnings on interstate corridors.
- Deploy specific freight technologies such as truck parking systems, border crossing technologies, and other mechanisms to provide freight operators and drivers with better travel information and mobility support.
- Share CAV V2I and V2V data with truck platooning technologies to improve the safety and efficiency of their operations.
- Use telecommunication technology to support CAV applications with DSRC for the I–35 corridor and cellular for rural areas of I–45 and I–10.[56]

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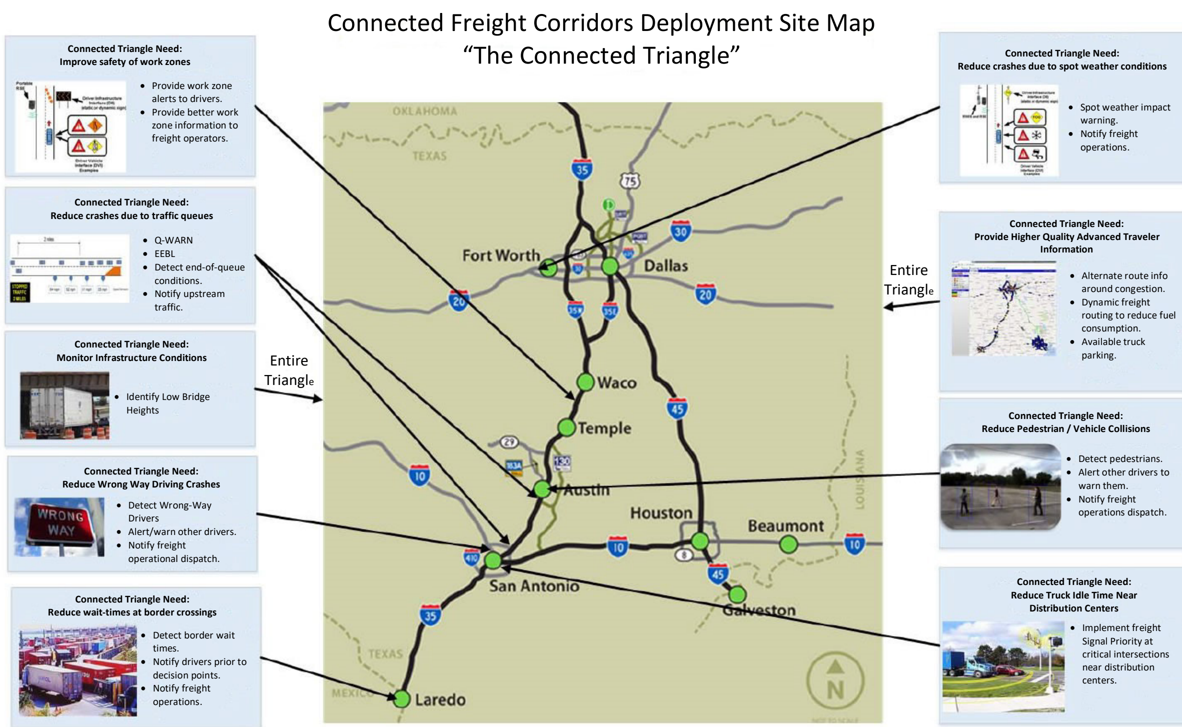
[55]TxDOT, TTI, Southwest Research Institute (SWRI), University of Texas at Austin (UT Austin). 2017. Texas Connected Freight Corridors Project.

[56]Ibid.

Figure 0.3 depicts the full range of freight technology options envisioned for the Triangle. All these options are expected to provide safety and or reliability benefits once fully implemented. The ecosystem will work together to support freight flows throughout the region and to grow and adapt to new technology as it comes online.

Figure 0.3. TCFC Proposed freight technology options.



Source: Federal Highway Administration.

Results

Currently, the TCFC is in the planning and design stages, with some initial deployments of work zone communications to trucks already in place. The project has developed a concept of operations that outlines how technologies would support truck drivers and managers. This concept of operations includes scenario analysis to determine the types of incidents a truck driver encounters daily on the Triangle and a warning system to drivers when incidents occur, or there is a problem such as a closed lane, stopped vehicle, debris, etc. To date, the first technology applications include:

- **End-of-queue warnings**—The project is deploying CV technologies to provide end-of-queue warnings for traffic congestion from incidents, inclement weather, and work zones. The system uses real-time traffic detection to inform drivers about upcoming stopped or slow traffic.

- **Work zone warnings**—The project is providing work zone alerts that urge drivers to use caution in work zones ahead. By disseminating better work zone information to freight operators, this system will improve safety in work zones.

- **Wrong-way driving alerts**—The project is deploying a system that will detect wrong-way drivers, alert and warn other drivers, and notify freight operations dispatch in order to reduce wrong-way driving crashes.

- **Freight signal priority**—The project will use a traffic signal priority application for CV-equipped freight vehicles. Signal, phase, and timing (SPaT) data can be used with freight vehicles to more efficiently move trucks through these corridors, reducing the heavy-vehicle impacts on the community.[190]

Conclusion

As the project progresses, TxDOT's goal is to implement the CAV ecosystem and have a final phase of performance measurement to capture how well the new ecosystem supports freight safety and flows. Then, the system can be calibrated to improve safety and reliability depending on the outcome of the measures. This type of visibility can support coordinated decisionmaking and stakeholder discussions regarding where investments or operational changes are needed to best support the system.

CASE STUDY: WYOMING I–80 CONNECTED VEHICLE PILOT AND ROAD WEATHER MANAGEMENT PROGRAM

Key Takeaways

The Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program, sponsored by the USDOT Intelligent Transportation System Joint Program Office, tests mobile and roadside technologies that advance multiple connected vehicle applications. The concept involves using DSRC capability between vehicles and roadside infrastructure so that the WYDOT can provide new applications to support driver awareness. These applications include:

- V2V communications
  - Forward-collision warnings
  - Distress notifications

- V2I communications
  - Driver response
  - Road weather warnings

- I2V communications
  - Traveler information messages
  - Variable speed limits

What this means for drivers is the availability of connected applications that may assist in improved trip planning by providing road closure information, road weather forecasts, and restrictions. While on the road, the system can provide notice of crashes ahead, slow-moving or stopped vehicle information, work zones, speed reduction, and road conditions. Additionally, the system can help drivers with parking, detours, reduced roadway speed, and safe stopping when there are issues like road weather.

This information can be important for freight mobility because freight users on Wyoming's stretch of I–80 will have information that can inform routing and en route decisionmaking. With this information, freight users may improve efficiency by traveling at less congested times, knowing where bottlenecks and weather slowdowns occur, and other details to help them make routing and travel decisions.[191]

Background

I–80 is an Interstate corridor running 402 miles through southern Wyoming and provides a link for freight and passenger travel. It supports over 32 million tons per year of freight movement. Truck volumes are 30 to 55 percent of the total traffic stream per year.[192]

A challenge in this corridor is weather-related safety. Several high-profile crashes involved both commercial and passenger vehicles and resulted in fatalities, long closures, and economic impacts due to loss and delay. An example WYDOT cites is an April 2015 event that produced icy roadways and poor visibility. The blizzard conditions contributed to a 45-vehicle pileup (figure 0.4). WYDOT reports that in the 10-year period from 2006 to 2016, there were 1,237 high-profile vehicles blown over due to high winds and other weather events that caused problems. Further, WYDOT reported that from October 2015 to September 2016, there were more than 1,600 crashes on I–80, resulting in 18 fatalities and 271 injuries. During this same time, roads were closed to all vehicles for over 1,500 hours. The societal impact of these crashes topped $85 million.[193]

Figure 0.4. Multivehicle pileup on I–80 due to weather conditions

Source: Wyoming Department of Transportation.

