FINAL REPORT

Analysis of Freight Transport Strategies and Methodologies

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Prepared by:

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Solutions for growing economies

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Technical Units Conversion

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	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	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 1000 L shall be shown in m^3				
		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

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16. Abstract

Transportation agencies are often blind to freight flows at the "last mile" level of truck movements. New strategies, data sources, and analytics have the potential to provide an empirical understanding of last mile truck movements and their impacts, without relying on commercially sensitive private sector data. This research project identifies best practices and recommends strategies for improving last mile observability — the ability to understand how, when, where, and which types of trucks are moving goods. It provides a set of approaches that the Florida Department of Transportation (FDOT) and Florida's metropolitan planning organizations (MPOs) can integrate into existing processes and implement in the near term, especially in the opportunity area of *freight fluidity* for the last mile. Detailed implementation procedures are offered for the three applications of Last Mile Flow Maps, Bottlenecks Analysis, and Travel Time Reliability Valuation.

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All opinions, findings, and conclusions expressed in this publication are those of the authors.

Executive Summary

Research Problem

Freight flows at the local "last mile" level of truck movements are often invisible because it is hard for transportation agencies to systematically track truck movements, or to access commercially-sensitive privately-held data that can help do so (Chapters 1 and 2). New strategies, data sources, and analytical approaches can overcome these barriers to provide an empirical understanding of last mile truck movements and their associated impacts, without relying on commercially sensitive private sector data (see Appendices B and C).

Project Objective

The objective of this research was to design and develop strategies, methodologies, and other solutions relevant to enhancing last mile observability – the ability to understand how, when, where, and which types of trucks are moving goods – so that the knowledge of these movements can be applied to existing and future freight-related transport analyses and investment decisions. This research thus identifies best practices and recommends strategies for improving last mile observability by developing a set of approaches that Florida Department of Transportation (FDOT) and Florida metropolitan planning organizations (MPOs) can practically integrate and implement.

Method

The research included analysis of existing FDOT data and tools, a review of literature and national best practices, and consultations. In our consultation outreach, we engaged a number of entities such as FDOT's freight data stakeholders, specialist industry vendors and data providers, and other transportation agencies from around the country that could inform site- or region-specific case studies. We also conducted field reconnaissance with FDOT staff to understand and classify last mile issues. We analyzed some of FDOT's existing freight-relevant data repositories, performance measurement frameworks, and technical guidance and documentation. This type of analysis was especially relevant for designing strategies and approaches for immediate practical implementation.

Findings

Our analysis of opportunities to improve last mile observability for FDOT identified two promising opportunity areas, with a number of applications in each.

The first is **Real-Time Corridors**, which involves the ability of agencies to sense and respond to, and perhaps even influence freight movements in real time (see Appendix D). FDOT's concurrent efforts in Intelligent Transportation Systems and Arterial Management Programs have positioned it well for the eventual architecture of Real-Time Corridors, as FDOT continues to integrate technologies, data collection systems, analytics and decision-support tools over time. For this reason, we prioritized the second opportunity area of

Freight Fluidity for detailed solution architectures and implementation recommendations. Freight Fluidity is a broad concept that addresses the efficiency with which goods move from one end of the supply chain to the other (see Chapter 3). Freight fluidity performance measures identify where bottlenecks or inefficiencies occur in the system, including last mile access challenges. These performance measures also connect the discussions of transportation and economic development. FDOT found this opportunity area to be immediately relevant to its ongoing freight planning and investment efforts, including tool modification and improvement. Our recommendations and solutions accordingly focus on three Freight Fluidity applications.

Recommended Strategies and Approaches

We recommend that FDOT should combine location-enabled mobile data sources, specifically vehicle probe GPS data, with its existing data and tools in the following ways:

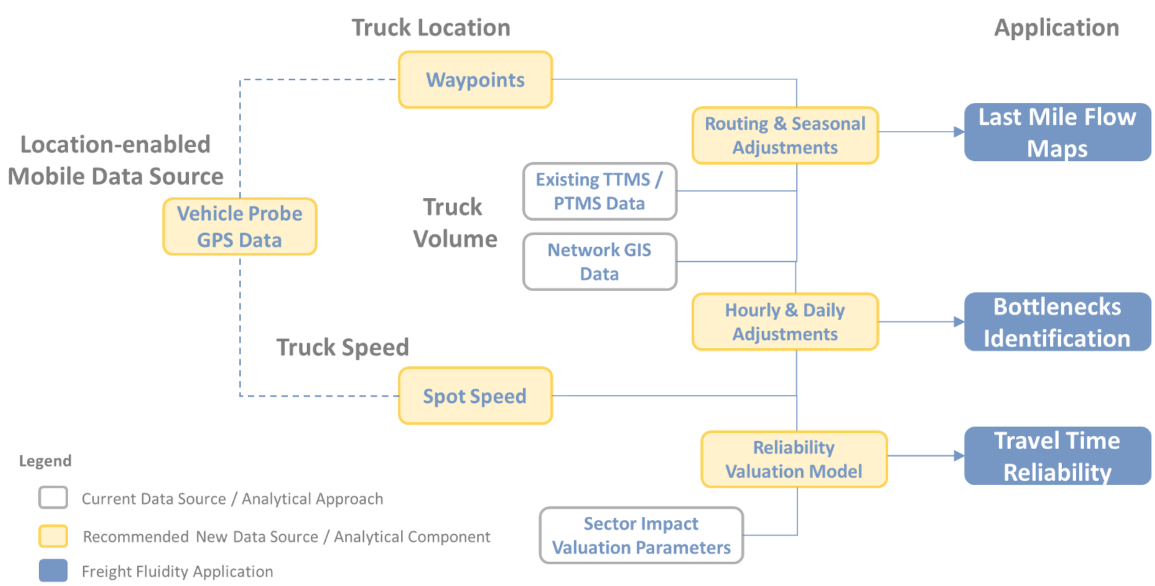
→ **Recommendation 1**: Use GPS waypoint data in conjunction with current data repositories to develop a finer-grained understanding of how trucks traverse the last mile network ("Last Mile Flow Maps", Chapter 4).

→ **Recommendation 2**: Use GPS spot speeds along with estimated truck volumes to identify and precisely locate truck bottlenecks ("Bottlenecks Analysis", Chapter 5).

→ **Recommendation 3**: Use GPS spot speeds, freight facility information, and sector-specific valuation data to assess the value of improving travel time reliability in certain corridors ("Travel Time Reliability Valuation", Chapter 6).

Figure ES-1 summarizes how these two related types of GPS data – waypoints and spot speeds – can be integrated into existing tools and transformed to produce Last Mile Flow Maps, Bottlenecks Analyses, and Travel Time Reliability Assessments.

Figure ES-1. Data needs and analytical components for the three Freight Fluidity applications



Source: CPCS

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Acronyms / Abbreviations

4G LTE	Fourth Generation Long-Term Evolution
ADMS	Arterial Dynamic Messaging System
AMP	Arterial Management Program
BCTED	Broward County Traffic Engineering Division
BlueTOAD	Bluetooth Traffic Origin and Destination system
BLE	Bluetooth Low Energy
CCTV	Closed Circuit Television
CFS	Commodity Flow Survey
CVRIA	Connected Vehicle Reference Architecture
DSRC	Dedicated Short-Range Communication
FAF	Freight Analysis Framework
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FFS	Free Flow Speed
FSP	Freight Signal Prioritization
GPS	Global Positioning System
HHD	Hand-Held Devices
ITS	Intelligent Transportation Systems
ITSDCAP	ITS Data Capture and Performance tool
LIDAR	Light Detection and Ranging
MAC ID	Media Access Control Identification
MPO	Metropolitan Planning Organization
MVDS	Microwave Vehicle Detection System
NHS	National Highway System
NPMRDS	National Performance Management Research Dataset
PTMS	Permanent Traffic Management System
RADAR	Radio Detection and Ranging
RFID	Radio Frequency Identification
SIS	Strategic Intermodal System
STB Waybills	Surface Transportation Board Waybills
TSP	Transit Signal Prioritization
TTI	Travel Time Index
USDOT	US Department of Transportation
V2I	Vehicle-to-Infrastructure communications
VIUS	Vehicle Inventory and Use Survey
WiFi	Wireless connection system (not Wireless Fidelity)
WIM	Weigh-in-Motion

1 Introduction

Key Chapter Takeaway

Transportation agencies are often blind to freight flows at the "last mile" level of truck movements. New strategies, data sources, analytics, and approaches have the potential to provide an empirical understanding of last mile truck movements and associated impacts without relying on commercially sensitive private sector data. This research project identifies best practices and recommends strategies for improving last mile observability — the ability to understand how, when, where, and which types of trucks are moving goods. It provides a set of approaches that FDOT and Florida MPOs can practically integrate and implement.

1.1 Problem Description

Understanding existing freight movements is essential to making informed planning and investment decisions for freight and the transportation system. The investment decision support tools available to DOTs and MPOs, including freight transport models, have traditionally focused on lanes, corridors, and interregional movements, on the national highway system (NHS) for example. Data and observations for calibrating model parameters or validating trends are more robust at this level.

Understanding the movement of trucks and goods at the local level — the so-called last mile — has been a persistent freight data gap.

The term *last mile* first became colloquial in the telecommunications industry and was used to denote the final leg or link in the network connecting a trunk or main backbone of the network to the end-user (Rodrigue et al., 2009). Since then, the use of the term has expanded into infrastructure networks broadly and is now prevalent in supply-chain networks to indicate the delivery of goods to and from the main lines of good movement.

The gap in understanding flows in the last mile of freight exists due to two fundamental challenges:

- Empirical observability of freight, defined as the ability to understand how, when, where, and which types of trucks are moving goods, and the nature of those goods; and
- Commercial sensitivity of some types of freight data held by private owners.

Freight planning/investment models and freight operations could become more realistic if the two following goals can be accomplished:

→ **Observability of "last mile" freight improves**. Empirical observations of freight flow, especially in the first and last mile, have not historically been available due to lack of systematic sensing capability, cheap storage, and robust analytical approaches. However, the proliferation of sensors and available data, commoditized storage, and improved analytics have created opportunities to improve freight observability at the last mile.

→ **Reliance on access to private data is mitigated**. Private firms in the freight value chain are reluctant to share data due to commercial interests. Typically, these data involve identifying information for specific vehicles, and transaction data that could reveal cost structures for carriers, or the shipments to freight receivers. Bypassing the need to source data at the shipment, firm or aggregator level can increase the flexibility of DOTs and MPOs in calibrating investment models.

This study consequently focuses on identifying the best practices, data sources, and the design of strategies, methodologies, and approaches to improve last mile observability without relying on private data. Where relevant, this research also places in context the nature of private data and the last mile decisions of private actors in the freight transportation system (shippers/receivers / 3PLs, and carriers) to address the study objectives.

1.2 Research Objective and Output

The objective of this research is to design and develop strategies, methodologies and other solutions relevant to enhancing last mile observability so that they can be applied to existing and future freight-related transport analyses and investment decisions at the Florida Department of Transportation (FDOT).

Ultimately, this research is about how Florida DOT can leverage increasingly available data and associated analytics to enhance observability in the last mile of freight and make it more efficient.

Last mile freight observability can be improved in both real time and over time. For this research, observability thus falls into two opportunity areas, each with their own objectives:

→ **Freight-related Planning ("observability over time")**: From a planning and investments perspective, the most critical need is understanding how to use data to map truck routes, classify trucks, identify bottleneck locations and choke points, assess the impact of delays or inefficient operations, and help prioritize public sector freight projects.

→ **Freight-related Operations ("observability in real time")**: From a Transportation System Management and Operations (TSM&O) perspective, the goal for observability is to better manage operations in a way that is cognizant of freight movements and aligned to support freight efficiency. This includes real-time signal plans in corridors and arteries, improved incident management, and more efficient traffic interactions such as truck behavior at railway crossings.

The final outcome of this project is a toolkit of practical options — a set of approaches — that FDOT and Florida Metropolitan Planning Organizations (MPOs) can deploy to address some persistent and emerging challenges affecting the last mile of freight.

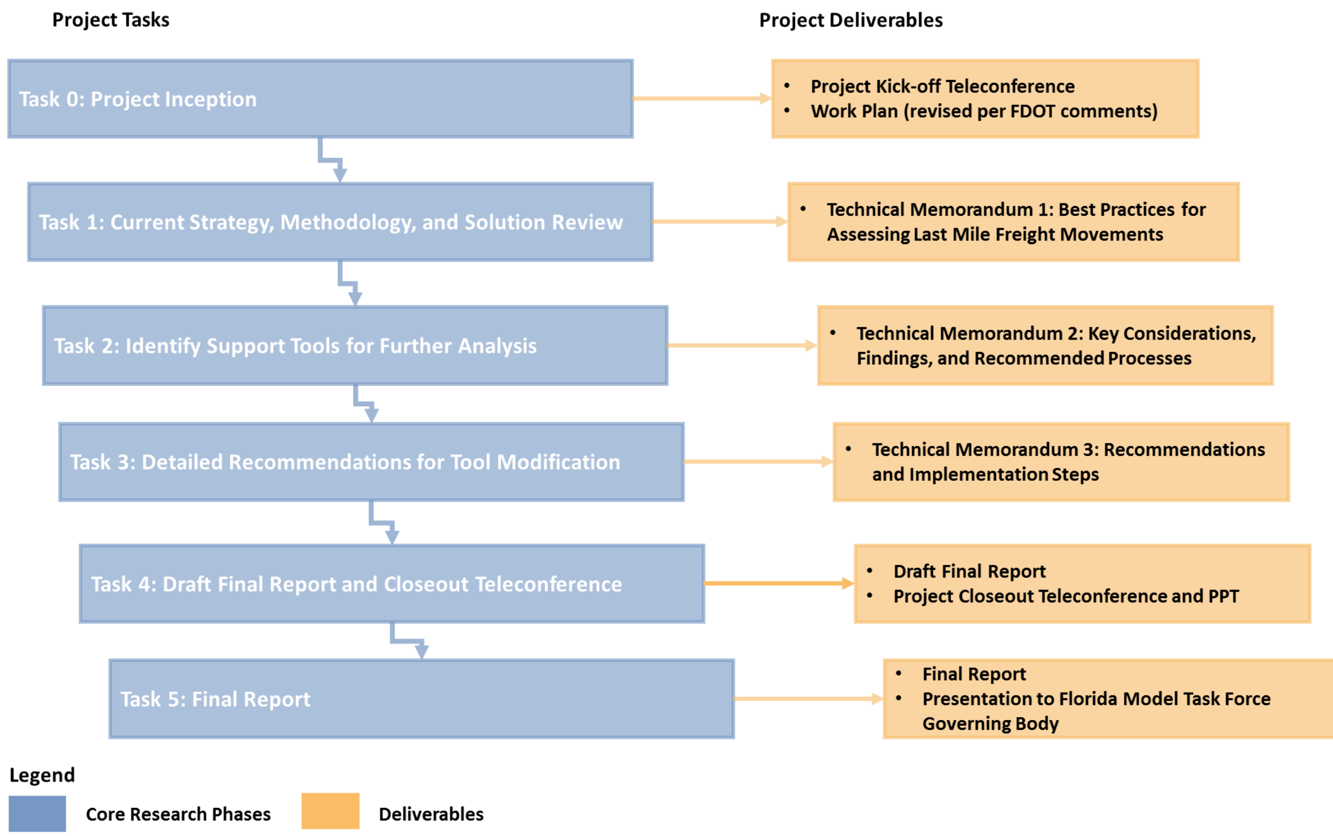
The study also highlights the potential impact of recommended solutions and the capabilities and implementation steps required for integrating these solutions into FDOT's existing best practices and systems.

1.3 Research Key Questions, Organization, and Outcomes

1.3.1 Project Organization

We divided the project into six separate tasks, as shown in Figure 1-1. Task 0 served the purpose of Project Inception, in which we clarified the research objectives, approach and research work plan. Research discovery and synthesis were performed thereafter in Tasks 1 through 3, and each of these three tasks had its own key questions, as described below in Table 1-1. Tasks 4 and 5 cover the final synthesis and reporting of research findings and recommendations.

Figure 1-1: Project task organization



Source: CPCS

1.3.2 Research key questions and outcomes

Table 1-1 lists the main research questions we used to address the project objective, describes the corresponding project tasks and summarizes their main outcomes.

Table 1-1. Research key questions, corresponding tasks, outcomes, and document reference structure

Research Key Question	Corresponding Task	Outcome	Document Reference
What are the current public sector best practices related to analyzing, identifying, and quantifying freight movements?	Task 1: Current Strategy, Methodology and Solution Review	In Task 1, we synthesized best practices into a framework for last mile freight "observability" – the ability to understand how, when, where and which types of trucks are moving goods.	Appendices B and C
What are the most promising investment decision support tools and methodologies for further analysis?	Task 2: Identify Opportunities and Support Tool(s) for Further Analysis	In Task 2, we identified the most promising applications in two opportunity areas: Freight Fluidity and Real-Time Corridors.	Chapter 2, 3; Appendix D
What are the detailed modifications to the existing support tools or new approaches that will allow for more accurate freight planning?	Task 3: Develop Detailed Recommendations for Tool Modification	FDOT feedback on Task 2 emphasized a focus on the Freight Fluidity opportunity area. In Task 3, we accordingly focused on this opportunity area and identified detailed modifications to decision support tools and methodologies, and implementation steps for integrating recommended updates.	Chapters 4, 5, 6

1.3.3 Methodology

Throughout the project, our research method integrated desk studies, literature reviews, and consultations. In our consultation outreach, we engaged a number of entities:

- FDOT's freight data stakeholders
- Specialist industry vendors and data providers, and
- Agencies that could inform site- or region-specific case studies.

We also analyzed some of FDOT's existing freight-relevant data repositories, performance measurement frameworks, and technical guidance and documentation. This type of analysis was especially relevant for designing strategies and approaches for immediate practical implementation.

1.3.4 Limitations

Some of the findings in this report are based on the analysis of third party data and the reported outcomes of other agencies' programs or projects. While CPCS makes efforts to validate data, CPCS cannot warrant the accuracy of third party data or the soundness of reported results.