The Wyoming I–80 Connected Vehicle Pilot and Road Weather Management Program uses DSRC that can support V2V and V2I connectivity. This system allows several services to work, including:

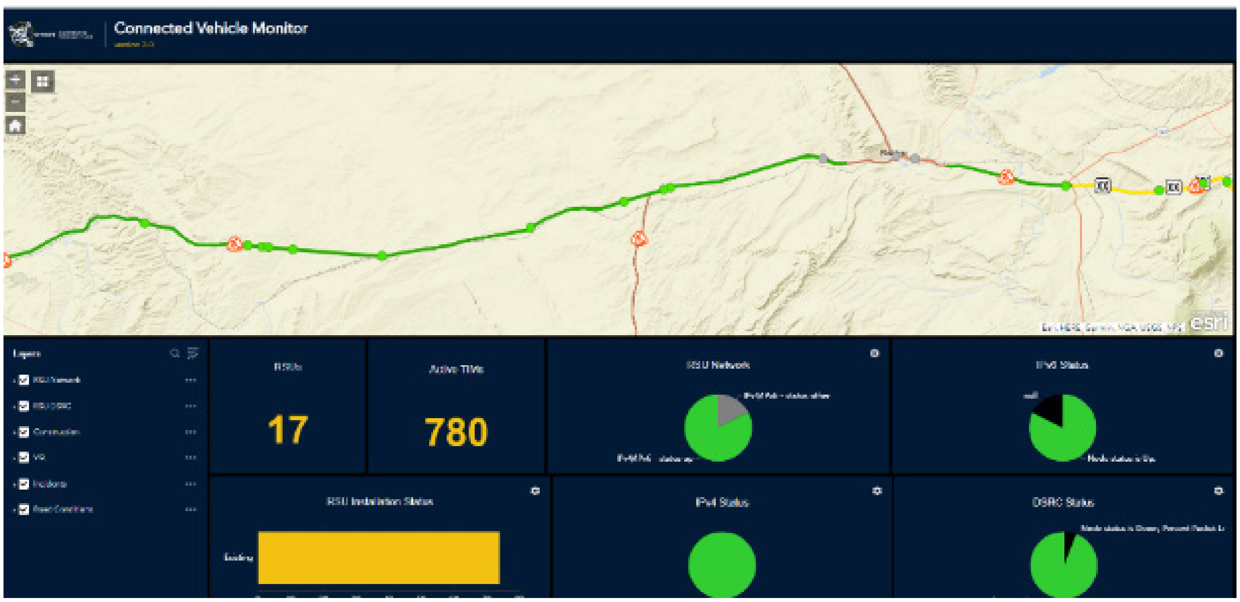
- Advisories
- Roadside alerts
- Dynamic travel guidance for freight and passenger travel[194]
- Advisories

- Roadside alerts
- Dynamic travel guidance for freight and passenger travel[57]

The pilot deployed 75 roadside units (RSUs) that receive and broadcast messages using DSRC along I–80. The RSUs were installed along I–80 based on a statistically driven approach to select hotspots. To support the testing of applications, onboard units (OBUs) were installed on 400 fleet vehicles and commercial trucks that regularly use I-80. The OBUs broadcast BSM and include a human–machine interface to share alerts and advisories with drivers. Some vehicles were also equipped to collect environmental data through weather sensors.[58]

The pilot is monitored through a CVM that can show the conditions of the roadway and the types of information passing through the RSU to vehicles. An example of the CVM is shown in figure 0.5.

Figure 0.5. Wyoming Department of Transportation (WYDOT) connected vehicle monitor.



Source: WYDOT.

The following applications are components of the pilot project.

Forward-Collision Warning (FCW)

FCW uses V2V communications to issue warnings to drivers if there is an impending front-end collision in the same travel lane. It can help drivers avoid or mitigate front-to-rear collisions, but it does not take control of vehicles to avoid collisions.

57 Ibid.
58 Ibid.

Infrastructure-to-Vehicle Situational Awareness

This application allows "relevant downstream road condition information including weather alerts, speed restrictions, vehicle restrictions, road conditions, incidents, parking, and road closures to be broadcast from an RSU and received by the connected vehicle." This is important in informing the placement of RSUs on a corridor.

Work Zone Warning

This application provides information to vehicles about work zone conditions that might impact their safety or cause slowdowns and stops, lane shifts or closures, and ingress and egress of other vehicles that could present safety issues.

Spot Weather Impact Warning

This application provides road condition awareness to drivers to know if poor weather conditions might impact their route. It provides segment-level information about what is happening in specific segments along a route.

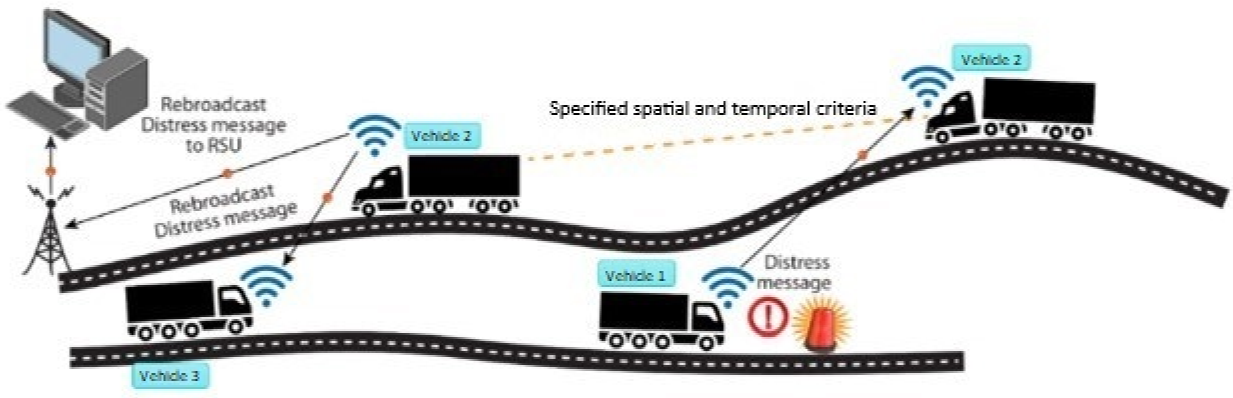
Distress Notification

This application allows connected vehicles to communicate distress status when a vehicle's sensors detect an event that might require help from others or when the operator manually initiates a distress signal.[195] WYDOT wanted to find a way to minimize the possibility of multivehicle crashes. They also wanted to be notified of crashes that have occurred in an isolated rural area with no witnesses so that the crashed vehicle could be located by emergency responders. Figure 0.6 illustrates the distress notification system:

- Distress notification system activates when the driver of vehicle 1, which is traveling in the eastbound direction and in distress, presses a distress notification button (in the future, it may be possible to tie into the vehicle's diagnostic system and detect an airbag deployment). The vehicle will begin to broadcast a distress notification.
- When vehicle 2 comes along in the opposite direction, it picks up the signal and rebroadcasts it. As vehicle 2 continues in the westbound direction, it will broadcast the signal for a prescribed distance or time.
- Continuing to the west, vehicle 2 will deliver the distressed vehicle's location to the nearest RSU (the unit does not need to be in the immediate area of the distressed vehicle), where it will be sent to the transportation management center (TMC) and on to the Wyoming Highway Patrol to improve emergency response.

- If another vehicle is traveling eastbound, approaching the distressed vehicle, it will be alerted to the problem ahead to slow down or take evasive measures.

Figure 0.6. Distress notification system.



Source: Wyoming Department of Transportation.

WYDOT's goal with this concept of using vehicles to propagate the signal is to reduce the number of multivehicle pileups.

Results

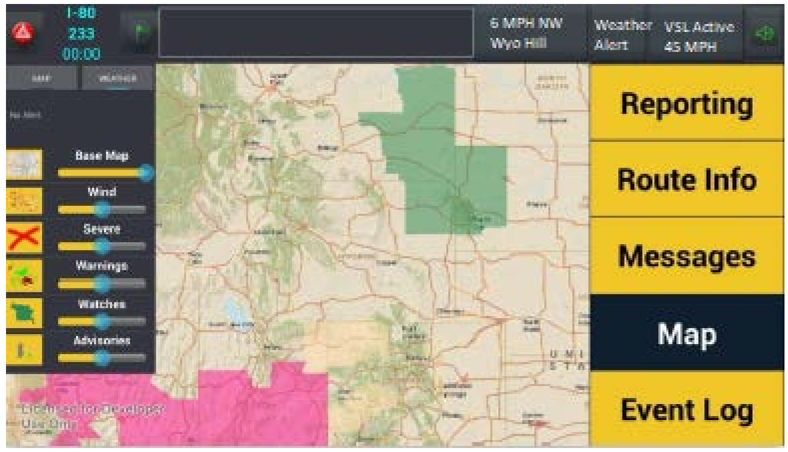
There are many expected benefits of the pilot project. The overall goal is to reduce crashes and crash severity on I–80, but WYDOT notes that the pilot will also help in the following ways:

- The road condition reporting system (Figure 0.7) will automatically collect important road weather data from snowplows and trucks to warn travelers of adverse road conditions.
- Truck drivers will receive information directly in their vehicles about safe travel speed, routes, parking, and emergency vehicle operations.

- Fleet management centers will have current and forecasted road conditions for better travel decisions to increase efficiency and productivity.

- The pilot will use V2V and V2I to give drivers road condition information and posted speeds and encourage compliance with speed limits.[196]

Figure 0.7. Road condition reporting system.



Source: Wyoming Department of Transportation.

The pilot project testing timeframe was from 2018 to 2019, but the testing and placement of the RSUs allowed for more robust information sharing. For example, a recent report showed that the road condition information could even be available to users.

Conclusion

Connected vehicles and corridors can enhance existing strategies and create new opportunities to improve safety and mobility. The Wyoming I–80 Connected Vehicle Pilot enhanced the preexisting weather management program by communicating the information to drivers and emergency responders earlier and to greater distances. When the weather programs and technology are combined, they reduce the likelihood of crashes by stopping, slowing, or diverting vehicles from potentially hazardous situations or notifying emergency response teams and other drivers of incidents for quicker resolution and situational awareness.

CASE STUDY: IOWA INLAND WATERWAYS

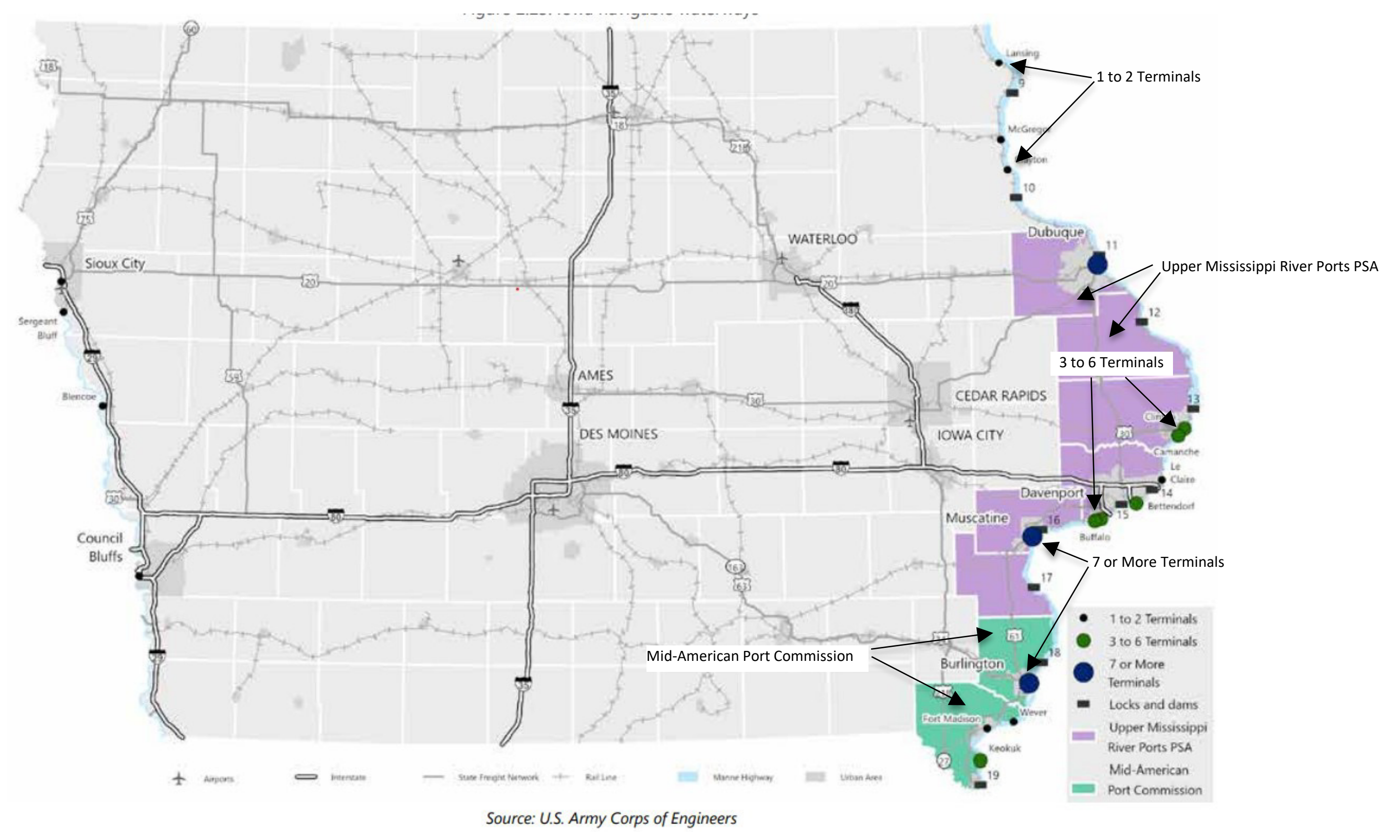
Key Takeaways

In Iowa, freight shippers have the convenience of multiple modal options for moving goods and materials. The State's 160,000-mile multimodal freight transportation system comprises air cargo facilities, highways, pipelines, rail networks, and two bordering navigable waterways. The two navigable rivers bordering Iowa—the Missouri River and Mississippi River—from Iowa's waterway system (Figure 0.8). They are part of two USDOT-designated Marine Highway Routes covering 491 miles:

- M–35, the Upper Mississippi River (312 miles in Iowa) on the west

- M–29, the Missouri River (179 miles in Iowa) on the east

Figure 0.8. Iowa's navigable waterways.



Source: Iowa Department of Transportation.

Background

Both marine highways connect to an extensive national inland waterway system and international deep-sea ocean port facilities on the Gulf Coast. The M–29 Marine Highway runs from Sioux City, IA; to Kansas City, MO. The M–35 Marine Highway runs from St. Paul, MN; to Grafton, IL. Along these rivers are 63 different barge terminals, 57 along the Mississippi River and 6 along the Missouri River. Iowa's private barge terminals are a key part of the movement of agricultural products, cereal grains, gravel, nonmetallic minerals, and machinery movement into and out of Iowa. These terminals transfer commodities between barge, rail, and truck. A system of 11 locks and dams on the Upper Mississippi River, operated by the United States Army Corps of Engineers (USACE), maintains adequate water levels for barge operations. Dams are built on rivers to hold back water and form deeper navigation pools, allowing river vessels to use a series of locks to "step" up or down the river from one water level to another.

Freight moving via waterway in Iowa is primarily moving through facilities on the Mississippi River within the boundaries of the Ports of Eastern Iowa and Western Illinois port statistical area (PSA) (shown in purple in figure 0.8). The other PSA on the Mississippi River is the Mid-American Port Commission PSA (shown in green in figure 0.8).
Waterways provide a lower cost–higher volume intermodal option to move grain and bulk materials to international markets. While transporting commodities via waterway is the slowest

and least flexible of the freight modes, it is the most fuel-efficient and cheapest and can handle the largest volumes per trip. One barge can handle 1,750 dry tons of cargo, the equivalent of 70 trucks or more than 16 rail cars.[197]

Waterway Performance Measurement

Iowa DOT tracks four performance measures for its waterway system: condition, utilization, safety, and reliability:

- *Condition*: This measure focuses on the waterway's locks and dams, which are aging and deteriorating, creating a large backlog of maintenance and rehabilitation projects to bring the system into a state of good repair.

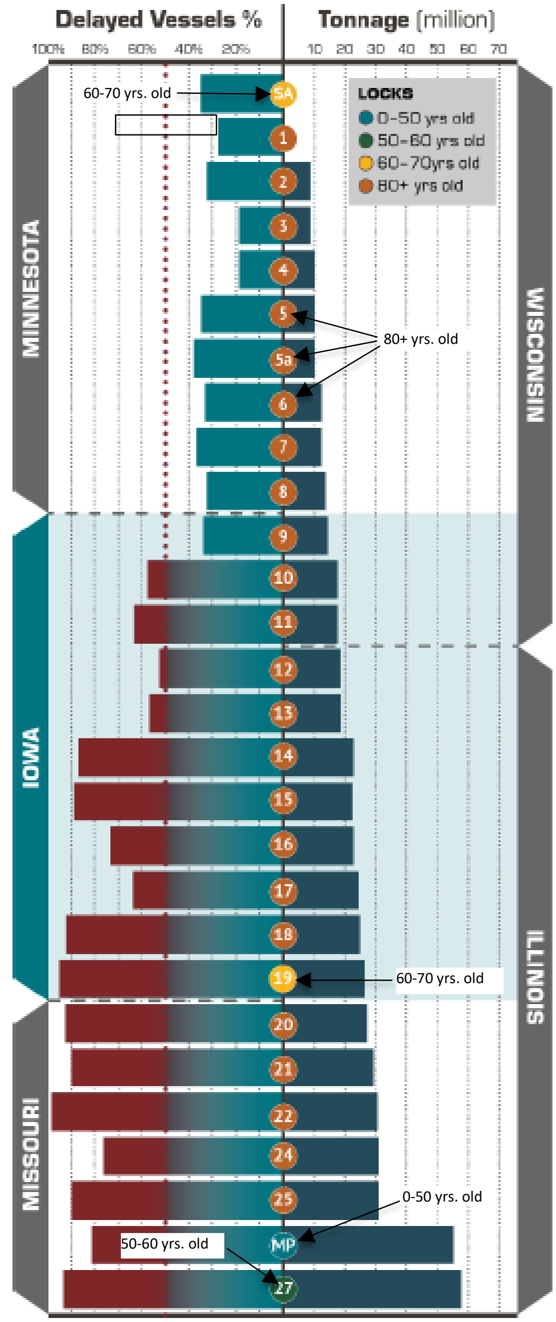
- *Utilization*: This measure tracks the use of the system. Overall, tonnage has been steadily increasing along Iowa's waterways. Figure 0.9 shows that the total tonnage by lock on the Upper Mississippi Waterway experiences more utilization the farther south the lock is located.