1.3.5 Structure of this report

This Final Report synthesizes the research findings, recommended strategies, and the approaches tailored specifically for FDOT's use. Table 1-1 also points to where the corresponding findings and discussions can be located within this Report.

In Chapter 2, we cover the role and value of data and analytical approaches for Florida's last mile context, based on observed issues and persistent planning and operations questions. Chapter 2 also summarizes the most promising opportunity areas and identifies the most immediately relevant and implementable opportunity: Freight Fluidity.

We then introduce the concept of Freight Fluidity in detail in Chapter 3 and outline the specific application areas chosen for detailed tool modifications.

Chapters 4 through 6 elaborate on the concepts, definitions, performance measures, data needs, recommendations and detailed implementation steps for each of the three applications: Last Mile Flow Maps, Bottlenecks Analysis, and Travel Time Reliability Valuation.

2 Florida's Last Mile Context

Key Chapter Takeaway

Data and appropriate supporting analytics are needed to characterize last mile freight behavior so that a case can be made for investments or changes to operations. Our field visits highlighted many last mile issues in Florida that relate to persistent planning and operations challenges. Overall, these are encapsulated in the question facing FDOT: "how to improve the overall observability of regional and local freight traffic?" A best fit analysis of promising opportunities to address the need for observability identified two opportunity areas of Real Time Corridors and Freight Fluidity, of which Freight Fluidity was deemed to be of immediate value to FDOT as a suite of implementable applications.

2.1 Decision-support for Last Mile Planning and Investment

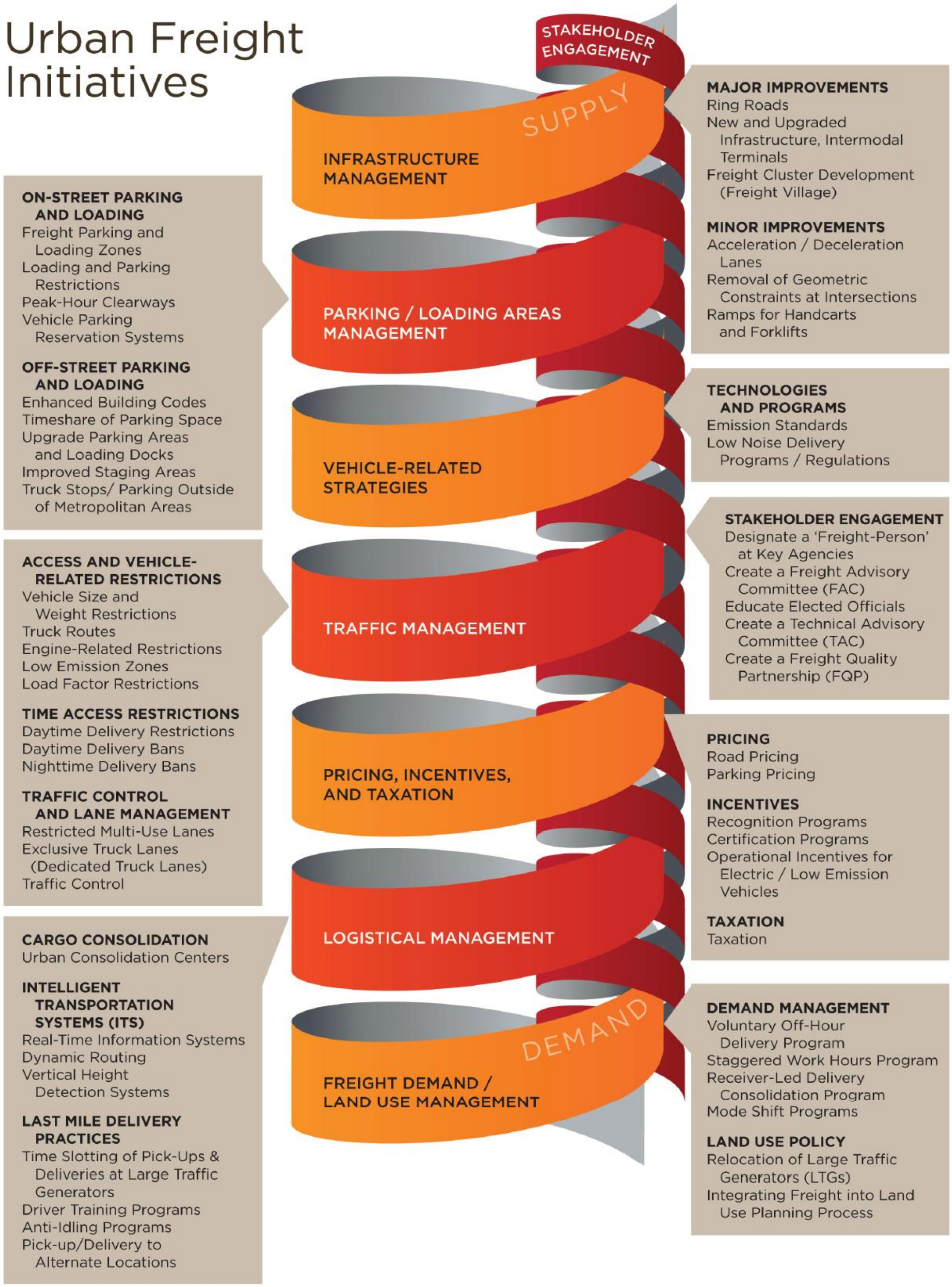
Freight observability and data are directly relevant to a number of last-mile urban and metropolitan freight-related planning and investment activities including infrastructure management, parking and loading, regulation of vehicle types and technologies, traffic management, incentives and pricing, regulations covering the logistical aspects of moving and consolidating freight, and monitoring freight demand and land use. Figure 2-1 summarizes the activities in each of these categories and arranges them along a spectrum from Supply (top) to Demand (bottom). Stakeholder engagement activities notably link all of the other categories and initiatives, shown by the red ribbon on the right of the figure.

Ideally, detailed analyses of empirical data and observation would precede most, if not all, of the initiatives summarized in Figure 2-1, which take the form of specific programming and projects. For example, infrastructure improvements whether major or minor or addition of parking capacity depend on the observed behavior of vehicles and trends over time. Policies and programs such as parking pricing or incentives also depend on a detailed understanding of the demand for freight and expected outcomes.

Data are needed to characterize freight behavior to make the case for investments or changes to operations.

The framework shown in Figure 2-1 refers to some delivery practices as last mile freight activities (bottom), however, we argue that almost all of these initiatives have last mile implications. The specific implications and initiatives will, in fact, depend on the urban or metropolitan area under consideration. For this reason, we identify examples in the following section of last mile freight issues in a metropolitan region in Florida, specifically Broward County in FDOT District 4, to inform the research.

Figure 2-1. Metropolitan freight initiatives for which observability and data access are relevant



Source: NCFRP 33: Improving Metropolitan Freight Performance: A Planning Guide

2.2 Examples of Last-Mile Challenges in Florida

Last mile challenges are inefficiencies or "frictions" that arise when freight movement interacts with freight infrastructure in the final leg or link in the network connecting a primary corridor to the end-user. To identify such frictions, the CPCS research team toured Broward County with staff from FDOT District 4's freight and traffic systems management offices in addition to the analysis of geospatial data and consultations. We observed the following last mile challenges in District 4. Similar conditions can, however, be observed in many other urban and metropolitan regions in the state.

2.2.1 Observed last mile issues

Facility Access: We observed a number of locations where trucks encountered difficult turns and circuitous routes while trying to access freight facilities, especially near busy intersections where wide turns and navigating traffic might be required (Figure 2-2).

Figure 2-2. Trucks waiting at a busy intersection to access a nearby freight facility

Source: CPCS

Queuing: Some locations such as the entrances to port facilities, ramps, intersections, or highway exits with restricted turning areas result in queues with a high volume of trucks (Figure 2-3).

Figure 2-3. Truck queues at Port Everglades Expressway near Eller Drive and McIntosh Road

Source: CPCS

Signal Timing: Arteries and intersections with higher volumes of trucks can benefit from enhancing traffic operations to allow smoother and efficient flow of trucks (Figure 2-4).

Figure 2-4. Restricted truck turns at an intersection with a high volume of trucks near Port Everglades

Source: CPCS

Truck Parking: The state currently has limited truck parking near freeways and freight facilities, and little visibility into which spots are occupied or into the real-time availability of spots (Figure 2-5).

Figure 2-5. A full truck parking lot – the Florida 595 Truck Stop near I-595 and Florida's Turnpike

Source: CPCS

Freight Affinity: Some communities are more accommodating towards freight than others. While some want to preserve or even encourage freight activity, others have issued moratoria on freight facility development and restricted truck movements (Figure 2-6).

Figure 2-6. A freight facility near a community with high residential occupancy and low freight affinity

Source: CPCS

While the specific instances of these last mile challenges were observed in Broward County, these challenges extend to other areas within District 4, and are also relevant for other regions and FDOT districts in Florida.

2.2.2 Persistent freight planning and operations challenges

In addition to the last mile challenges observed above, our literature review, consultations, and analysis of national best practices identified the following persistent planning and operations questions that require data and information on last mile movements.

- How to make access to freight facilities more efficient, and reduce miles and circuity?
- Where do the data suggest that there is freight traffic congestion hotspots and bottlenecks?
- What measures (and the data sources for these measures) should be used by a Traffic Management Center to monitor and manage truck traffic performance?
- How to dynamically optimize intersections based on freight traffic?
- How to sense and influence truck parking in real-time?
- How to predict traffic and enhance truck/rail crossings?
- What are the specific community concerns, calibrated to freight activity?

Overall, these questions can be summarized at a strategic level as follows:

How to improve overall observability of regional and local freight traffic?

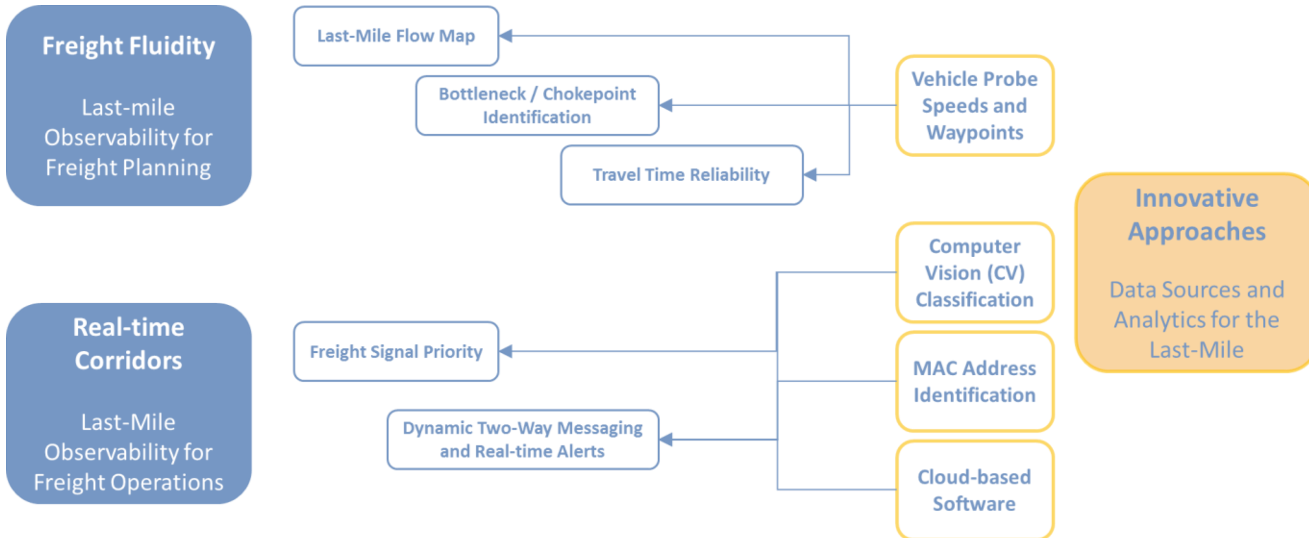
Some of the persistent questions involve issues of freight observability "over time", i.e. understanding trends and developing a feedback loop to planning and investment decisions. Other questions relate to operations issues needing improved observability in "real time" to help address freight operations challenges. We adopted this distinction in our best fit analysis of opportunities available to FDOT for improving last mile observability.

2.3 Best Fit Analysis

We relied on the findings of our research in Task 1: Current Strategies, Methodologies and Solutions and the best practices framework we developed for last mile observability (documented in Appendices B and C) to conduct a best fit analysis of opportunities (Task 2: Identify Opportunities and Support Tool(s) for Further Analysis).

Two distinct promising opportunity areas emerged based on discussion with and feedback from FDOT stakeholders: "Real-Time Corridors" and "Freight Fluidity." Each of these opportunity areas has specific applications, as shown in Figure 2-7.

Figure 2-7: Promising last-mile opportunity areas with their specific applications and new data sources



Source: CPCS

The Freight Fluidity opportunity area involves three applications that can address the need for last mile observability for planning and can be implemented immediately by FDOT:

- Mapping truck flows in the last-mile
- Identifying bottlenecks and chokepoints
- Assessing travel time reliability and associated impacts

Key Considerations: The recommended approach for Freight Fluidity applications is to use vehicle probe speeds and waypoint observations (i.e. GPS data) as the main data source because of the increasing volume and fine-grained resolution of truck speeds and waypoints, at relatively low cost. A variety of analytical approaches can transform these data into decision-support insights through flow maps, "hot spot" or bottleneck analysis, and travel time reliability analyses. Coupled with FDOT's existing detailed freight facility data set, this approach can help accomplish a high-resolution freight map and nuanced reliability impact and value estimates. <u>Recent applications of GPS data in Florida have satisfactorily addressed commercial concerns for privacy, and private sector participation or data sharing is no longer a pre-requisite.</u>

The Real-Time Corridors opportunity area focuses on last mile observability for operations and includes the applications of:

- Freight Signal Prioritization
- Dynamic Two-Way Messaging

Key Considerations: A fusion of cloud-enabled Computer Vision (CV) analysis and wireless MAC Address tracking can support detailed real-time vehicle classification, path analysis, and arterial performance measurement. These applications cover a wider variety of freight traffic phenomena (such as turning, stopping, dwell times, interactions, potential conflicts), which are all linked together by the need to understand how specific truck types behave and interact with both traffic and the road infrastructure itself.

Florida DOT's ongoing efforts in the areas of Intelligent Transportation Systems and artery/corridor management have implications for the prioritization of these opportunity areas and applications, so we discuss some of the relevant efforts next.

2.4 Recent FDOT Efforts relevant to Last Mile Observability and Decision-support

FDOT has deployed advanced Intelligent Transportation Systems (ITS) capabilities to improve system performance at the interstate/freeway level and a number of pilots for key arteries across the state. In the future, these systems may be able to produce data or supplement data for last mile freight observability as the density and location of sensors, communications infrastructure, and use of these data for decision-support increases. We summarize two of these systems below, as they showcase the trend and direction of FDOT's current efforts.

2.4.1 ITS Data Capture and Performance Management

FDOT developed the ITS Data Capture and Performance Management Tool (ITSDCAP) as a data environment to capture and fuse data from multiple sources to support applications such as performance measurement, transportation system modeling, assessment of ITS application benefits, and data mining and visualization techniques. The tool is now Web-based and is integrated with a real-time decision support environment (FDOT, 2010).

The ITSDCAP data environment and web software have mostly focused on freeway facilities. FDOT is updating the system to include data from signalized arterials and from emerging data sources such as sensors in connected vehicles. In the future, an expanded ITSDCAP system with an increased density of sensors and appropriate analytics could generate or utilize data for last mile freight observability for application such as Freight Signal Prioritization and Dynamic Two-Way Messaging.

2.4.2 Broward County Arterial Management Program

In 2014, FDOT District 4 broadened its Arterial Management Program (AMP) to actively monitor, manage and improve arterial operations along major corridors in Broward County. This program has been executed in collaboration with Broward County Traffic Engineering Division (BCTED).

District 4 has constructed a network of ITS devices and fiber optic communications to support the AMP and collect data in real time. The devices include Closed Circuit Television (CCTV) cameras, Arterial Dynamic Message Signs (ADMS), Microwave Vehicle Detection Systems (MVDS), Bluetooth Traffic Origin and Destination (BlueTOAD) detection devices, and Permanent Traffic Management Systems (PTMS) detection devices, as well as in-pavement sensors and 24/7 continuously operating traffic counters that are capable of classifying vehicles by number of axles into FHWA's standard 13-category scheme at various locations (equipment examples shown below in Figure 2-8). AMP servers and workstations provide for storage as well as data access and program operations.

Figure 2-8. Inroad detectors (left) and MVDS and BlueTOAD sensors mounted on ADMS pole (right)

Source: CPCS

The AMP collects real-time data in the following corridors: Oakland Park Boulevard, Sunrise Boulevard, Broward Boulevard, University Drive, US-441, US-1, Griffin Road, Pines / Hollywood Boulevard, Pembroke Road, and Hallandale Beach Boulevard. The data also enable vehicle classification in these corridors and estimating Travel Time Index (TTI) in the region. However, the AMP does not yet operate at the level of detail necessary to produce data at a resolution that supports true last mile freight observability, because the necessary infrastructure and analytics are in the early stages of deployment.

2.5 Implications of FDOT efforts for solutions to last mile freight observability

FDOT has made concerted efforts both in its ITS program and its AMP program to improve data collection and performance measurement. However, these efforts must scale to a density and footprint that is large enough to provide data at a resolution that is meaningful enough for tackling the last mile issues we have highlighted. FDOT will continue to make advances in the area of technology deployment over the coming years, which will eventually enable the high-resolution data and analytics needed to address last mile issues.

Given FDOT's long-range plans for ITS technology deployment and eventual infrastructure buildout, we focused this research on more immediate and practical non-infrastructure solutions to enhancing last mile freight observability for planning and investment decision-making. Detailed discussions with FDOT Central Office, and District 4 freight and TSM&O staff narrowed the focus and scope of the later stages of this research to the Freight Fluidity opportunity area, for the following reasons:

- Freight continues to be an important component of the economy in Florida's urban and metropolitan regions, as evidenced by the freight-intensive activity clusters in many parts of the state (see Appendix A for example maps). Relating freight fluidity to economic impact indicators (i.e. Bottleneck Analysis impacts and value of freight travel time) is, therefore, a priority.