- *Safety*: This measure tracks waterway safety. From 2011 to 2020, there were a total of 276 freight-related allisions (where a breakaway barge or navigating vessel makes contact with a stationary object), collisions (where two objects underway or navigating vessels make contact), and groundings (unintentional contact with the shore or bottom of the river, including unknown submerged objects) on the Mississippi (270) and Missouri (6) rivers along Iowa's borders. There were no fatalities or missing crew members aboard towing vessels or barges along Iowa's border over that same period.

- *Reliability*: This measure examines delays, unscheduled closures of locks, and bottlenecks.

- Figure 0.9 shows the percentage of vessels that are delayed at each lock in Iowa, with all but one delaying over 50 percent of vessels each time they try to lock through. Given the overall condition, size, and average delay of the 11 locks bordering Iowa, all are considered freight bottlenecks in the Draft 2022 Iowa State Freight Plan.[198]

Figure 0.9. Upper Mississippi River lock performance, 2020.



Source: United States Army Corps of Engineers.

Results

State Freight Plan

Iowa DOT is looking to address freight performance, reliability, and bottlenecks on its waterway system through the implementation of its State Freight Plan (SFP). The SFP includes inventories, performance metrics, planning considerations, and implementation strategies for improvements and investments for all freight modes, including waterways.

The Iowa SFP's overall freight improvement strategy includes a listing of prioritized implementation strategies that were developed in consultation with freight stakeholders. These strategies were prioritized by the State Freight Advisory Committee. The prioritized implementation strategies for Iowa's inland waterways include:

- #1. Explore additional sustainable funding sources to increase investment in the freight transportation system.
- #4. Advance a 21st-century farm-to-market system that moves products seamlessly across road, rail, and water to global marketplaces.
- #7. Improve freight transportation system resiliency.
- #9. Support opportunities to develop new intermodal freight facilities in the State.
- #10. Target investment to address mobility issues that impact freight movements.
- #12. Advocate for the funding and improvement of the inland waterway system and explore ways to expand Iowa's role.
- #13. Optimize the availability and use of freight shipping containers, including exploring other options for repositioning empty containers.
- #15. Mitigate the impacts of freight transportation on the environment and communities.[199]

Specifically, the Iowa DOT is partnering with the USACE to support their priority project lists for improving the M–29 and M–35 waterways. For the Missouri River (M–29), Iowa DOT is working with the USACE Omaha District to advance its project priorities. Chief among these priorities is the Bank Stabilization and Navigation project, which will maintain the navigation channel to achieve as close to a full navigation season as possible.

For the Mississippi River (M–35), Iowa DOT is working with the USACE St. Paul and Rock Island districts to advance their priority projects for the 11 locks and dams in Iowa. There are over $948 million in funding needs for the USACE-identified deferred/backlog maintenance and major rehabilitation and repair projects for the 11 locks and dams bordering Iowa. These are Federal (USACE) projects, but Iowa DOT has identified them in the SFP in recognition of the fact that addressing these needs is essential to ensure the continued viability of the Mississippi River for transporting freight to and from Iowa.

New Barge Terminal

Iowa DOT backed a new barge terminal located on the Missouri River between Sioux City and the Omaha metropolitan area. The new barge terminal is a significant milestone for the revitalization of the Missouri River waterway, which saw barge traffic decline in the past. Freight traffic is now picking up on the Missouri River, with positive economic developments and trade flows between St. Louis and Kansas City on the waterway. Trade is also being sent farther up the river to the Port of Blencoe, which is the northernmost port on the river.

The barge terminal at Port Blencoe opened in June 2021 as an alternative to inefficiencies from bringing fertilizer up the Mississippi River to Dubuque and trucking it to northwest Iowa. Using barge transportation at the Port of Blencoe now saves an estimated 248,000 truck miles and 58,000 gallons of fuel annually, significantly reducing carbon emissions. In 2021, the port received 35 loaded barges upstream and shipped 28 loaded barges downstream.[59]

New Port Statistical Area

States, area MPOs, and regional planning associations on both sides of the Mississippi River in the tri-state area (Iowa, Illinois, and Missouri) began an initiative to create the Upper Mississippi River Ports PSA. The Mississippi River Ports of Eastern Iowa and Western Illinois (MRPEIWI), doing business as Upper Mississippi River Ports, consists of the existing ports and terminals in the two States.[60] The PSAs were established in recognition of the fact that accurate reporting showing more tonnage moving in and out of a PSA will attract more investment and funding for the USACE to improve the performance and reliability of the waterway system.

Mooring Cell Pilot Project

Iowa DOT is working with USACE to construct a new mooring cell near LeClaire, IA, at Lock 14 (figure 0.10). This initiative is the result of Iowa DOT's 2019 Alternative Financing Evaluation: Upper Mississippi River Inland Waterway study, which analyzed pilot project scenarios and the return on investment for each. The report found the highest benefit-cost ratio for the implementation of the new mooring cell.

The mooring cell is a large cylinder constructed next to the navigation channel that barge tows can tie up to while they are waiting to lock through a dam. The benefits of the project include:

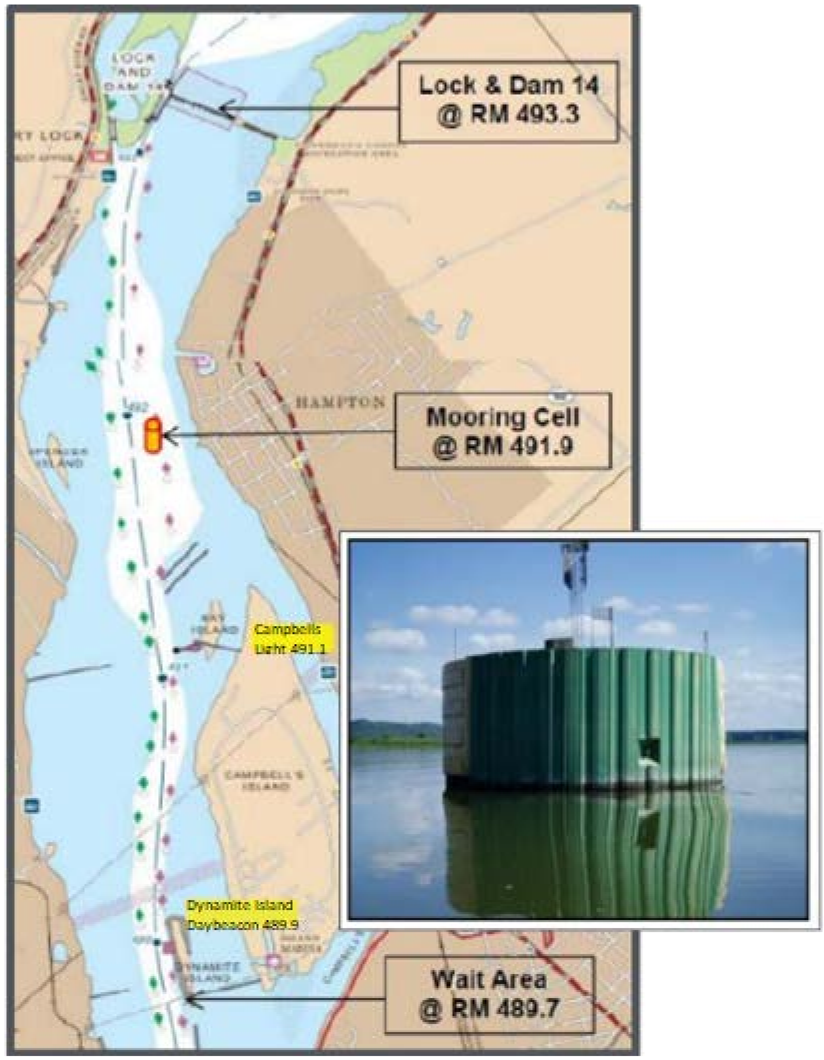
- *Improved lock approach times*—Barge tows can get closer to locks, which saves time
- *Reduced environmental impacts*—less idling in the middle of the river as barges wait

[59]Iowa DOT. 2022. *Draft Iowa State Freight Plan: Chapter 2, System Inventory and Performance*, last accessed March 6, 2023.