- Freight fluidity applications can inform not only planning (for ex. by informing freight project selection) but also help inform TSM&O approaches by identifying specific areas and zones where freight-related operations could be streamlined. A deeper understanding of tours and truck paths (i.e. Last Mile Flow Maps) can help.

→ Florida DOT and District 4, in particular, have either already deployed some technologies that can eventually support real-time arterial management or are actively exploring and piloting such technologies for the long-run. A strategic focus on freight fluidity will complement FDOT's ongoing efforts to eventually address real-time freight operations issues.

The next chapters introduce the concept of Freight Fluidity and its relevant promising applications. A detailed discussion of Real-Time Corridors, i.e. the possibilities for improving last mile observability in real time, are in Appendix D.

3 Freight Fluidity: Concept and Applications

Key Chapter Takeaway

This section covers the concept of Freight Fluidity as a category of applications to understand last mile freight behavior over time. Recommended approaches to understanding and using fluidity analysis are provided in the following chapters.

3.1 Understanding the last mile Freight Value Chain

The freight value chain includes a set of agreements and decisions that govern how, why, and where freight is moving. By understanding the impact of frictions on Florida's private sector freight value chain, FDOT can accomplish two main objectives: support private sector freight efficiency, and manage overall transportation system performance.

3.1.1 Private and public implications of last mile freight "frictions"

Entities in the private sector freight value chain are primarily motivated by the objective of reducing Total Logistics Costs (TLC). Transportation of goods by truck is often a major component of TLC, and delays due to congestion are a costly friction to the private sector.

A **freight value chain** is the firms who are involved in the supply chain processes to deliver goods from the point of production or origin of those goods ("origin") to the point of use or destination ("destination"). These firms are often sequentially linked together by one or more business transactions, forming a "value chain".

Trucks change how they pick up and deliver goods to account for the inherent variability of trip times or recurring congestion (bottlenecks) impacts. This friction increases the operating costs of trucking (fuel, wages, and equipment-related costs). Further, firms and service providers place a premium on the predictability of transportation to support their own planning and operations. These premiums are often reflected in the transportation cost component in the form of penalties for delays or service disruptions.

While congestion is a significant issue in Florida – Florida topped ATRI's list of top ten states by congestion cost in 2016 – much of this congestion is concentrated in Miami-Dade and Broward counties. However, ATRI also estimated that the cost of congestion in Broward County alone is over $400 million per year, enough to place 5th in the list of top ten most congested counties in the US (American Transportation Research Institute, 2016).

> **Total Logistics Cost (TLC)** is an umbrella term for a wide range of supply chain-related costs that are eventually included in the "all in" price of a good or service. Transport and warehousing costs are two major elements, but TLC also includes inventory carrying, administration and order processing costs.

By many accounts, route planning is one of, if not the most commonly employed responses to inconsistent travel time. To improve route efficiency, trucking companies plan for the most predictable and cost effective routes (subject to some constraints like truck route restrictions) to minimize TLC. Increasing variability in travel time or the risk of trip disruptions on those routes has the potential to increase TLC, and drivers may resort to undesirable and unsafe behavior such as violating route restrictions, parking illegally, or driving at times and in a manner that increases noise and environmental pollution. In addition to increasing the private costs of freight, route-related issues and travel time variability can thus result in negative externalities for communities.

Trucking companies, carriers, and other logistics providers across a wide range of industries cite truck route-related issues as the most significant factor in travel time variability.

FDOT's freight decision-makers can work to minimize frictions that reduce private freight efficiency and impose costs on communities by making targeted investments over time. To do so, however, they must understand the effect of frictions such as variability of travel times on principal truck routes, bottlenecks locations, and relate these to sector-specific impacts – cost of congestion to manufacturing in District 4, for example. Data on local freight movements are needed to accomplish these goals.

3.1.2 Absence of Public Data on Local Freight Movements

While there are many ways to estimate how and when trucks move at the local level using travel demand models, FDOT does not currently have a detailed empirical understanding (i.e. ground observations) of actual truck movements across the complete local highway and road system. This is true of most public transportation agencies. As a result, agencies are often blind to how carriers and 3PLs are making scheduling, routing, or other behavioral decisions. The blind spot exists because:

→ **Data are costly to acquire**: Truck observation and classification studies ("counts") have historically been conducted manually and are expensive, making them infrequent and sparse, i.e. limited to the most important sites in a local network. Depending on the study approach, truck movement direction may not be available. Alternatives such as sensor-based observations using Telemetered or Portable Traffic Monitoring Sites (TTMS or PTMS) require sensor assets to be deployed at a sufficiently high density and at strategic locations in the network.

- **Data are incomplete or inaccurate**: Solutions that enable continuous truck data collection have typically been intrusive, i.e. sensors are embedded into the road or roadside infrastructure and data collection are hampered by obstructions, wear and tear weather, or other interference. These physical sensing approaches are inference-based; physical phenomena such as light, pressure, or acoustic waves are transformed into electrical signals, and calculations performed to discern trucks from other vehicles, which are typically best guesses. Inaccuracies and errors such as false positives can creep in.

- **Data are private or commercially sensitive**: Owners and operators of private fleets do not have strong incentives to share their telematics or fleet performance data with agencies. In fact, firms take precautions to safeguard any data of a proprietary nature for competitive reasons and are reluctant to disclose the specifics of their decision-making to agencies.

The private freight value chain does not suffer from this blind spot, because of its strong and immediate incentive to minimize Total Logistics Cost (TLC), for which fleet operators invest in and collect detailed fleet tracking and performance data. Nonetheless, private fleets look to the public sector freight planners to reduce the number of frictions that create inefficiencies in their operations. Freight fluidity as a concept and set of applications can assist District 4 in minimizing last mile frictions.

3.2 Freight Fluidity Concept and Applications

3.2.1 Definition

Freight Fluidity is a broad concept and set of approaches that addresses the efficiency with which goods move from one end of the supply chain to the other. Freight Fluidity performance measures identify where bottlenecks or inefficiencies occur, and the interrelationship with other modes. These performance measures also connect the discussions of transportation and economic development. Freight Fluidity, therefore, has spatial (where) and modal (how) analytical components, as well economic, environmental, and social impact components (Transportation Research Board, 2014).

More formally, Freight Fluidity may be defined as follows (Eisele et al., 2016):

Freight Fluidity is a broad term referring to the characteristics of multi-modal supply chains and associated freight networks in a geographic area of interest, where any number of specific modal data elements and performance measures are used to describe the performance (including costs and resiliency) and quantity of freight moved (including commodity value) to inform decision-making.

Some aspects to consider when analyzing freight fluidity include (Transportation Research Board, 2016) whether the analyses are:

- **Comparable**: can the measures be used to compare fluidity or performance across space, time, and modes?

- **Scalable**: can the approach scale from last-mile levels of resolution to corridor level or the supply chain as a whole?

- **Repeatable**: can the analysis be replicated using the same data, or updated data in the future?

The rest of this report and our findings and recommendations focus on truck Freight Fluidity applications at the last mile as relevant to Florida DOT Districts and MPOs. Also, the specialized applications and solution architecture are designed to be repeatable and comparable at the last mile level.

3.2.2 High-Value Applications for FDOT

We have defined last mile observability as the detailed knowledge of where, when, and why trucks are moving in the last mile, and related factors and impacts. The Freight Fluidity opportunity area involves three applications that can address FDOT's need for last mile observability for planning over time:

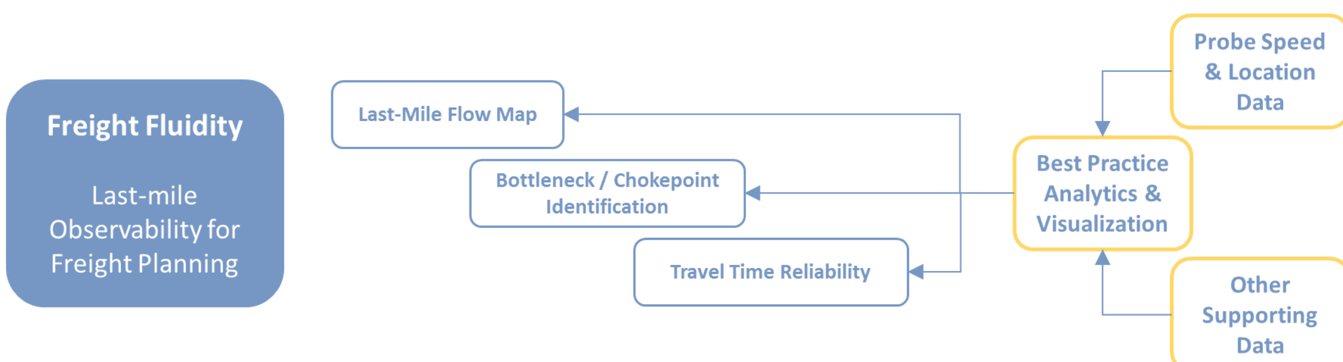
- **Last Mile Flow Maps** - mapping truck flows in detail to understand chosen routes

- **Bottlenecks Analysis** - identifying bottlenecks and chokepoints and estimating their impacts

- **Travel Time Reliability** - assessing the value of travel time in freight-intensive sectors

FDOT already collects and maintains a variety of data needed to develop these applications. These include traffic counts, road network and asset data, and freight facility databases. FDOT has typically pre-processed, standardized, and published these data in easily implementable formats such as GIS shapefiles. The overall approach to using various existing and new data sources for this set of applications is shown in Figure 3-1.

Figure 3-1. Promising applications and data sources identified in the Freight Fluidity opportunity area



Source: CPCS analysis

FDOT should continue to use its best practice of **data fusion** – systematically integrating data from different sources – across these data sets to inform the three Freight Fluidity applications. Nevertheless, FDOT does currently face gaps in its datasets for truck observability. The main gaps are the lack of precise truck location, speed, and route information at a resolution that is detailed enough to support performance estimation on the last mile network.

Our recommendations in the rest of this report focus on the data needed to address the gaps, and the corresponding approaches to tool modification to fully implement the Freight Fluidity applications. We focus on the following key questions for each application:

→ What are the detailed modifications to the existing support tools or new approaches that will allow for more accurate planning for the last mile of freight?

- How can the agency integrate strategies, methodologies, and solutions identified into existing decision support tools?
- What data and information are required for the proposed strategies, methodologies and solutions?
- How should the agency interpret and analyze outputs?

Each of the three specialized applications listed above is covered in detail in the following chapters.

4 Last Mile Flow Maps

Key Chapter Takeaway

Last Mile Flow Maps can be developed by using GPS waypoint data to study how trucks use the last mile road network. FDOT would use waypoint data in conjunction with its existing TTMS / PTMS traffic counts, and enhanced RCI network maps to produce visualizations of last mile truck flows.

4.1 Objective

A Last Mile Flow Map provides a high-resolution spatial understanding of truck flows over a network of interest. The network of interest for this project in District 4, for example, is composed of the principal and minor arteries, collectors, and other local roads that trucks use to travel to and from the mainline transportation links (interstates and major highways) and freight facilities (warehouses, distribution centers, ports, airports, intermodal terminals). A Last Mile Flow Map can also shed light on the prevalence of economic activity in different parts of the network of interest, as truck traffic is an indicator of commerce.

A detailed understanding of how trucks traverse the last mile can inform freight investment priorities by identifying which assets trucks use the most and where trucks experience performance challenges.

4.1.1 Relevant Indicators and Performance Measures

Last Mile Flow Maps help planners trace truck flows through or over the last mile network of roads. Such a Flow Map can be designed to assess a variety of performance measures:

- Truck volume and density, as a share of overall traffic
- Truck volume and density, by time of day (day parts)
- Typical Origins-Destinations and choices of road links
- Convergence and Dissipation of trucks across the network
- Directional variations on the above

At minimum, four pieces of information are needed to develop the flow map-related performance measures above. The first three are related to trucks and truck trips or tours, whereas the fourth involves the representation of the network of interest.

Truck-related:

1. Truck presence on a road, a binary variable
2. The location of the truck when its presence is detected, a geo-spatial variable
3. The truck's direction of travel, obtained from at least two adjacent observations of the same vehicle

For truck-related variables, any additional available information on truck class, weight and speed can help further refine the flow maps for specific applications. As we discuss below, FDOT already collects detailed traffic and truck count data using industry best practices. Our analysis and suggestions focus on the practical updates and integration recommendations to further refine these processes.

Network-related:

4. A digital reference network (ex. GIS shapefile) for the physical network of interest on which to pin the locations at which trucks are detected/observed

FDOT also follows robust processes to collect and maintain detailed data on road networks across the state, which are updated monthly. We only recommend the updates and steps that are necessary to accomplish the development of Last Mile Flow Maps using the existing road network data.

The inset box below discusses how FDOT currently collects and utilizes data on both traffic and road networks, to inform the discussion in the following sections.

Current Truck Traffic and Network Information at FDOT

FDOT Transportation Data and Analytics Office's Transportation Monitoring Section maintains data on the usage of the State Highway System. Typical attributes of the data include annual average daily traffic (AADT), vehicle classification (auto, 3-axle 6-wheel truck, etc.), speed, and weight. Traffic data can thus be reported based on their attributes.

Traffic information is obtained for each traffic break on the State Highway System. A traffic break is a segment of road with relatively uniform traffic characteristics. A break/segment may range from one interchange to the next on an Interstate highway, or it may include several minor intersecting roads on a smaller highway.

FDOT frequently updates and publishes these data, available online at:

http://www.fdot.gov/planning/statistics/trafficdata/default.shtm

4.2 Approaches and Data Needs

In this section, we discuss not only the general approaches and data eventually needed for Last Mile Flow Maps, but also summarize FDOT's current data and capabilities in implementing these maps.

4.2.1 Fixed-point Data Collection

Fixed-point data sources have traditionally enabled traffic data collection such as vehicle counts. "Truck counts" are studies that typically collect and analyze the information for the first three elements listed above in Section 4.1.1, and related information. **Truck counts can be divided into two broad categories: manual surveys, and sensor-based surveys** (fixed-point or location-enabled mobile sensors).

Manual surveys tend to be labor-intensive, expensive, error-prone, and inflexible in how frequently they can be conducted. Further, as sensor technologies have matured and commoditized, they are increasingly providing reliable and cost-effective options to truck-related data collection. We accordingly focus on the best practice truck count approaches identified in Task 1 of this project and build on FDOT's tried and tested approaches for our analysis and recommendations. These best practices fall into the sensor-based category of truck counts, which are essentially a subset of the data collected in traffic counts (inclusive of all vehicle types).

FDOT currently collects traffic data across the state using two types of fixed-point sensor sites: Telemetered Traffic Monitoring Sites (TTMS) and Portable Traffic Monitoring Sites (PTMS). The difference between the two is that TTMS sites can continuously collect and stream data to servers with dedicated communications equipment, whereas some equipment must be rotated among and activated at PTMS sites for occasional data collection. The fixed-point electromechanical sensors at the TTMS and PTMS are largely the same, as shown in Figure 4-1.

Figure 4-1. In-road fixed point sensors for vehicle volume, speed, weight, and weigh-in-motion data collection

Source: FDOT (2016)

Figure 4-2 shows a map of FDOT's TTMS, PTMS and Weigh-in-Motion (WIM) locations across the state. TTMS sites are concentrated along the major interstates and arterials of the State Highway System, whereas PTMS sites tend to be co-located with population along minor arterials and other local roads.

Figure 4-2. FDOT's Telemetered, Portable, and Weigh-in-Motion Traffic Monitoring Sites in Florida

Source: FDOT General Interest Highway Statistics Source Book (2016)

About 360 mostly solar-powered Telemetered Traffic Monitoring Sites collect data continuously. All of these count traffic volumes, and most also collect vehicle classification and speed data. About 33 active TTMS can also measure vehicle weights in motion (WIM). Data from a TTMS is downloaded nightly to the FDOT Transportation Data and Analytics Office's (previously Transportation Statistics Office) Transportation Monitoring Section in Tallahassee. The seasonal variations in data at the TTMS are used to apply seasonal corrections to the spot counts at the PTMS to make them representative of year-round averages (FDOT Transportation Statistics Office, 2016).

FDOT's District planning offices typically collect data at Portable Traffic Monitoring Sites using portable equipment. There are over 18,000 such sites across the state. Traffic counts are collected at each PTMS for one or two days each year. Vehicle classification data are collected at about 25% of these sites and used to estimate vehicle classification data at the remaining locations (FDOT Transportation Statistics Office, 2016).

FDOT already has a rich repository of traffic and truck data, yet the data are limited in their ability to trace, or re-identify vehicles as they move through the network.

We discuss other approaches to fill this gap below to shed light on last mile movements.

4.2.2 Location-enabled Mobile Source Data

Data sources in this category rely on communication between an in-vehicle device/transmitter and sensors/infrastructure that are located outside the vehicle to primarily convey location information. Other performance measures such as speed, direction, and route can then be imputed from a stream of messages, i.e. observations of vehicle location over time and space. Devices with Global Positioning System (GPS) capabilities, cellular signals, or devices supporting Wireless Address Matching (WAM) (such as Bluetooth) have all demonstrated value as mobile data sources and are now prevalent (see Appendix E for a summary of attributes of these sources).

The main source of value from mobile data sources in an application such as Last Mile Flow Mapping is that these sources enable the function of "re-identification" for truck traffic. In other words, re-identification is the ability to track the same vehicle as it traces a path through the network of interest. Equipment at TTMS and PTMS sites such as in-road inductive loops cannot provide this feature because there is no identity-specific information or unique digital signature captured from passing vehicles.

The advantage of mobile data sources over fixed point sensors for freight fluidity applications is the ability to re-identify trucks as they move through the road network.

One of the historical limitations of mobile data sources is the issue of sample size. Re-identification works well when the unique signature or ID of a vehicle is available and known to the observer. Historically, only about 1-2% of vehicles had devices that possessed the ability to convey unique digital signatures. However, consumer devices such as smart phones and navigation systems, and on-board computers, fleet telematics instrumentation, and wireless devices have dramatically increased the visibility of these unique signatures in the transportation system. The risk of sampling bias from location-enabled mobile sources is thus significantly mitigated.

As an example, the two maps of "pings" or truck location observations across Florida's road network in Figure 4-3 show the massive increase in the volume of available location data between 2006 and 2016. The observations are truck GPS data points generated by embedded on-board systems in combination unit trucks, i.e. trucks in a tractor-semitrailer configuration with three or more axles. Each data point typically has a unique truck ID, latitude, longitude, time/date stamp, speed, heading and other information. The map on the left shows the available readings for one hour during 2006, and the chart on the right shows the readings for the same hour on the same day of the year in 2016. The snapshot from 2016 contains 50 times more observations than the sample from 2006.

Figure 4-3. A 50x increase in observations of truck "ping" locations between 2006 and 2016

Source: data from and consultations with ATRI (2017)

FDOT currently does not rely extensively on mobile source data collection to impute traffic counts. It has however used mobile-source data from GPS and in vehicle Bluetooth devices for in pilots and feasibility studies and has already validated some aspects of their use. The inset box below discusses some of FDOT and District 4's recent experience with mobile data sources.

FDOT SHRP C20 Port Everglades Study: FDOT wanted to understand the supply and demand chain for petroleum commodities distributed from Port Everglades (PEV) to the 12 counties of southern Florida. To accomplish this, FDOT leveraged the best practice of fusing different data sources together, including truck GPS data from ATRI. The approach enables truck re-identification for trip/tour tracing, but not Origin-Destination mapping.

FDOT USF ATRI Study: FDOT wanted to understand how to leverage truck fleet data in combination with other data sources for freight modeling and planning. To do so, large streams of truck GPS data from the American Transportation Research Institute (ATRI) – corresponding to 10% of heavy truck flows in Florida -- were transformed to generate average speed and performance profiles, and detailed Origin-Destination (OD) estimates using matrix estimation techniques. Further, truck travel times were derived for more than 1,200 OD pairs in the Florida Statewide Model (FLSWM) for model calibration.

FDOT study of Bottlenecks on Florida SIS: FDOT used a combination of existing volume (traffic count) data along with speed data from INRIX across the SIS for approximately one year spanning 2010-2011 to identify bottleneck characteristics. The data corresponding to the SIS for 5-minute intervals over this time horizon comprised 293 million records.

Statewide Vehicle Bluetooth Data Collection: FDOT wanted to develop and test the feasibility of deploying a statewide truck monitoring network across Florida with a focus on freight activity between Florida's seaports, regions and across the State line. Using data from Bluetooth sensors, the project analyzed a data set of more than 25 million records reflecting the movements of almost four million unique vehicles detected at multiple locations (re-identification) around the state.

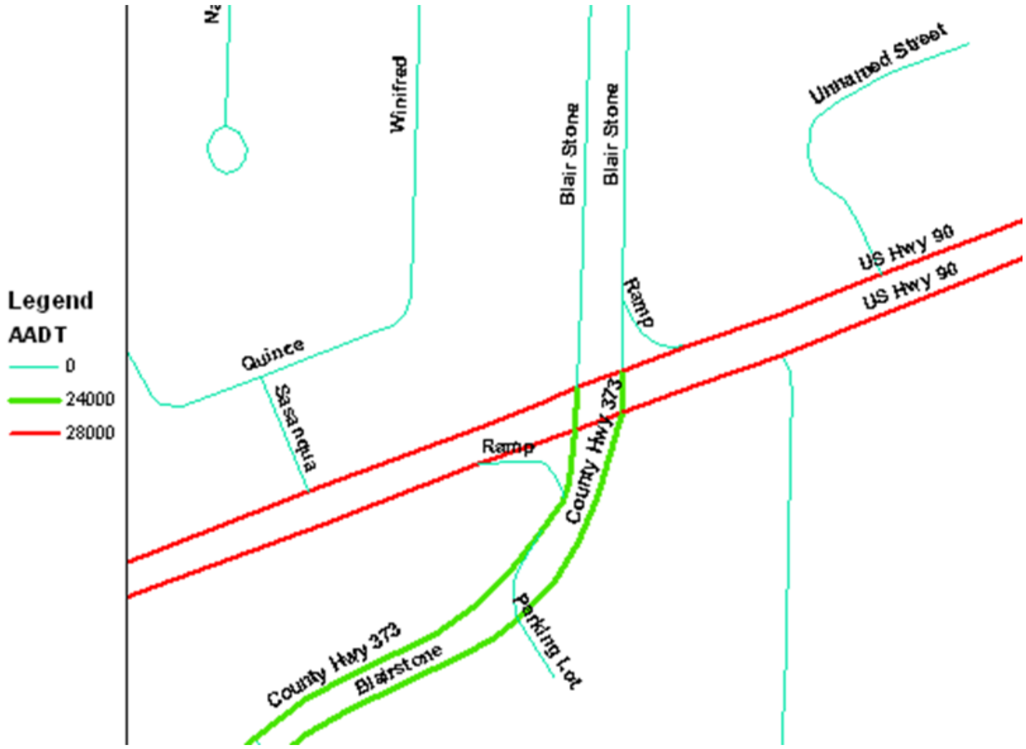
4.2.3 Supporting Information on Road Network

Once data on truck locations and movements have been obtained, the ability to geolocate observations, i.e. pin these data to a realistic and representative map of the actual road network, becomes important. As the road network evolves incrementally over time, maps and digital representations must also be continuously updated for accurate geolocation. These procedures are routinely executed in using GIS frameworks and tools.

FDOT has systematic processes and guidance in place for obtaining and updating roadway network data and maps. FDOT currently uses:

- HERE (previously Navteq) transportation network and points of interest data for base layers,
- To improve reporting accuracy, the base layers above updated with its own Linear Referencing System (LRS), a measurement system used to locate events along a linear feature like a road or a stream
- Roadway Characteristics Inventory (RCI), a database and query system containing the detail to be visualized in the Linear Referencing System (bi-directional observations, roadway characteristics, asset inventory, etc.), of which traffic volumes and truck counts are one important dimension.
- Final shapefiles that can contain variants or "slices" of the information above to suit the objective of the map or visualization, or for the National Performance Management Research Dataset.

Figure 4-4. FDOT map example with LRS and RCI information



Source: FDOT All Roads initiative (accessed 2017)

The example above in Figure 4-4 shows AADT information for a sample network of interest. This representation is simplified; supporting visual detail on road footprints, other assets, and features, water bodies, political boundaries, etc. can be added in through standard GIS procedures.

Since FDOT's approach is already well-developed and robust, we only focus on geolocation compatibility issues in the recommendations and implementation section, to ensure that any new data acquired can be properly geolocated.

4.3 Recommendations and Implementation Steps

As discussed above, FDOT collects detailed traffic data and updates road network data frequently. The gap in understanding truck flows over the last mile can be resolved by supplementing FDOT's existing efforts with new mobile source data on truck movements.

Among various mobile data sources, we recommend GPS waypoint data over cellular and Bluetooth because:

- GPS 'pings' are more accurate and precise than cellular and WAM based observations, allowing for path tracing
- FDOT does not need to invest in sensors or related assets, as vendors already collect these data

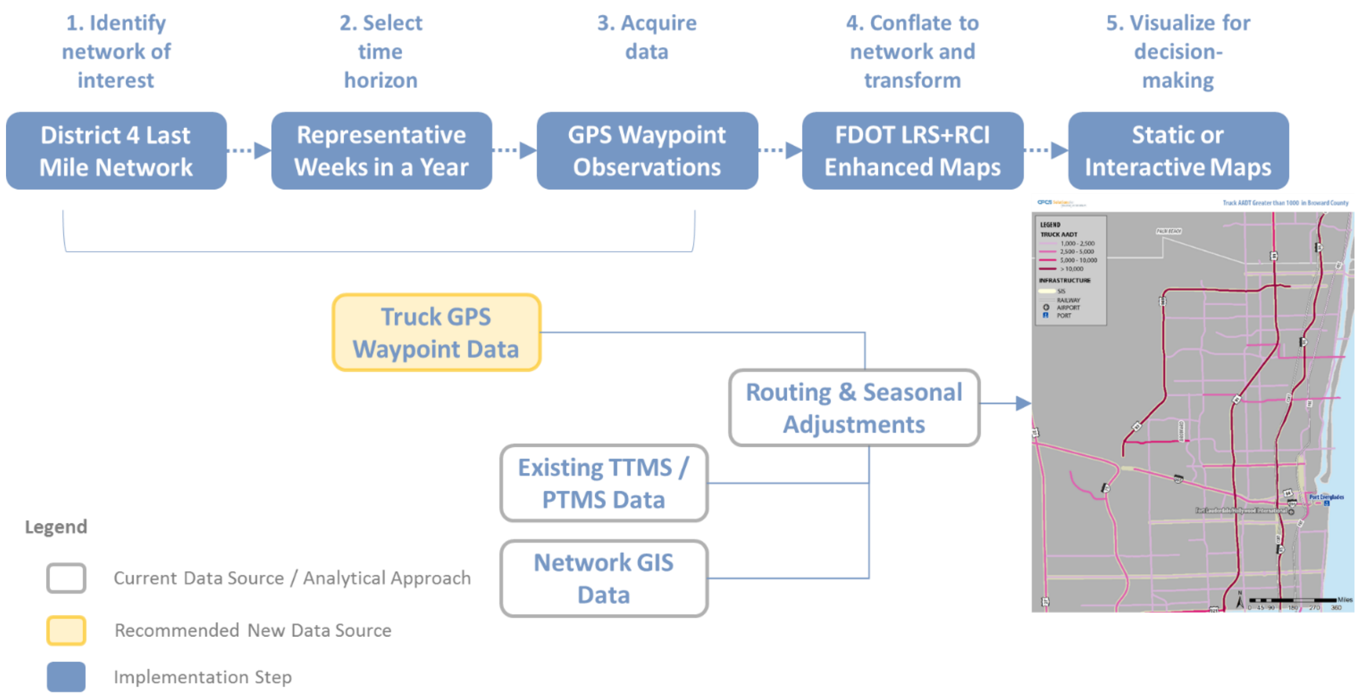
- The landscape of vendors who are proficient at collecting and readying data for analysis is competitive and suggests decreasing data acquisition costs (to FDOT) over time

- GPS data can be transformed in ways complementary to other freight fluidity applications, minimizing the need for new sources and the types of procedures required.

Recommendation 1: Use GPS waypoint data in conjunction with current data repositories to develop a finer-grained understanding of how trucks traverse the last mile network

Five implementation steps can help FDOT, and specifically, District 4, update existing procedures to develop Last Mile Flow Maps. These are summarized in Figure 4-5.

Figure 4-5. Implementation steps for updating existing procedures for Last Mile Flow Maps



Source: CPCS

1. **Identify network of interest**: The first step is to geofence the roads of interest, i.e. spatially restrict the particular breaks (segments) or links in a study area. This helps focus the analysis (and eventual map) on the relevant jurisdiction. Some options for District 4 include:

→ District 4 in its entirety

→ County-level networks, ex. Broward, Palm Beach etc.

→ Road classes across District 4, ex. SIS freeways and signalized arterials, certain ramps, connectors

→ All links emanating from an origin or destination of interest, ex. Port Everglades

2. **Select time horizon and resolution**: Since FDOT already collects detailed traffic data for annual averaging, the additional GPS data sought must be sufficient to introduce the seasonal, day-part, or hourly variation that planners may desire to develop nuanced profiles for network usage. We recommend the following:

→ Seasonal: two "representative" weeks in each quarter of the year for a total of eight weeks

→ Intra-day: no restrictions or averaging, i.e. obtain all truck waypoint observations for chosen weeks

These data can be later analyzed and correlated with existing traffic data to develop hourly / daily / seasonal patterns of truck flows over the network of interest.

3. **Choose vendor and acquire data**: Many commercial vendors have now begun to offer GPS data, either for individual studies or as a subscription service. We consulted a number of well-established vendors to understand their capabilities and offerings. All of the vendors are essentially data aggregators in that they purchase data from participating truck fleets and telematics providers. Table 4-1 summarizes our findings in the form of a competitive analysis.

Table 4-1. Competitive Analysis of GPS Data Vendors

Vendor / Attribute	ATRI	HERE	INRIX
Waypoints	√		√
Spot speeds	√	√	√
Medium-duty trucks			√
Heavy –duty trucks	√		√
Fleet penetration rate	10%	3%	10%

Source: CPCS

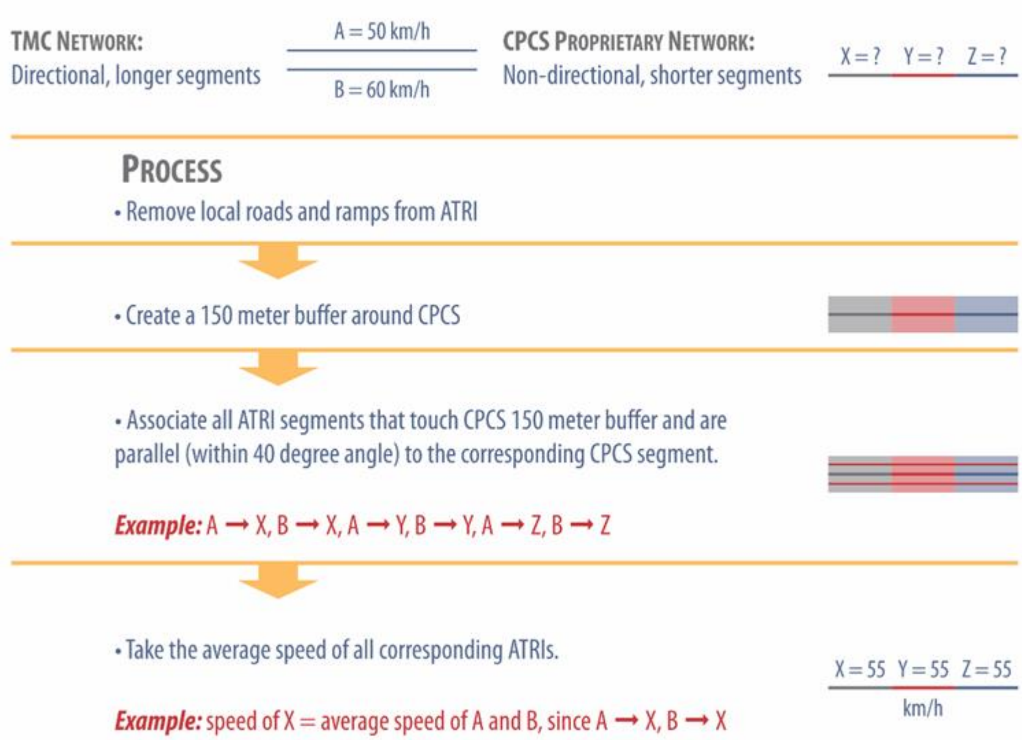
Options vary by vendor. Notably, some vendors have developed the ability to distinguish between medium and heavy-duty trucks. The truck type is assigned to the whole fleet of a data provider based on "fleet preponderance" in which the truck type comprising the majority share of the fleet (e.g. >50%) is the truck type representing the entire fleet.

Our experience working with a number of these vendors suggests that a preliminary price estimate for the recommended eight representative weeks is $25,000 - $30,000 (per year) for one-time use for a geography spanning District 4. For frequent updates and use, a subscription agreement (obtain 8 weeks every year) could reduce the estimate. Pricing is often dependent on the area, mileage, population in the catchment area of the network of interest, and the frequency of new data downloads.

4. **Conflate to network and transform**: Vendors typically provide data in GIS shapefiles with their own version of the road segment and feature IDs. Conflation is the process of joining the information from two files denoting the network while eliminating errors and minimizing redundant information. For example, District 4 could obtain already mapped waypoint data, and conflate it to FDOT's LRS enhanced network with RCI information.

Alternatively, if minimally processed waypoint data are obtained, FDOT's GIS analysts could build these observations into the FDOT shapefiles through link analysis and associated transformations. The schematic shown in Figure 4-6 depicts the conflation process for a road segment across different GIS representations (conflation to a non-directional network, because bidirectional networks are often not available for the region of interest). Once the network (shapefiles) are prepared, analysts can query and generate variants of the network as needed.