[60]Ibid.

- *Improved operational safety*—less chance of running aground protects crews working on tows
- *Replicability*—If the contributed funds agreement between Iowa DOT and USACE is successfully executed, it could provide for Iowa DOT and other State DOTs a replicable way to fund other micro (small-scale) navigation efficiency improvements at additional sites.[200]

Figure 0.10. Mooring Cell Project Location and Photo



Source: Iowa Department of Transportation.

Conclusion

Iowa's multimodal freight transportation system features two Marine Highway Routes that provide an alternative to shipping goods to and from inland locations by truck. Waterways provide a lower cost–higher volume intermodal option to move grain and bulk materials to international markets. It is a fuel-efficient, inexpensive, and cost-efficient way of handling the largest volumes of freight.

Iowa's inland waterway locks and dams are in need of maintenance and rehabilitation. While the condition of the locks creates freight bottlenecks, the overall tonnage carried on Iowa's inland waterways has been steadily increasing. To address performance, reliability, and bottlenecks in its waterway system, Iowa DOT has taken deliberate planning, partnering, and project delivery steps, including recommending waterway improvements in the Iowa State Freight Plan.

CASE STUDY: GEORGIA'S INLAND PORTS

Key Takeaways

For the Georgia Ports Authority (GPA), the inland port model has proven valuable in terms of reduced highway and seaport congestion, as well as local economic development. Containers can be trucked for shorter distances and staged at the inland port intermodal yard, where they are loaded onto trains moving hundreds of containers in a single trip. This extends GPA's reach and capacity to meet growing demands, offers important opportunities for economic development, stages cargo closer to population centers, extends port gates, saves millions of truck miles, and attracts new businesses.

Background

Georgia Ports Authority

GPA is a State authority governed by a 13-member Board of Directors appointed at large by the Governor from the State. Though it is owned by the State of Georgia, GPA operations are funded completely by their own revenues.

GPA's assets include the Port of Savannah, the Port of Brunswick, other seaside facilities, and inland dry ports. As shown in figure 0.11, GPA's deepwater assets include two main terminals at the Port of Savannah (the Garden City Terminal just north of Savannah and the Ocean Terminal in downtown Savannah) and three terminals at the Port of Brunswick (Colonel's Island Terminal, Mayor's Point Terminal, and East River Terminal). GPA also owns and operates inland terminals at Bainbridge and Columbus, which move dry bulk commodities to and from the southeastern United States.

Figure 0.11. Georgia Ports Authority (GPA) deepwater and inland terminal options.

Source: GPA.

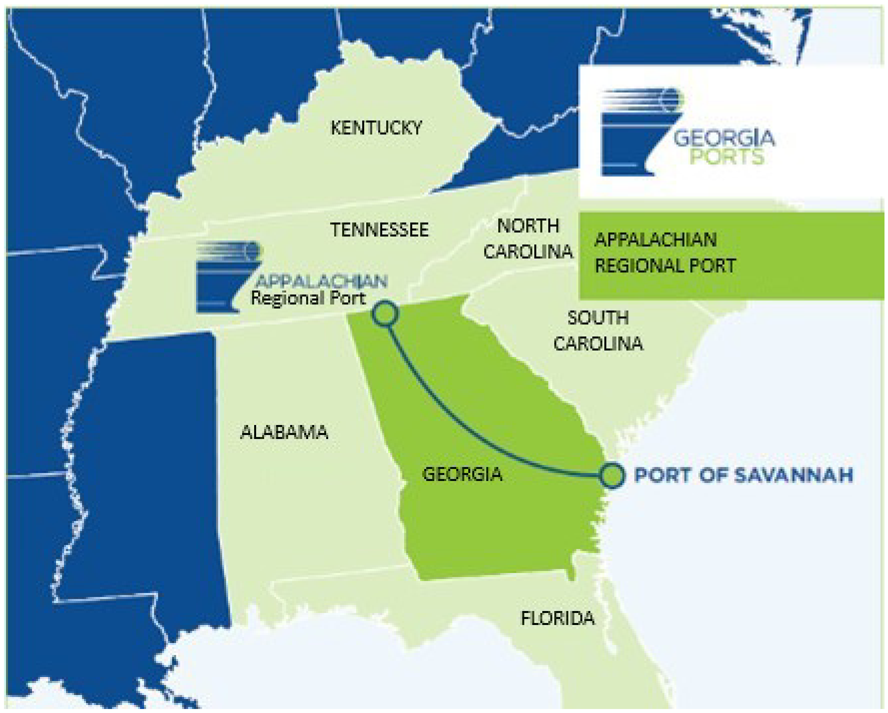
GPA's dry port is an inland intermodal facility called the Appalachian Regional Port (ARP). Located in Murray County at the Tennessee border. GPA has another planned dry port facility called the Northeast Georgia Regional Port set to go into construction in fall 2022.

Appalachian Regional Port

The Appalachian Regional Port (ARP) opened in August 2018 at the cost of $27 million as a joint effort of the State of Georgia, Murray County, GPA, and CSX Transportation.[201] ARP provides manufacturers and shippers in target markets in the Midsouth region of northwest Georgia, Alabama, Tennessee, Kentucky, and South Carolina an alternative to an all-truck dray to/from the Port of Savannah (figure 0.12).

ARP provides an inland gateway to global markets with highway access to I–75 and US 411 and exclusive CSX freight rail service on a direct 388-mile route to/from the Port of Savannah's Garden City Terminal. The facility is located in a rural area, offering customers proximity to key highway connections away from the inefficiencies of urban congestion. US 411 runs adjacent to the facility, providing direct access to I–75 (less than 23 miles from I–75 northbound and 25 miles from I–75 southbound). The facility also offers 6,000 feet of working freight rail track serviced by CSX.

Figure 0.12. Appalachian Regional Port in relation to the Port of Savannah.



Source: Georgia Ports Authority.

With a 40-acre footprint, ARP can currently accommodate approximately 2,400 TEUs at any time. This translates to a capacity of 50,000 containers each year. The site is set up for 50,000 lifts a year (i.e., since a box-on and box-off movement counts as two lifts, ARP can handle 25,000 lifts on and 25,000 lifts off). However, the facility has the capability to add additional equipment and rail to increase capacity to 80,000 lifts per year. Currently, ARP operates approximately 20,000 to 25,000 lifts per year. On average, there are about 130 trucks in and out of ARP a day, and during peak periods, ARP sees 375 to 400 trucks a day.

A goal of GPA's with ARP is to cut down on truck miles carried into the northwest Georgia region to and from the Port of Savannah. Each round-trip container moved via the ARP will offset 710 truck miles on Georgia highways and result in savings on the costs of fuel, congestion, safety, and a state of good repair that would otherwise be incurred from truck traffic.

ARP is also intended to reduce highway and rail congestion in the Atlanta metropolitan area. CSX typically serves the Atlanta area out of its Fairburn Yard. Without ARP, trains would have to travel around or through Atlanta to reach the markets served by ARP. This would be challenging due to urban congestion. Instead, ARP pulls freight traffic out of the Atlanta area, allowing for shorter drayage runs and the ability to move flexibly back and forth through the Port of Savannah and ARP facilities.

ARP was constructed not only as an opportunity to reroute cargo around Atlanta but also for local economic development opportunities in Murray County, GA. The ARP facility is located 20 miles east of Dalton, GA, which has long been known as the carpet capital of the world. The carpet and flooring industry had suffered during the Great Recession with high unemployment and a lack of jobs. However, today the industry has bounced back. A number of businesses have been located in Murray County due to available land and the availability of the dry port terminal at ARP. ARP is expected to continue to bring a broad array of jobs to the area, from advanced manufacturing and logistics to the retail and support services necessary to supply new industries and their employees.