Figure 4-6. Conflation process to the CPCS network, using the ATRI network as an example



Source: CPCS

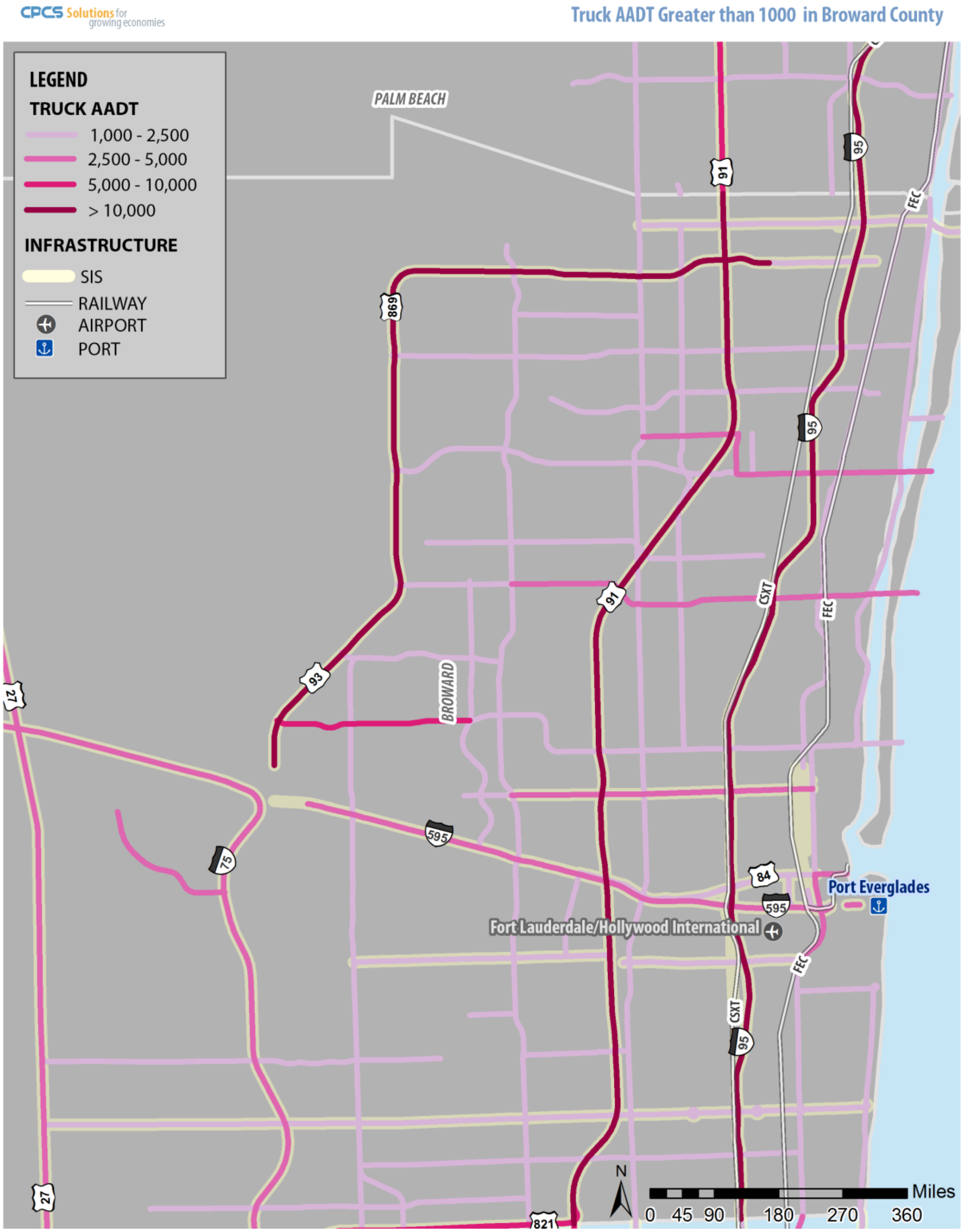
5. **Visualize and map**: The final step is to visualize the resulting data and generate flow maps. The following series of figures shows some examples, based on current FDOT data.

One approach is to limit the information in the visualization to roads that experience a certain threshold of truck activity. Figure 4-7 shows a flow map of Broward County and highlights roads with Truck Annual Average Daily Traffic of more than 1,000.

Another approach is to visualize specific road classes, such as major or minor roads, and the full extent of AADT information on the selected network of interest. Figure 4-8 and Figure 4-9 are map examples of major and minor roads in Broward County.

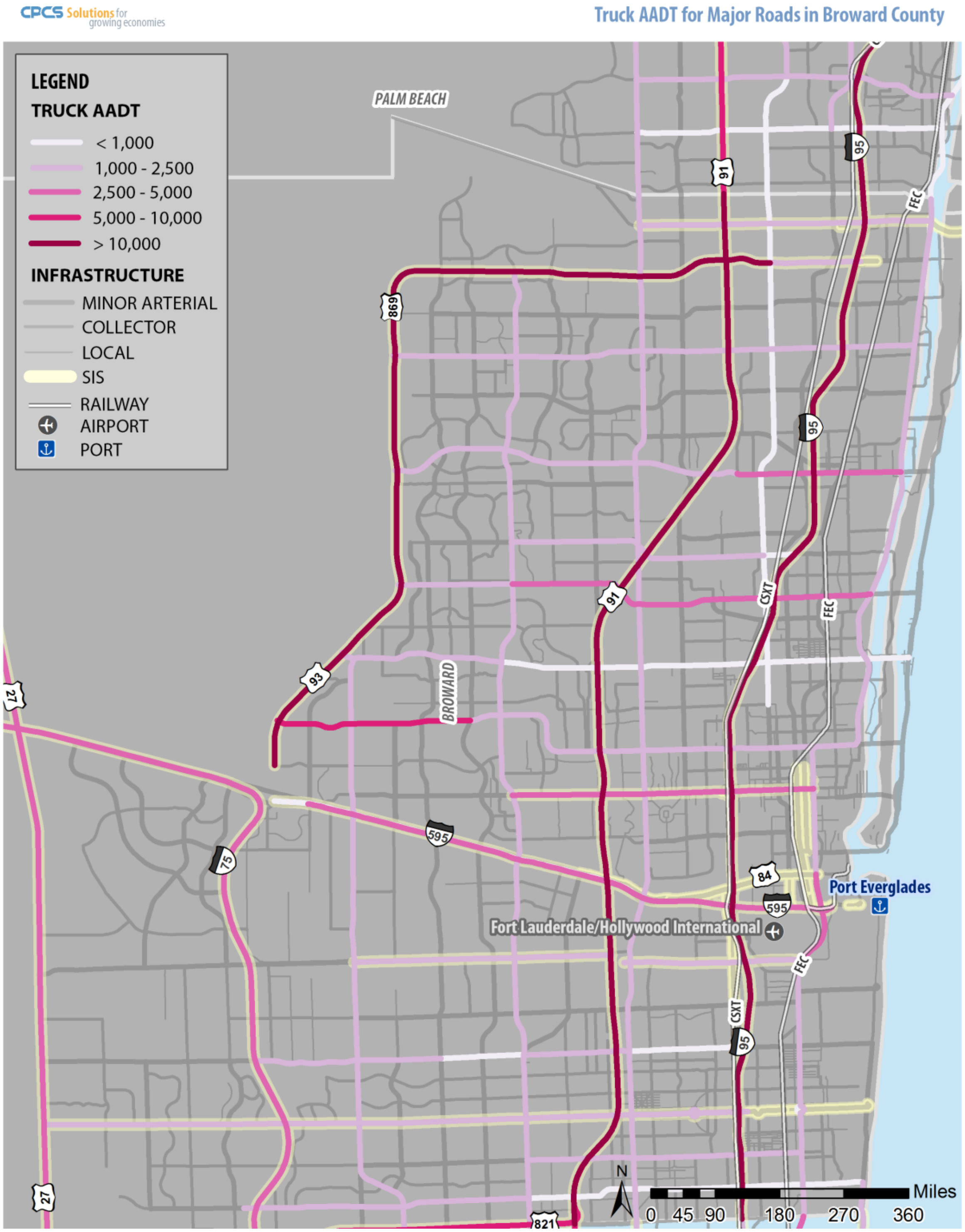
Updated data on flows and volumes will help show a finer degree of variation across these road types, as described in the implementation process for this application. These data can be displayed using web-enabled interactive dashboards to slice/filter and transform either flow-related or network-related information.

Figure 4-7. Flow map of Broward County with Truck AADT greater than 1,000



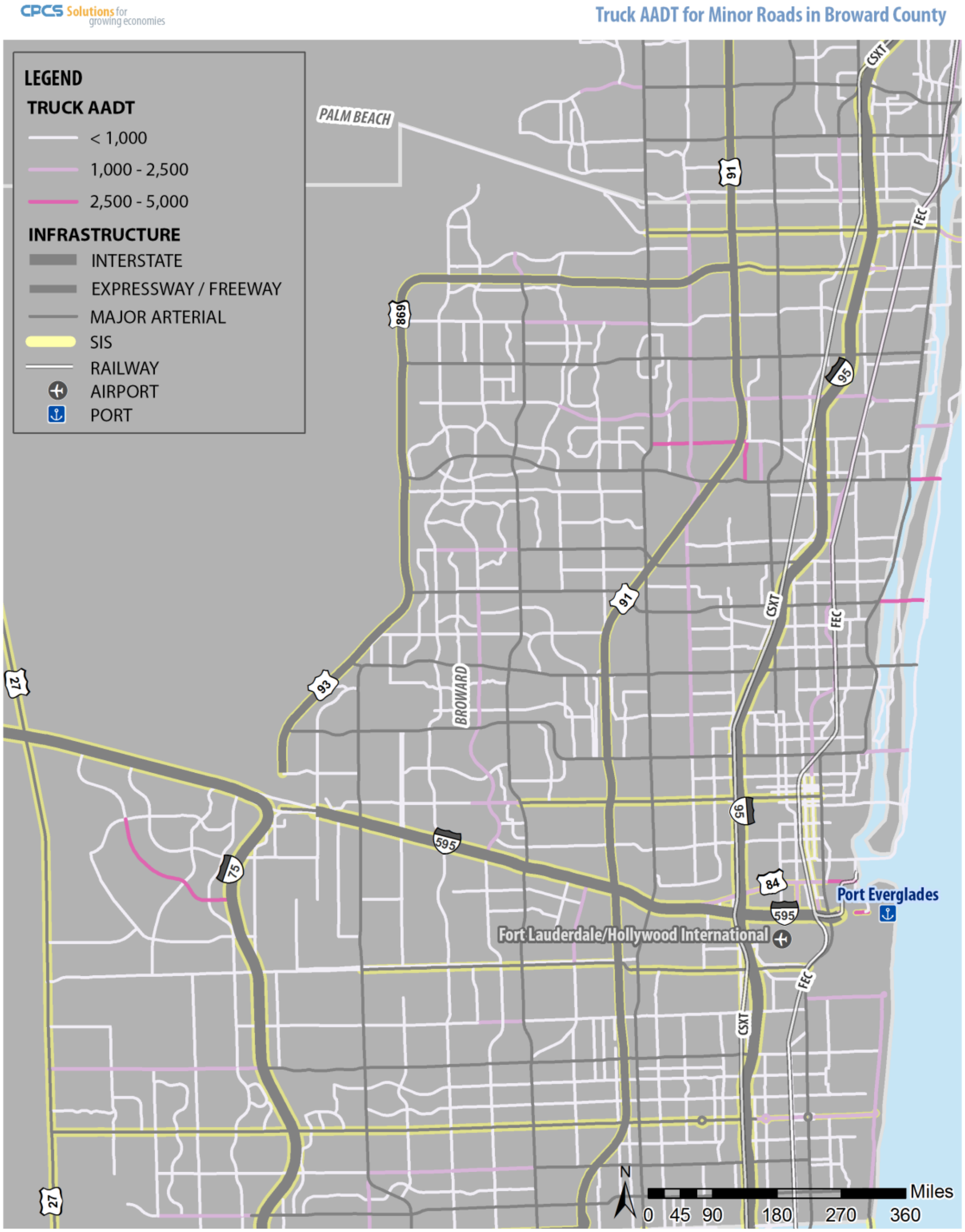
Source: CPCS

Figure 4-8. Flow map of Broward County by road class – Major Roads



Source: CPCS

Figure 4-9. Flow map of Broward County by road class – Minor Roads



Source: CPCS

5 Last Mile Bottlenecks

Key Chapter Takeaway

Bottlenecks analyses pinpoint the precise location and impact of truck congestion in the last mile network. GPS spot speed data, updated last mile truck volume information, and road network GIS data are integrated to identify and rank bottlenecks in terms of the severity of congestion impacts.

5.1 Objective

Bottlenecks are severe traffic chokepoints where demand for roadway use far exceeds available road capacity resulting in congestion. Congestion often implies "delays", in that it takes longer for vehicles to go from Point A to B. The economic consequences of bottleneck congestion are lost time and productivity. Other societal impacts include emissions, fuel use, noise and similar externalities in excess of those associated with efficient use of road infrastructure.

We define bottlenecks as stretches of road that are routinely and consistently congested. The delays in these stretches are generally more than just a peak-period or rush hour problem. A large number of vehicles passing through bottlenecks experience severe delays, over the 24-hour course of a weekday.

Even though bottlenecks are commonly associated with gridlocked conditions, there are many stretches of highway where even minor delays of a few minutes per vehicle add up across the many vehicles traveling those stretches. For example, in its 2014 Cost of Congestion report, the American Transportation Research Institute (ATRI) determined that 89% of truck-related congestion costs were associated with only 12% of the road miles, and ATRI's later studies continue to point to this disproportionate impact. Most of the negative impact from congestion can often be narrowed down to a handful of problematic locations on the network.

The objective of last mile Bottlenecks Analysis as a freight fluidity application is to identify the locations and impact of recurring bottlenecks causing congestion on the last mile network of interest.

Precise locations of recurring last mile bottlenecks provide a starter list of sites for further causal analysis and eventual project programming.

While most bottleneck studies address overall congestion broadly at a regional level, the approach discussed here focuses on identifying the small handful of bottlenecks that, when addressed, will provide most of the available benefit.

NOTE: we do not address other causes of delays such as circuitous routing due to policies, one-off road closures, or other such incidents under the last mile bottlenecks application.

5.1.1 Relevant Performance Measures

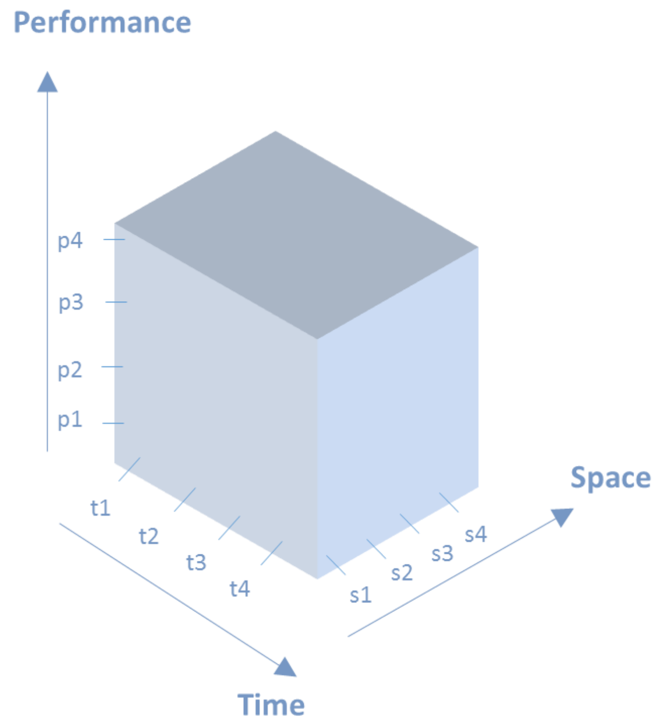
Bottleneck studies typically reveal the following performance metrics about specific stretches of road on the network of interest at different times (Federal Highway Administration, 2015).

- Lost time, i.e. minutes or hours of delay
- Value of lost time, in dollars
- Excess fuel use, and cost of that fuel
- Externalities such as CO2 emissions and other pollutants

Each of the measures above can be normalized or aggregated up by distance and volume (ex. total delay, delay per vehicle per unit distance). Of these, estimates of lost time are the most objective, since they are based on physical principles (first-order performance measures) whereas the others typically require assumptions and subjective judgments to transform time-related performance (second-order measures). How to ascribe economic value to time lost in congestion involves judgment, for example, either from the person making the trip choice or from the planner.

The best practice framework for describing and visualizing congestion and related road performance is the so-called 'cube' because three dimensions of information are usually presented. Figure 5-1 shows a general cube model. The first dimension is geography, or the specific road segments being studied. The second dimension is time, in hours, days, weeks, or any other intervals or horizon than is useful for decision-making. The third and final dimension is the performance dimension, and performance measures are typically selected from the list included above.

Figure 5-1. The 'cube' framewwork for visualizing the impact of congestion / bottlenecks



Source: CPCS

In going from general congestion analysis to bottleneck analysis, however, the best practice is typically to compress the time-dimension to identify and rank the bottlenecks with most severe impact over time. In the next section, we discuss how the corresponding measures might be estimated or calculated to populate a cube-type or compressed visualization.

5.2 Approaches and Data Needs

The matrix shown below in **Error! Reference source not found.** summarizes the types of approaches used for Bottlenecks Analysis. Along the vertical is the Analytical Approach (whether modeled or empirical) and on the horizontal is the Focus (whether on a truck trip or a unique segment).

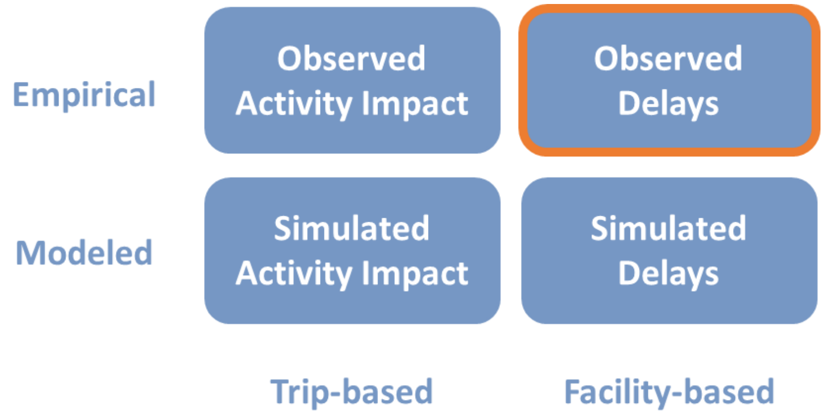
5.2.1 Model-based Approaches

Model-based analyses have historically been the more common analytical approach for the network-wide identification and classification of bottlenecks.

Trip-based models: In many cases, analysts simulate the demand for trips using activity-based models (i.e. freight trip generation, four-step models) and assign those trips to feasible routes. Bottlenecks are created when the demand for trips on a particular route becomes constrained by available capacity, resulting in congestion.

Facility-based models: Another type of model-based analysis is the simulation of traffic flows (using stochastic techniques, or agent-based models) across particular roadway links, without

Figure 5-2. A matrix of approaches for bottleneck analysis and identification



Source: CPCS

regard to the nature or purpose of trips. Traffic flows are not typically linked to the factors generating those flows. Simulated delays are once again generated by capacity constraints limiting the predicted flows and possible queuing.

An advantage of model-based bottleneck analyses is that once the models (trip-based or simulation) are set up and functioning, they can be run repeatedly in a variety of ways using different parametric scenarios to study the possibilities of where congestion might occur on the system. However, the cost to develop models (time, expertise, computational power) represents a significant upfront investment. Further, models can be inflexible in how easily they can accommodate structural changes, i.e. updates for network representations, policy changes, or market dynamics to represent realistic flows on the system (Transportation Research Board, 2016).

The amount and quality of data and observations needed to calibrate these models can impose significant additional data collection and survey costs. When detailed data collection is less feasible or unaffordable, modelers typically resort to heuristics. One such heuristic is to begin with a hypothesis that identifies an interchange as a possible location of congestion (based on driver experience) and model flows within a two- to three- mile radius of the location to estimate possible congestion using assumptions about historical flows. Model-based heuristic approaches often result in discrepancies between where congestion is predicted to occur, and where it actually occurs on the system. Empirical approaches using observations of traffic flows are therefore considered superior.

Model-based approaches remain useful for forecasting trips on a network, by studying the underlying demand factors.

Models remain useful for forecasting but have rapidly become obsolete for identifying bottlenecks that already exist in the road network today.

With the increasing proliferation of devices and sensors generating high-resolution data that can help analysts study traffic flows, however, empirical approaches based on traffic observations are now the best practice.

5.2.2 Empirical Approaches

Empirical approaches to studying congestion and bottlenecks tend to rely directly on data about traffic flows across the network of interest over time. These data can be collected in a variety of ways, ranging from manual counts (observers at a site of interest manually recording flows) to minute by minute observations of overall speed collected by sensors.

Trip-based observations: Manual and survey based empirical approaches can often provide a more holistic description of the congestion since data on trip purpose and other causal factors are simultaneously recorded and linked to performance variables such as wait times in queues (ex. border crossing surveys). The trade-off with these types of observations is that they are a snapshot in time, and often limited to major chokepoints that are selected in advance based on previous knowledge of conditions. Because of these scope limitations and cost, such studies are typically conducted separately from or at a later stage of congestion analysis, after initial screening analyses across the entire network have been completed.

Facility-based observations: Delay studies that evaluate observed performance across large tracts of the network (facilities) fall into this category. These types of *screening* analyses can compare the relative severity of congestion across an entire network and can help categorize, rank, and prioritize bottlenecks that deserve further study or interventions.

Screening-type bottleneck studies are becoming more common because of the increasing availability of relatively low-cost performance observations based on vehicle probe readings. In fact, the use of vehicle probe data is the current best practice for bottleneck identification and can be applied to last mile analysis. We thus focus on the considerations of this facility-based empirical approach in the rest of this discussion.

5.2.3 Data Needs for Facility-based Empirical Approaches

The three main types of data that are needed for facility-based empirical bottlenecks analyses are:

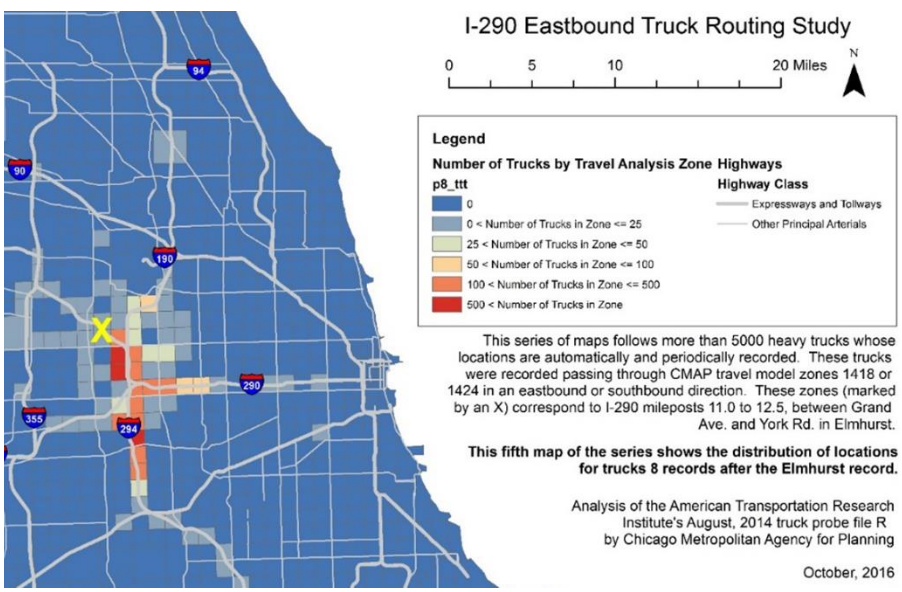
- → **Speed** data for performance calculations, typically from vehicle location-enabled probes
- → **Volume** data to convert from indexed or normalized performance to aggregated impacts
- → Last mile **network** of interest for spatial analysis of bottlenecks and eventual visualization

The three data types must be transformed and combined to identify bottlenecks, as we will discuss below. Speed and volume observations across the network of interest are both needed for ranking the impact of bottlenecks. When speed and volume data are available for the same time windows over a long time horizon (ex. multiple years), bottleneck progression analyses are also possible. In other words, such longitudinal data can show how bottlenecks change over time in their severity and impact. As discussed above, however, such data are useful for model calibration but do not directly support forecasting travel demand or congestion impacts.

To the extent that analysts want to establish causal relationships or at least correlations between congestion and other factors, the three data types above can be supplemented with data on weather, incident statistics, information on special events, etc. Such data can also be used as a precursor for programming and project planning, as an input into before-after studies. The inset box below provides an example.

The Chicago Metropolitan Agency for Planning (CMAP) used truck probe data for Bottlenecks Analysis to identify the negative impact of facility constraints on truck flows through the Chicago region. By observing truck speeds on an hourly basis over specific road links in the last mile, the analysis was able to pinpoint the interchange responsible for congestion and recommend design improvements for to alleviate the bottleneck. To accomplish this, the performance cube was compressed into 2D map visualizations of truck flows in space and time, before and after the problematic facility of interest.

Figure 5-3. Example of bottleneck analysis from the CMAP I-290 study using probe data



Source: CMAP I-290 Eastbound Truck Routing Study, 2016

An important distinction between location-enabled mobile source data used for Last Mile Flow Maps and Bottlenecks Analysis is the information that is extracted from the same raw data. For flow maps, the precise locations of vehicles are important for generating truck paths (waypoints), as discussed in Section 4.2.2. In contrast, bottleneck analyses rely on speed observations, i.e. the rate of change in probe-based location readings over time. While the raw data are the same, the desired performance observations (i.e. speed or location) dictate the types of transformations necessary.

A key component of congestion measurement is the baseline or "reference" speed to which actual speeds are compared. A driver typically compares the driving experience at slow congested speeds with Free Flow Speed (FFS), the speed that vehicles would typically drive when few vehicles are on the road. For the purposes of congestion analysis, however, we are more interested in poor roadway performance compared to the optimal level of throughput and speed. This congestion is in "excess" of optimal conditions.

The excess congestion in bottlenecks is calculated by using Maximum Throughput Speed (MTS) as the reference condition.

In this regard, using probe data for Bottlenecks Analysis provides distinct advantages over other techniques because parameters such as FFS and MTS for each road segment of interest can be directly observed from the data, and error-prone assumptions can be avoided.

5.2.4 Supporting Information on Truck Volumes and Truck Network

Accurate volume counts on a representative network are essential for aggregated performance calculations such as total delays across a road segment. As discussed in Section 4.2.3 in the previous chapter, FDOT already collects and publishes detailed volume data across different possible last mile networks of interest. These AADT counts can be further disaggregated by day parts as part of the Last Mile Flow Maps analysis, which could also provide a finer resolution for Bottlenecks Analysis.

5.3 Recommended Steps

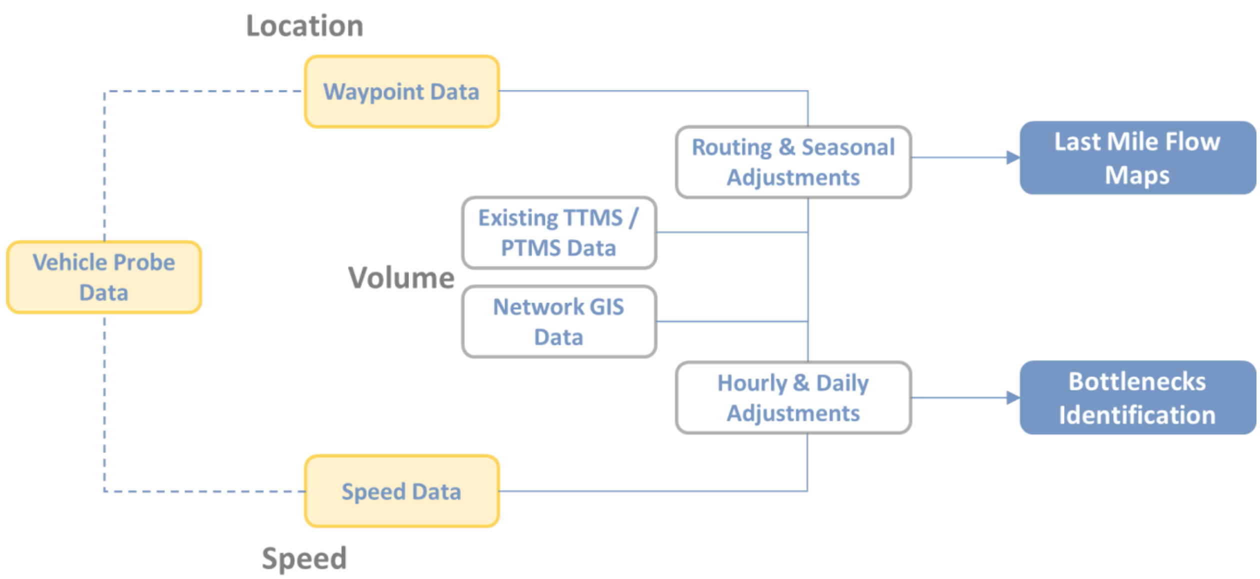
In Chapter 4, we recommended that FDOT obtain GPS waypoint data for developing Last Mile Flow Maps (Recommendation 1). The recommendation for the Bottlenecks Analysis application builds on the previous recommendation, in that FDOT should obtain and use GPS data from the same mobile sources. The important difference is that raw data must be transformed to study speed as a performance indicator, i.e. GPS spot speeds establishing the rate of change of a truck's location over time.

Recommendation 2: Use GPS spot speeds along with estimated truck volumes to identify and precisely locate truck bottlenecks.

Detailed truck volume estimates (e.g. hourly or by day-part) are an important input into the calculation of bottleneck –related impacts. One of the outputs of the Last Mile Flow Maps application is adjusted volume estimates of truck volumes on the last mile network of interest. These estimates, obtained by adjusting normalized delays in a bottleneck with the volume of trucks that experience it, can be used in conjunction with the GPS speed data to understand the specific impacts of truck bottlenecks. The Bottlenecks Analysis thus builds on the outputs of the Last Mile Flow Maps application.

Figure 5-4 below clarifies the ways in which probe data such as GPS data could be used for the two related freight fluidity applications of Last Mile Flow Maps and Bottlenecks Analysis. Both types of transformations of GPS data (waypoints and speed) supplement FDOT's existing data on TTMS / PTMS – based counts, and FDOT's frequently update GIS network datasets.

Figure 5-4. Using GPS waypoint and speed data for both Last Mile Flow Maps and Bottlenecks Analysis



Source: CPCS

The implementation steps for conducting a last mile Bottlenecks Analysis are shown in Figure 5-5. Many of the steps are similar to the implementation steps previously described for the Last Mile Flow Maps application because the logic for these last mile Freight Fluidity applications builds on the same components. The steps are as follows:

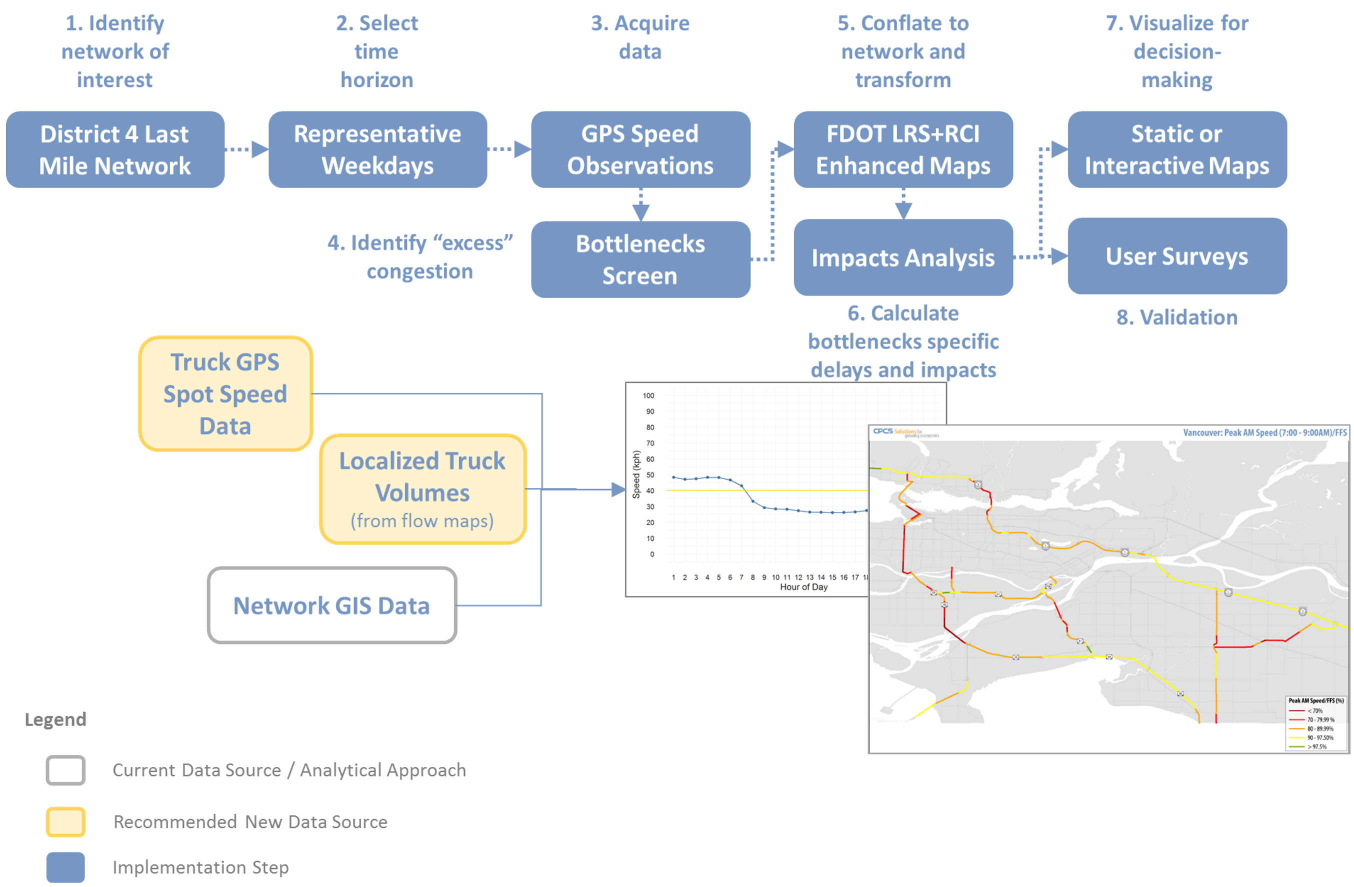
1. **Identify network of interest**: The first step is to geofence the roads of interest, i.e. spatially restrict the particular breaks (segments) or links in a study area. In contrast with Flow Maps, Bottlenecks Analysis would ideally prioritize/leave in the roads with highest truck volumes on segments and also by the strategic importance of some road classes. Some options for conducting analyses of bottlenecks for District 4 include:

- → Selected road classes across District 4, ex. SIS freeways and signalized arterials, certain ramps, connectors, etc.
- → All links emanate from an origin or destination of interest, ex. Port Everglades

2. **Select time horizon and resolution**: For developing meaningful speed profiles for the relevant road segments, a typical weekday pattern is generated from observed historical data comprised of:

- Seasonal Data: two "representative" weeks in each quarter of the year for a total of eight weeks or 40 days of speed observations
- Bins: appropriate time intervals over which speeds are either weighted or simply averaged for a typical speed in that time interval (ex. 5 minutes, 15 minutes, etc).

Figure 5-5. Implementation steps for last mile Bottlenecks Analysis



Source: CPCS

3. **Choose vendor and acquire data**: Based on the competitive analysis of vendors discussed earlier in Chapter 2, we recommend that FDOT procure spot speed data from the same vendor that it selects for waypoint data, to ensure consistency and streamline the standardization that is needed in processing and joining these data sets. The premise for this recommendation is

that FDOT will likely conduct conflation and analysis using its internal GIS experts, or obtain and provide this data to an external analyst.

Our experience working with a number of these vendors suggests that a preliminary price estimate for the recommended eight representative weeks is $25,000 - $30,000 (per year) for one-time use for a geography spanning District 4. For frequent updates and use, a subscription agreement (obtain 8 weeks every year) could reduce the estimate. Pricing is often dependent on the mileage of the road segments in the network of interest, and the frequency of new data downloads.

4. **Identify "excess" congestion**: Much of the congestion analysis required to identify bottlenecks can be performed outside the GIS environment. In fact, very large data sets (tens of millions of observations) can be quickly processed to analyze whether the observed speeds on road segments are within the expectations of typical operating speeds. In other words, road segments where bottlenecks are unlikely can be screened out. Segments with speeds that might indicate bottlenecks are retained for further analysis within a GIS environment.

5. **Conflate to network and transform**: The next step is to conflate the subset of data on segments that indicates congestion to the road network of interest. Conflation is the process of joining the information from two files denoting the network while eliminating errors and minimizing redundant information. The resulting shapefiles help accomplish two things – precise identification of the bottleneck length and extent using segment geocodes, and visualization of those bottlenecks on maps.

Once the bottlenecks network (shapefiles) is available, analysts can query and generate variants of the bottlenecks network as needed, and then estimate impacts.

6. Calculate bottleneck-specific impacts: The primary performance indicator in bottleneck analyses is 'delays', or the time lost due to excess congestion. Depending on the level of aggregation, delays per road segment can add up to minutes, hours, or even days of delay. A year is an established time horizon for aggregating impacts. Delays can then be estimated in terms of the annual impact of delays. Other performance measures include transformations of the time estimate (ex. opportunity cost of time lost in congestion in $) or related to variables such as the excess emissions due to vehicles operating in congested congestions. Table 5-1 shows an example of a ranking of bottlenecks and their estimated impacts in terms of delays, the cost of those delays, and potential fuel and emissions savings.