Port Bainbridge

GPA's Bainbridge Terminal is located on the Apalachicola-Chattahoochee-Flint Waterway, or Tri-Rivers System. Bainbridge was a waterborne terminal when it started out, occupying approximately 67 acres of land. The facility is equipped to handle a variety of dry bulk cargo via barge traffic, including nitrogen solution, gypsum, ammonium sulfate, urea, cottonseed, and cypress bark mulch.[61] However, because water levels on the Apalachicola-Chattahoochee-Flint Waterway have been problematic over the years, the port has not had a barge call at the facility in many years. As such, GPA is working with USACE on funding waterway deepening for barge traffic.

Even so, Port Bainbridge still sees frequent traffic from inbound dry bulk cargo via CSX rail. The product that is brought to the port by rail is then distributed by truck to farms and farm services in the region.

Northeast Georgia Inland Port

Just north of Gainesville, GA, in Hall County, GPA has planned the construction of the 104-acre dry port (outlined in yellow in figure 0.13). This facility will provide a direct link to the Port of Savannah via NS rail service. The rail terminal will open with 9,000 feet of working track, expanding to 18,000 feet at full build-out.

With a top capacity of 150,000 container lifts per year, the facility will offset 600 roundtrip highway miles for every container moved by rail. Along with NS rail access, the dry port will have convenient highway access to the I–985 corridor. It is also located 20 miles from I–85. This will further extend the Port of Savannah's reach into northeast Georgia.

[61]GPA. 2023. "Inland Ports—Bainbridge" (web page), last accessed March 6, 2023.

The Northeast Georgia Inland Port will enter into construction in fall 2022. Already, businesses are positioning themselves to take advantage of the benefits the Northeast Georgia Inland Port will offer.

Figure 0.13. Northeast Georgia inland port site.

Source: Georgia Ports Authority.

Methodology

Popup Container Yards

Recently, when American port terminals were inundated with import containers, GPA worked with NS, CSX, and other entities to establish six temporary, popup container yards near manufacturing and distribution centers in Atlanta, Savannah, Statesboro, and Murray County in northwest Georgia, as well as Huntsville, AL; and Rocky Mount, NC. Those yards have served as a pressure relief valve to combat dockside congestion at the Port of Savannah's Garden City Terminal.

These facilities bring cargo closer to customers and reduce the length of container storage time at the Port of Savannah. The six popup yards provide inland and off-dock storage for long-dwell import containers. The use of these sites has not only eased the movement of cargo across the terminal but also expedited vessel service by opening up space for offloaded containers. GPA has the ability to expand the popup sites depending on demand, bringing the total annual capacity for the off-port locations to 500,000 20-foot equivalent container units (TEUs) or the equivalent of 27 mega container ships.[202]

The new facilities are reducing truck traffic, with 1 (the Atlanta yard) anticipated to avoid more than 500 roundtrip truck miles per container, with anticipated volumes of 1,200 containers per month. The Port of Savannah has already seen a dramatic drop in the length of time containers are on the terminal, with the number of import containers on the port for more than 4 weeks dropping by 53 percent in December 2021 compared with September 2021.

Results

GPA, in its long-term plans, is looking to develop more inland dry port facilities in west Georgia and has analyzed central and southwest Georgia locations as potential new sites.

If cargo movements at ARP continue to exceed expectations as they do today, the facility may be in need for capacity expansion by 2026. GPA is looking to expand capacity by another 5,000 to 10,000 containers.

Conclusion

GPA's inland ports have shown to be effective in reducing highway and seaport congestion and supporting jobs and economic development. The ARP, GPA's dry port in Murray County at the Tennessee border, and GPA's planned Northeast Georgia Regional Port allow for diversion of inland truck trips to rail. ARP is already cutting down on truck miles carried into the northwest Georgia region to and from the Port of Savannah on Georgia highways, offsetting 710 truck miles for every round trip shifted to rail.

The inland port model offers States the opportunity to have containers trucked for shorter distances from seaports and staged at the inland port intermodal yard, where they are loaded onto trains moving hundreds of containers in a single trip. This extends the seaport's reach and capacity to meet growing demands, offers important opportunities for economic development, stages cargo closer to population centers, extends port gates, saves millions of truck miles, and attracts new businesses.

By diverting one-way truck trips to rail, manufacturers, shippers, and distributors can realize significant shipper cost savings, from reduced fuel consumption, lower labor costs, and reduced vehicle maintenance. Reducing truck trips has a positive impact on congestion, reliability, and freight bottlenecks, as well as safety, air and noise emissions, pavement damage, and urban roadway congestion.

CASE STUDY: VISUALIZING FREIGHT PERFORMANCE IN TEXAS AND MARYLAND

Key Takeaways

It is important to be able to explain what is happening with freight throughout a State and how it is performing. Using pictures, graphs, maps, and other visual concepts can help explain freight performance for all audiences. These freight performance visualizations use mobility data and conflate it to the HPMS network to fully explain freight performance. The Texas Department of Transportation (TxDOT) and the Maryland Department of Transportation (MDOT) State Highway Administration (SHA) each have several freight visualization tools, which will be discussed further in this section:

- Texas’ 100 Most Congested Road Sections
- Truck Congestion Assessment Tool (TCAT)
- Congestion Management Performance Assessment Tool (COMPAT)
- Maryland Roadway Performance Tool (MRPT)
- Maryland Truck Parking Dashboard

Background

Visualizing freight performance through pictures, graphs, maps, and other visuals can help tell freight stories to multiple audiences and stakeholders in an easily digestible way. This is important because when someone can see what is happening, they may be more compelled to engage in solutions.

The following are examples of freight visualization resources that are helping to improve decisionmaking by providing States and stakeholders with easy-to-understand freight performance information.

Texas Department of Transportation Freight Visualization Resources

TxDOT has been successful in the development of freight performance visualization. Their success is based on their ability to align mobility data with their HPMS network. This is critical because they can align any other data conflated to the HPMS segments and see mobility and reliability along with HPMS information. This provides a more robust or holistic understanding of where freight bottlenecks are and what other conditions exist, such as pavement or safety issues.

Maryland Department of Transportation Freight Visualization

MDOT SHA is also developing visual decisionmaking resources like those used by TxDOT. One distinction is that MDOT SHA has a robust geospatial data platform that MDOT SHA links to its tools. This helps to broaden the connection of freight performance to geographic information system data like locations of freight generators, traffic volumes, safety, climate action boundaries (flooding and climate change vulnerability/resiliency), and more.