Table 5-1. Example of bottlenecks ranking and comparisons from a study of Canadian provinces

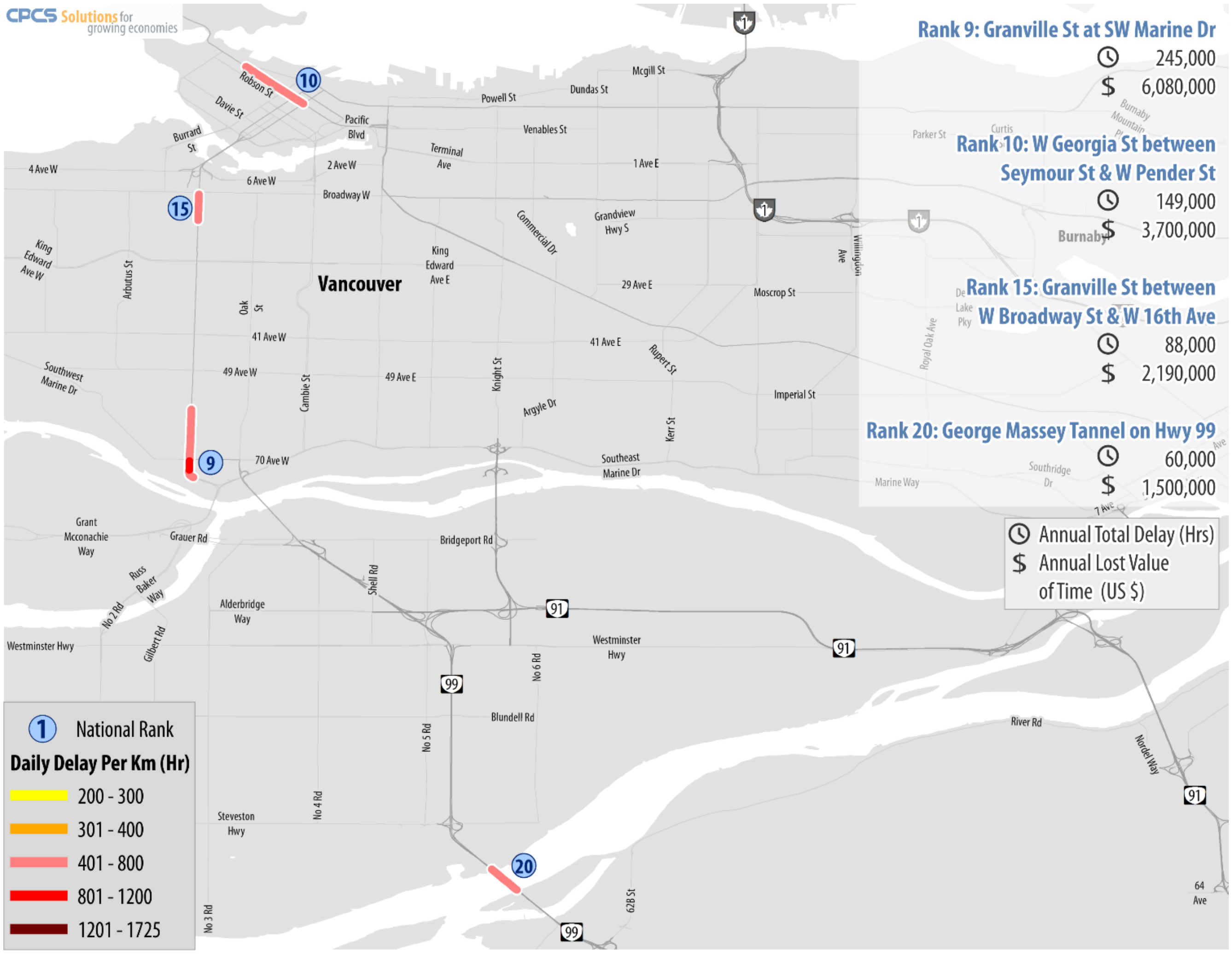
Rank	CMA	Location	Length (km)	Annual Total Delay ('0000 hours)	Annual Delay Cost (CAD millions)	Potential Annual Fuel Savings ('000 litres)	Potential Emissions Savings ('000 kg CO2)
1	Toronto	Hwy 401 between Hwy 427 & Yonge St	15.3	3,218	82.28	5,721	15,250
2	Toronto	DVP/404 between Don Mills Rd & Finch Ave	10.5	2,174	55.51	3,478	9,209
3	Montreal	Hwy 40 between Blvd Pie-IX and Hwy 520	10.6	1,956	45.60	4,197	10,901
4	Toronto	Gardiner Expy between S Kingsway & Bay St	7.4	1,076	27.51	1,671	4,447
5	Montreal	Hwy 15 between Hwy 40 & Chemin de la Côte-Saint-Luc	3.9	812	18.93	1,653	4,273

Source: CPCS

7. **Visualize for decision-making**: Once bottlenecks have been identified, they can be mapped and compared in terms of their impact statistics. Figure 5-6 shows an example of severe bottlenecks in the last mile network of Vancouver, British Columbia and how they compare in terms of time delays, and the economic opportunity cost of those delays. With these data and base maps in hand, interactive maps can be easily created to show different aspects of performance.

8. **Validation**: An important final step is to compare the locations and impacts of bottlenecks with road users who typically experience them. In this case, engaging truck drivers or fleet owners can help confirm locations of bottlenecks, assist in determining why truck bottlenecks are occurring, or provide a sense of which mitigation efforts to consider for truck bottlenecks.

Figure 5-6. Last-mile bottleneck map of Vancouver, BC showing most severe chokepoints on arterials and interconnectors



Source: CPCS analysis

6 Travel Time Reliability

Key Chapter Takeaway

Travel Time Reliability (TTR) analysis is an advanced freight fluidity application that builds on both Last Mile Flow Maps (volume estimation) and Bottlenecks Analysis (congestion impacts) to identify supply chain impacts as seen from a private sector point of view. TTR analysis is accomplished using a Reliability Valuation Model that uses reliability estimates as well as sector-specific parameter values.

6.1 Objective

Travel times are uncertain from any individual driver's perspective. Across the population, i.e. all drivers, travel times vary probabilistically. In other words, there is a wide range of travel times for any trip, and these times depend on the level of traffic, weather, light conditions, incidents, and driver behavior. System design and operating factors such as signal timing, lane closures, traffic management plans for events also influence the variation in travel times for the same trip in the last mile.

The Travel Time Reliability (TTR) application is about understanding the value of on-time performance for truck deliveries in the last mile in different freight-intensive sectors. District 4 can use TTR analysis to identify the most expensive links or problematic segments in last mile routes in terms of *private sector impacts*, i.e. the cost of congestion or impact of unreliability in the private supply chain. These impact estimates can be tailored to factor in industry specific parameters for a more nuanced understanding.

Travel time reliability (TTR) is the degree to which truck travel time between any given origin and destination can be predicted.

Since TTR is another approach to understanding truck flows and supply chain performance under congested conditions, this application is closely related to the two freight fluidity applications presented earlier. TTR is an advanced application in that raw data, roadway links, volumes identified in flow maps, bottleneck locations, information on freight facilities, and sector-specific value of reliability information must be integrated to study performance.

To capture variability in travel times, TTR is measured based on the probability distribution of travel times and is bounded by percentile yardsticks (NCHRP Report 824, 2016). There are many ways to define and apply these metrics, as the discussion below shows.

6.1.1 Relevant Performance Measures

There is considerable variation in approaches to defining and measuring travel time reliability; there is no standardized definition, measurement, source, or valuation of travel reliability, either for passenger or freight movement. For example, a 2013 study developed as part of the Strategic Highway Research Partnership (SHRP) Program detailed seven distinct definitions of reliability along with corresponding performance measurement (Kittleson & Associates, 2013). Similarly, a 2012 study identified 13 different definitions in wide use (Cambridge Systematics, 2012).

On-time performance is a colloquial approach to defining travel time reliability. More precisely, TTR is measured based on the probability distribution of travel times along a particular route, and during certain time windows. It is a metric that compares the different effects between the average or median conditions and extreme conditions, such as a 95th percentile estimate. In other words, this metric incorporates the effect of uncertainty in road conditions on travel time through a single quantifiable estimate. For example, TTR is worse if 5% of trips along a route are at least an hour late than if 5% of trips are at least 30 minutes late.

Reliability is usually measured using indices so that the measures are comparable at different locations and at different times. The most commonly used measures are Travel Time Index (TTI), Planning Time Index (PTI), and Buffer Time Index (BTI). Each of these is a probabilistic measure and is used in combination with the others to indicate the median, extreme, and spread of travel time respectively. The measures are defined as:

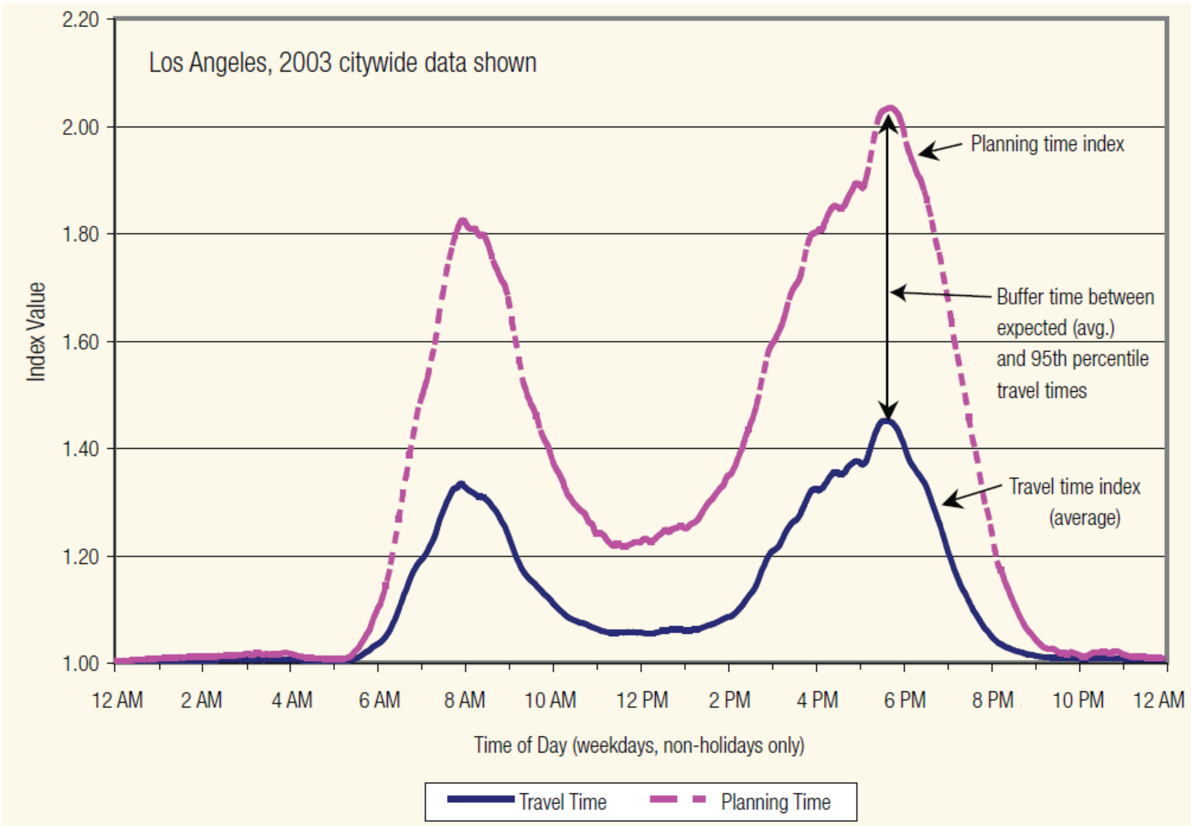
→ **Travel Time Index**: the expected duration or travel time for traveling a set of road segments. The expectation is based on either the median (50th percentile) or the simple average of all observations of the segments of interest. When measured as a ratio, the range of the TTI has a lower bound of 1.00. An index value of 1.00 for a road at a certain time of day represents ideal conditions, i.e. free flow speeds and little or no delays on average. A TTI value of 1.5 implies that it takes 50% more time on average at that time of day to travel the same road segment.

→ **Planning Time Index**: an extreme value of the travel time for traveling the same set of road segments. Typically, the 95th percentile of all travel time observations on the road segments of interest is used to discard outliers. Under ideal system conditions, the Planning Time Index is statistically the same as the Travel Time Index, i.e. close to 1.00. A PTI value of 2.00 implies that it can take up to twice as long to travel the road segment at a certain time of day.

→ **Buffer Time Index**: the ratio or buffer (difference) between the Planning Time Index observation and the Travel Time Index observation. This represents the amount of extra time that could be budgeted to ensure that estimated travel time does not exceed the statistical maximum. For example, if TTI is 20 minutes for a trip, and PTI is 45 minutes for the same trip, the BTI is 25 minutes or a ratio of 2.25.

Figure 6-1 illustrates these index values for the city of Los Angeles taken as a whole across the 24 hours of a representative weekday.

Figure 6-1 Travel, Planning, and Buffer Time Indices shown for Los Angeles



Source: FHWA

Freight carriers are typically most interested in the Buffer Time value, i.e. the spread between the median (or average) travel time (given by the Travel Time Index), and the worst case given by the Planning Time Index) for a particular route and time of day. The use of Buffer Time for route planning and delivery schedules affects their operating costs, which cascades through the freight value chain. However, only the most recent studies have started to consider high-resolution freight specific analyses of travel time that can reveal this value for public sector planning purposes. Further, the latest findings recommend a sector-specific approach to understand the differential impacts on freight-intensive sectors. Our recommended approach accounts for both the issues of travel time measurement and sector-specific valuation.

6.2 Approaches and Data Needs

The best practice for Travel Time Reliability analysis is to use a Reliability Valuation Model (RVM). A RVM calculates truck trip economic costs of travel time uncertainty for different levels of trip time variability within a given truck freight corridor. These per truck trip costs can then be applied to or aggregated for total truck flow volumes in a freight corridor. Costs of (un)reliability in a corridor can then be reported daily, annually, or to suit any other time horizon for decision-making.

The basic logic of reliability valuation is to model trip cost first with TTI and then with BTI, to reveal the "hidden" cost of reliability.

There are two main types of data needed for TTR analysis using a Reliability Valuation Model:

- → **Travel time estimates** for the last mile road links/freight corridor of interest
- → **Sector-specific valuation parameters** to differentially assess the value of reliability to sector participants.

TTR analyses for District 4 would build on the previous two applications of Last Mile Flow Maps and Bottlenecks Analyses because it is important to first identify corridors of interest where truck flows and road link utilization is highest, and the location and impacts of any bottlenecks in those corridors.

Since the approach and implementation steps for those two applications have been discussed in detail, this section focuses on the two main data components above that are inputs to the Reliability Valuation Model.

6.2.1 Travel Time Estimation

Similar to the other two freight fluidity applications, the use of location-enabled mobile data sources has made the systematic calculation of TTR feasible. The GPS spot speed data that were recommended for Bottlenecks Analysis can also be re-purposed for estimating travel times on road segments in the last mile network of interest. These observed travel times would then be used as inputs into the Reliability Valuation Model.

FDOT has experience with the use of GPS data for TTR calculations. A recent study on supply chain performance in different freight intensive sectors such as ranching and perishable goods distribution identified highly variable travel times on some last mile road links as a major concern for shippers and carriers (FDOT, 2016). Table 6-1 shows the Travel Time Reliability performance and index value calculations of selected road segments in some freight corridors in Florida. The value for TTR (on time delivery) ranges from 19% to 88%. The PTI value indicates that a trip could take up to 80% more time on some road links than when conditions are ideal on those roads.

Table 6-1. Travel Time Reliability Analysis results for selected road segments in Florida freight corridors

Corridor	Segment	Travel Time Reliability	Planning Time Index	Average Speed (MPH)
Palmetto Expressway (SR 826)	I-75 to Golden Glades Interchange	75%	1.84	46
Palmetto Expressway (SR 826)	NW 25th ST to Okeechobee Rd	79%	1.74	51
Palmetto Expressway (SR 826)	Okeechobee Rd to I-75	88%	1.48	52
Deerfield Beach MP to Lakeland DC	Polk Parkway	19%	1.26	59
Deerfield Beach MP to Lakeland DC	SR-60	41%	1.27	55
Lakeland MC to Jacksonville DC	US-301	64%	1.28	55
Deerfield Beach MP to Jacksonville DC	I-95	78%	1.3	69
Lakeland MC to Jacksonville DC	N US Hwy 441	78%	1.4	51

Source: FDOT Freight Performance Measures study (2016)

While these reliability calculations give fluidity performance estimates, the impact of these reliability estimates is felt differently by different freight participants. Independent sources of data are therefore needed for sector-specific impact valuation.

6.2.2 Sector Focus and Valuation

A sector-specific approach is important because shippers and carriers exhibit a wide range of willingness-to-pay to save time or to travel on more reliable routes, and their willingness is associated with the specific cost structures and value of freight in the respective sectors. The value placed on reliability also varies by the type of entity, whether shippers (with or without their own transportation assets) or carriers. Further, the cost structures and parameters change over time.

The Value of Time (VOT) and Value of Reliability (VOR) are two related metrics that quantify the value placed by freight participants on on-time performance. Table 6-2 presents a summary of a range of VOT and VOR estimates derived for various freight value chain participants in Florida (Jin & Shams, 2016). The study found a value of $37.00 per shipment-hour ($1.53 per ton-hour) for travel time savings and $55.0 per shipment-hour ($3.81 per ton-hour) for improvements to reliability across all entities that participated in the research study. Freight users valued reliability approximately twice as much as the travel time. These observations are within the range indicated in the broader literature.

VOT values ranged from $12.00 to $277.00 per shipment-hour among user groups and $0.50 to $23.00 per ton-hour, while the VOR values ranged from $28.00 to $177.00 per shipment-hour and $3.00 to $22.00 per ton-hour. Further, among commodity types, perishable products showed higher VOT and VOR values than non-perishable products, as both time savings and reliability are important in shipping perishable items.