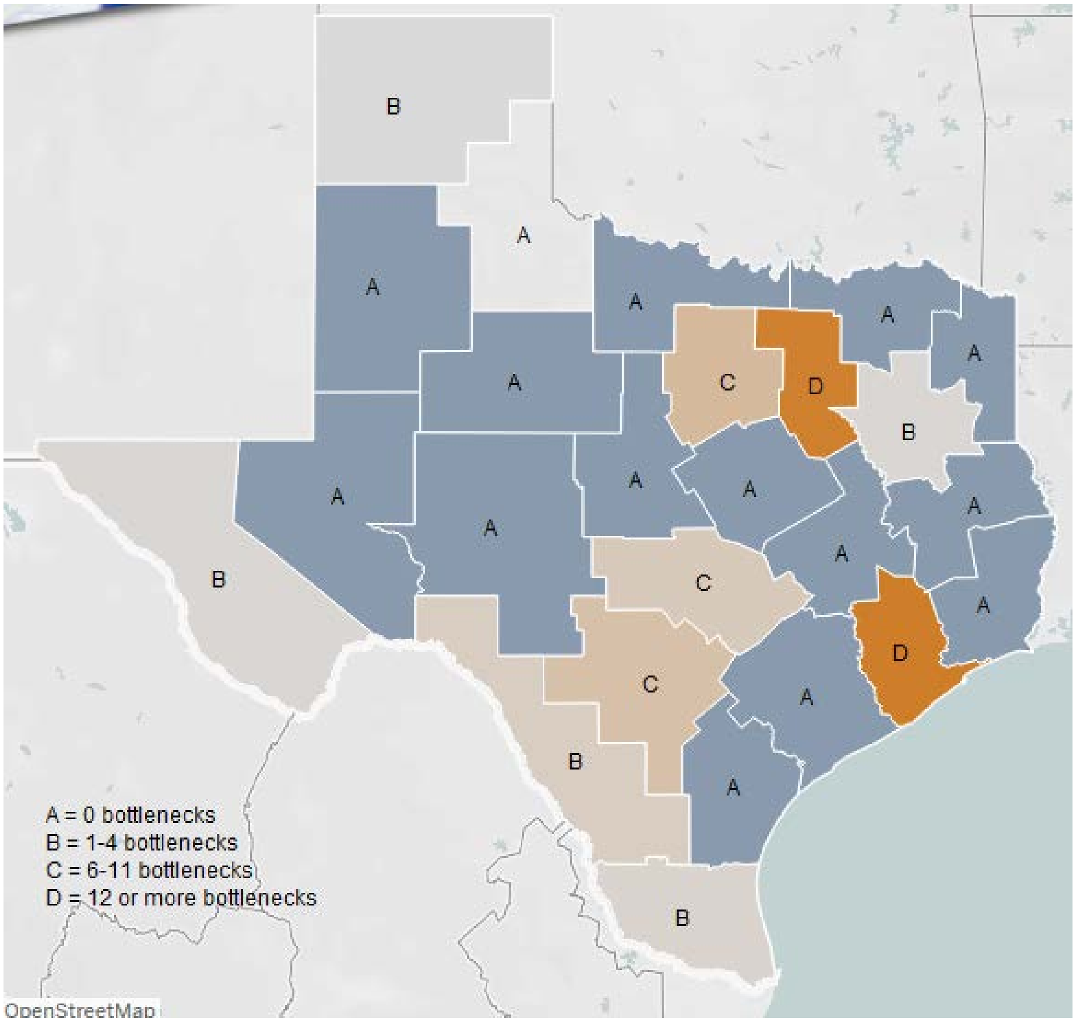
Results

Texas’ 100 Most Congested Road Sections

Texas’ 100 Most Congested Road Sections (Texas 100) tool identifies freight bottlenecks (figure 0.14). It was originally developed in 2009 in response to the Texas State Legislature when it mandated that TxDOT annually create a ranked list of the most congested roadways in the State. From there, TxDOT commissioned a list of bottlenecks that evolved into the Texas 100 and subsequent tool. The Texas 100 tool now includes over 1,800 road sections as bottlenecks, providing a visual, interactive way for people to easily see the bottlenecks, know where the bottlenecks are located in the State, and have useful performance statistics all in one view that tells the freight performance story.

In developing both the list and the tool, the Texas A&M Transportation Institute (TTI) combined TxDOT's HPMS roadway network (TxDOT's Roadway Highway Inventory (RHiNo)) and traffic volume data with speed data from INRIX. Doing this makes it possible to evaluate these bottlenecks with any other information aligned to RHiNo. This way, TxDOT can further evaluate

Figure 0.14. Texas 100 Most Congested Roadways snapshot.



Source: Texas A&M Transportation Institute

bottlenecks alongside the pavement, safety, and other critical performance information. Using this information, TxDOT produces Annual Truck Congestion Report Cards for each of the Top 100 Truck Congested Roadways and predefined regions and geographies, which quickly examine performance trends.[203] The tool benefits users as diverse as TxDOT planners to the public, providing greater visibility of bottlenecks throughout the State, the ability to pinpoint areas of truck congestion, integrated data for planning purposes and TSMO treatments, and informed stakeholders' engagement.

Truck Congestion Assessment Tool (TCAT)

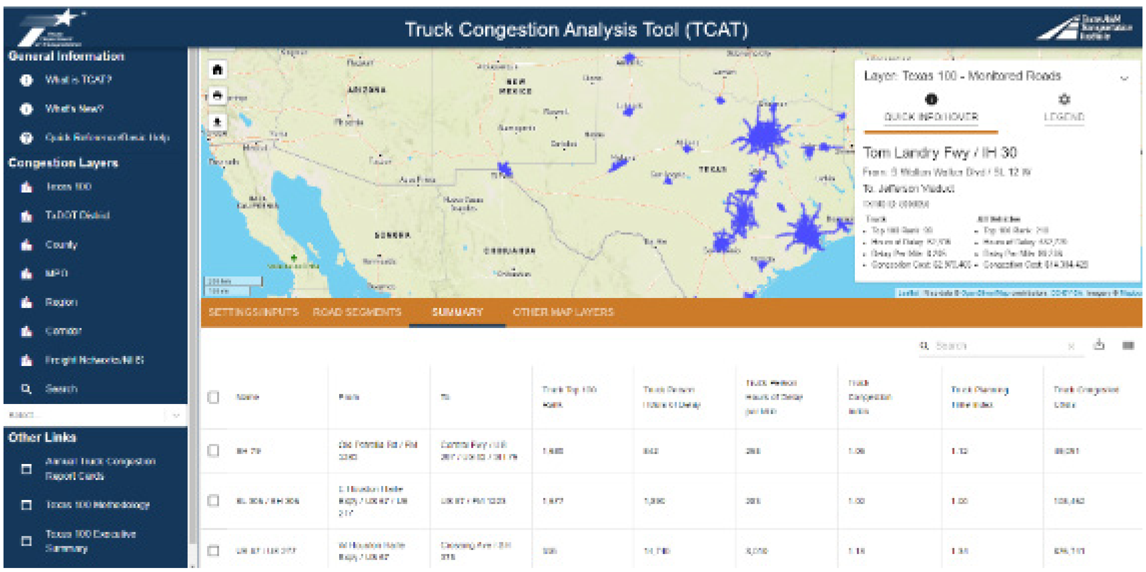
Evolving from the Texas 100, TxDOT developed TCAT, which allows users to access freight mobility performance measures on most of the major roads in Texas beginning in the data year

2017. TCAT relies on the mobility performance measures generated by the Texas 100 and offers more information specifically for trucks. Through TCAT, users have access to the Top 100 Congested Roadways information, primarily focused on the top 100 truck congested roadways (figure 0.15).

TCAT offers users traditional mobility and reliability measures such as:

- Annual delay
- Delay per mile
- Congestion cost
- Travel time index
- Planning time index[204]

Figure 0.15. TCAT dashboard.



Source: Texas Department of Transportation.

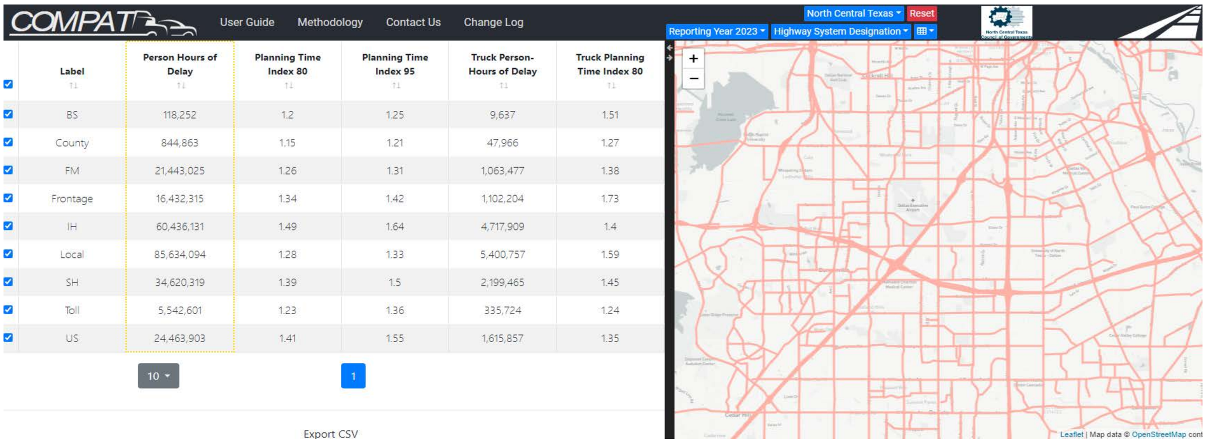
TCAT outputs performance summaries at different levels, including individual roadway segments, custom-generated corridors defined by the user selecting a start and end point, regional/geographic areas, and predefined corridors. In addition, TCAT can visualize TxDOT's transportation projects and access Annual Truck Congestion Report Cards for each of the Top 100 Truck Congested Roadways, as well as each of the predefined regions/geographies. These report cards were designed to quickly examine performance trends.[205]

Congestion Management Performance Assessment Tool (COMPAT)

A parallel tool is TxDOT's COMPAT tool, which is targeted more to MPOs at the regional level. It is a resource primarily for stakeholders involved in congestion management planning, performance-based planning and programming, and corridor study development roles. COMPAT is useful to these users because it includes performance assessment options, including MPO region summaries and the capability to zoom into corridors or segments for overall traffic and trucks (figure 0.16).

COMPAT uses annual averages for all Wednesdays and Saturdays from an INRIX XD speed dataset procured by TxDOT to compute the Texas 100. The shapefiles from this INRIX XD speed data were conflated over the shapefiles for volume-based and TxDOT-maintained RHiNo data sets. COMPAT visualizes performance measures by drawing upon associated Texas' 100 Most Congested Road Section Report volume and speed data.[206]

Figure 0.16. Congestion Management Performance Assessment Tool dashboard for North Central Texas Councils of Government region.

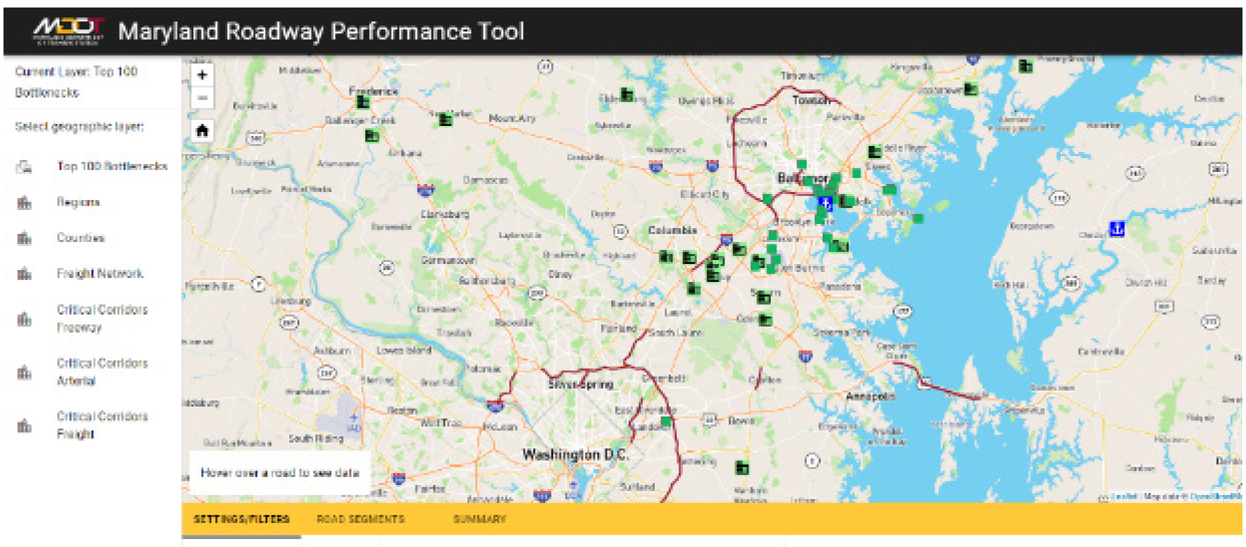


Source: Texas Department of Transportation.

Maryland Roadway Performance Tool (MRPT)

The MRPT (figure 0.17) was developed to provide a similar type of performance visualization. Like Texas 100, the MRPT conflates INRIX's XD network to the HPMS network allowing for Maryland to use mobility data (all traffic and truck) to view congestion by HPMS segment and smoothed bottleneck segments. This can be helpful in evaluating segments with other HPMS-level information such as asset condition (e.g., pavement condition) and the Freight Analysis Framework (FAF) to provide a segment freight value. Further, the MRPT links to MDOT SHA's sophisticated geospatial data and mapping platform, pulling relevant GIS maps so that performance may be viewed in relation to important layers like freight generators, resiliency and vulnerability, and land uses.[207]

Figure 0.17. Snapshot of Maryland Roadway Performance Tool top truck bottlenecks visualization.



Source: Maryland Department of Transportation.

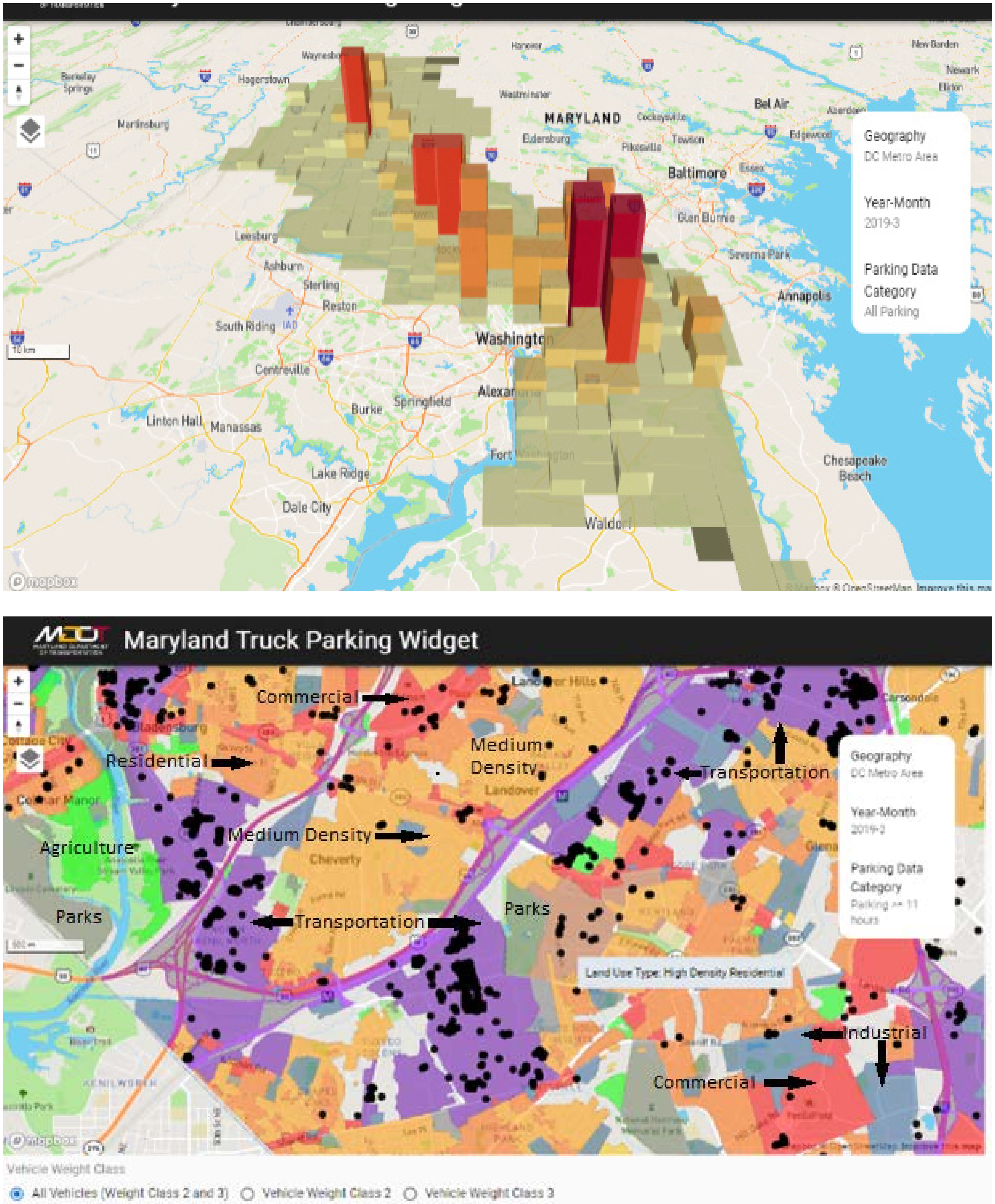
Maryland Truck Parking Dashboard

MDOT SHA is also finalizing a truck parking dashboard (figure 0.18) that uses INRIX trips data to show parking demand statewide and usage at State-owned lots. The goal is to align this with mobility information in the MRPT in the future to show parking in relation to mobility. This may help users understand where truck parking expansion or opportunities are needed.[208]

Conclusion

Freight performance visualizations can be valuable tools for State DOTs and other freight planners and researchers, offering a resource to more fully understand freight mobility and reliability data. These visualizations allow a more thorough understanding of freight bottlenecks and other reliability concerns across a State. Both TxDOT and MDOT SHA have created freight visualization tools that provide a thorough understanding of freight performance across their roadways. Both agencies' tools align and conflate mobility data with the HPMS network. In this way, the tools give users a better understanding of pavement and safety issues and identify freight generators, traffic volumes, and other vulnerable locations that may impact freight.

Figure 0.18. MDOT Truck Parking Dashboard.



Source: Maryland Department of Transportation.

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