Table 6-2. Derived estimates for Value of Time and Value of Reliability for freight Value Chain participants in FL

Type	Sub-groups	Value of Time ($)		Value of Reliability ($)		Reliability Ratio (based on shipment)	Reliability Ratio (based on tonnage)
		Per Shipment-Hour	*Per Ton-Hour*	*Per Shipment-Hour*	*Per Ton-Hour*		
All		**37.0**	**1.53**	**55**	**3.81**	**1.5**	**2.5**
User Group	Carriers	12.0	0.50	29.0	3.0	2.41	6.0
	Shippers with Transportation	22.0	1.0	177.0	22.0	8.0	22.0
	Shippers without Transportation	277.0	23.0	75.0	5.13	0.3	0.22
	3PL	-	-	51.0	-	-	-
Commodity Group	Agriculture and Food	22.0	1.50	74.0	4.38	3.4	2.9
	Heavy Manufacturing	30.0	1.75	25.0	2.25	0.8	1.3
	Paper, Chemicals & Non-durable Manufacturing	40.0	2.75	17.0	1.38	0.4	0.50
	Petroleum & Minerals	21.0	4.3	24.0	10.2	1.1	2.4
Product Type	Perishable	28.0	0.63	79	4.38	2.8	7.0
	Non-perishable	23.0	1.43	56	3.14	2.4	2.20

Source: Jin & Shams (2016), prepared for FDOT

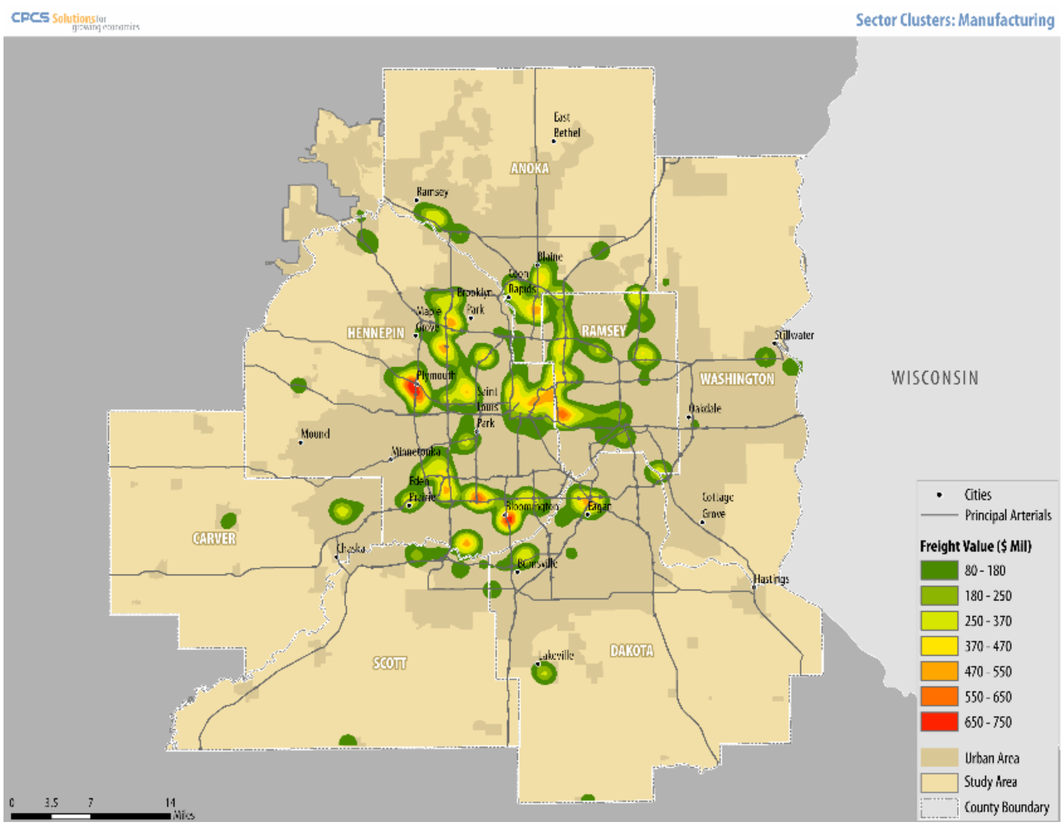
The value of reliability *within* a sector can be more informative for planning and investment project prioritization when tied to the relative volume and importance (by freight value, for example) of freight flows within a region, and combined with Bottlenecks Analysis. Such an analysis could be performed for District 4 for its freight intensive sectors.

Consulting with sector stakeholders is also an important step as the "revealed preference" information evolved over time. Periodic surveys and targeted interviews tend to be most useful in this regard.

FDOT's existing freight facilities dataset can inform this type of study as a starting point for more detailed analysis, as it has detailed location information and attributes on a wide range of facilities associated with the main freight-intensive economic sectors in District 4. Appendix A contains sample maps of the location of freight facilities in District 4 by sector. In addition to location data that can inform the choice of road segments for analysis, the freight facilities data set can be updated to include typical sector specific cost parameters for use in the Reliability Valuation Model.

Figure 6-2 shows the relative spatial distribution of freight value in the manufacturing sector in the Twin Cities region of Minnesota, as an example. Last mile routes and any bottlenecks on them can be linked to these zones for further study. By applying VOT and VOR estimates specifically derived for manufacturing, the Reliability Valuation Model can develop estimates for the premium that shippers, carriers, or receivers place on reliability in that sector.

Figure 6-2 Freight value distribution in the Twin Cities region of Minnesota for the manufacturing sector



Source: CPCS

In summary, GPS spot speed data must be combined with information on different variables such as Value of Time / Reliability in a particular freight sector, and sector participants' associated costs and supply chain impact estimates. The implementation steps discuss how to integrate these data sources and analyses into a Reliability Valuation Model for the Travel Time Reliability application to help FDOT determine which last mile improvements are most critical to TLC.

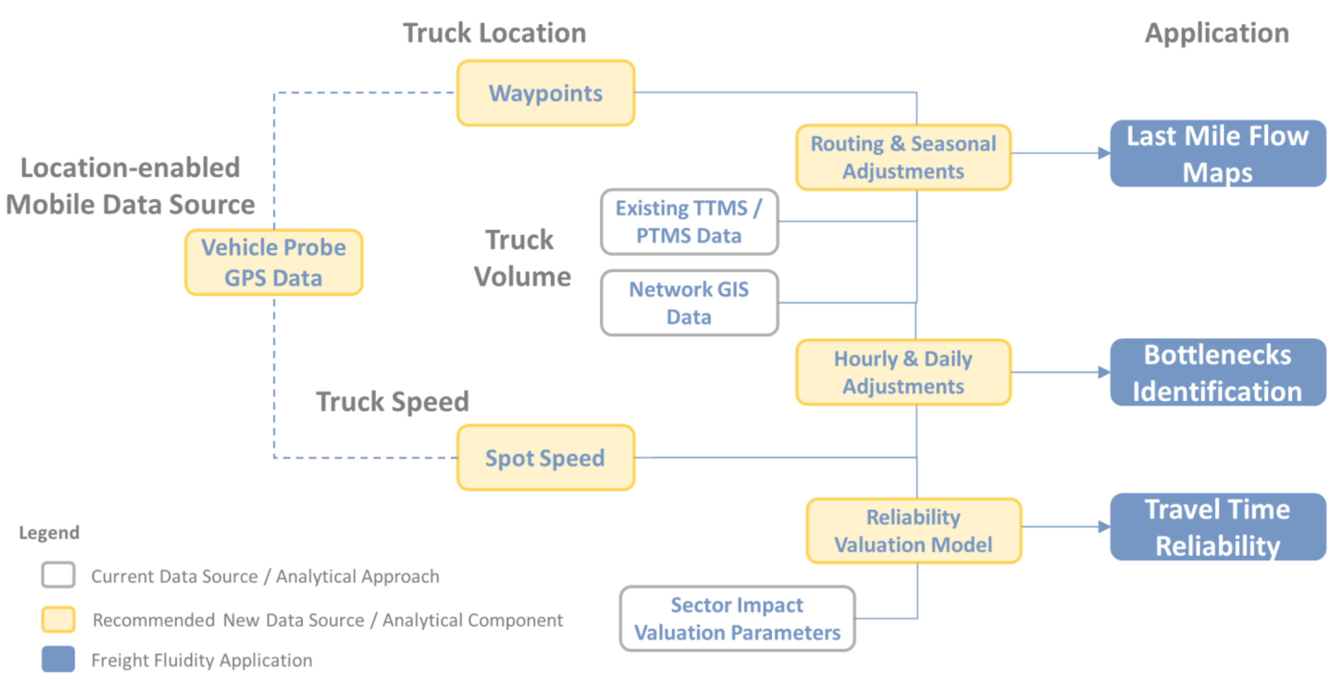
6.3 Recommendations and Implementation Steps

In Chapters 5 and 6 of this Report, we recommended that FDOT obtain GPS waypoint data for developing Last Mile Flow Maps (Recommendation 1) and GPS spot speed data for conducting a Bottlenecks Analysis (Recommendation 2). The recommendation for the Travel Time Reliability application builds on the previous recommendations, in that FDOT should obtain and use GPS data from the same mobile sources. Once again, speed data must be complemented with other data sources to accomplish the desired objectives of the application. For the TTR application, these sources involve sector-specific cost and impact parameters.

Recommendation 3: Use GPS spot speeds, freight facility information, and sector-specific valuation data to assess the value of improving travel time reliability in certain corridors.

Figure 6-3 below describes how probe data such as GPS data used for the two other freight fluidity applications of Last Mile Flow Maps and Bottlenecks Analysis can also be used for Travel Time Reliability analyses. These data would be supplemented by sector-specific costs and other information for use in the Reliability Valuation Model.

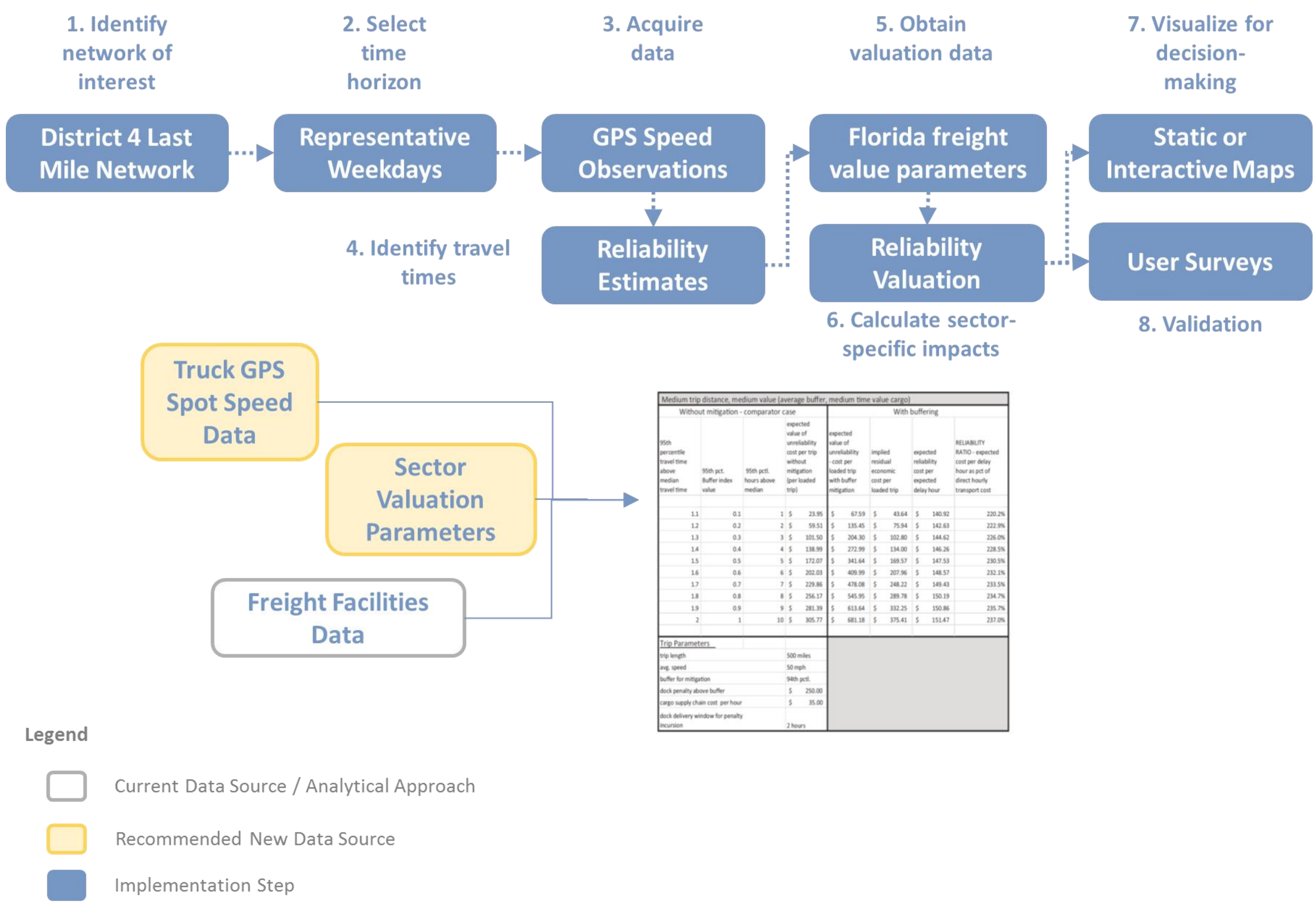
Figure 6-3. Use of GPS spot speed and other freight sector data for Travel Time Reliability valuation in relation to the other freight fluidity applications



Source: CPCS

The implementation steps for conducting a Reliability Valuation are shown in Figure 6-4. Many of the steps are similar to the implementation steps previously described because the logic for these last mile freight fluidity applications builds on the same components. The steps are as follows:

Figure 6-4. Implementation Steps for Travel Time Reliability Analysis



Medium trip distance, medium value (average buffer, medium time value cargo)							
Without mitigation - comparator case				With buffering			
95th percentile travel time above median travel time	95th pct. Buffer index value	95th pctl. hours above median	expected value of unreliability cost per trip without mitigation (per loaded trip)	expected value of unreliability - cost per loaded trip with buffer mitigation	implied residual economic cost per loaded trip	expected reliability cost per expected delay hour	RELIABILITY RATIO - expected cost per delay hour as pct of direct hourly transport cost
1.1	0.1	1	$ 23.95	$ 67.59	$ 43.64	$ 140.92	220.2%
1.2	0.2	2	$ 59.51	$ 135.45	$ 75.94	$ 142.63	222.9%
1.3	0.3	3	$ 101.50	$ 204.30	$ 102.80	$ 144.62	226.0%
1.4	0.4	4	$ 138.99	$ 272.99	$ 134.00	$ 146.26	228.5%
1.5	0.5	5	$ 172.07	$ 341.64	$ 169.57	$ 147.53	230.5%
1.6	0.6	6	$ 202.03	$ 409.99	$ 207.96	$ 148.57	232.1%
1.7	0.7	7	$ 229.86	$ 478.08	$ 248.22	$ 149.43	233.5%
1.8	0.8	8	$ 256.17	$ 545.95	$ 289.78	$ 150.19	234.7%
1.9	0.9	9	$ 281.39	$ 613.64	$ 332.25	$ 150.86	235.7%
2	1	10	$ 305.77	$ 681.18	$ 375.41	$ 151.47	237.0%

Trip Parameters	
trip length	500 miles
avg. speed	50 mph
buffer for mitigation	94th pctl.
dock penalty above buffer	$ 250.00
cargo supply chain cost per hour	$ 35.00
dock delivery window for penalty incursion	2 hours

Source: CPCS

1. **Identify a network of interest**: The first step is to geofence the roads of interest, i.e. spatially restrict the particular breaks (segments) or links in a study area. In contrast with Flow Maps or Bottlenecks Analysis, TTR analysis would ideally prioritize/leave in the roads with known congestion and bottlenecks near major freight facilities. Some options for conducting TTR analyses for District 4 include:

- Selected road classes across District 4, ex. SIS freeways and signalized arterials, certain ramps, connectors
- All links that emanate from freight facility of interest, ex. Port Everglades, Publix distribution center

2. **Select time horizon and resolution**: For developing meaningful travel time profiles for the relevant road segments, a typical weekday pattern is generated from observed historical data comprised of:

- → Seasonal Data: two "representative" weeks in each quarter of the year for a total of eight weeks or 40 days of speed observations
- → Bins: appropriate time intervals over which speeds are either weighted or simply averaged for a typical speed in that time interval (ex. 5 minutes, 15 minutes, etc).

3. **Choose vendor and acquire data**: Based on the competitive analysis of vendors discussed earlier in Chapters 2 and 3, we recommend that FDOT procure spot speed data from the same vendor that it selects for waypoint data, to ensure consistency and streamline the standardization that is needed in processing and joining these data sets. The premise for this recommendation is that FDOT will likely conduct conflation and analysis using its internal GIS experts, or obtain and provide this data to an external analyst.

Our experience working with a number of these vendors suggests that a preliminary price estimate for the recommended eight representative weeks is $25,000 - $30,000 (per year) for one-time use for a geography spanning District 4. For frequent updates and use, a subscription agreement (obtain 8 weeks every year) could reduce the estimate. Pricing is often dependent on the mileage of the road segments in the network of interest, and the frequency of new data downloads.

4. **Identify travel times**: Calculating travel times, and reliability indices such as TTI, PTI or BTI can easily be automated in GIS across the network of interest. Alternatively, these measures can be computed outside the GIS environment and then joined to the GIS shapefiles that will be used for visualization.

5. **Obtain valuation data**: Freight sector participants in Florida such as shippers, carriers, and receivers place different value on time savings and reliability, as discussed above. To be able to estimate the value of improvements in reliability across a sector as a whole, data on a number of variables are needed to populate the Reliability Valuation Model. These variables included routes, direct and indirect costs, typical buffer time assumptions, other supply chain factors, and challenges. Stakeholders can be engaged through targeted consultations to elicit these data.

Table 6-3 shows some examples of factors for which parameter values could help differentiate the reliability valuation.

Table 6-3. Examples of sector-specific factors for which valuation results could be differentiated

Factor Affecting Cost	Cost Impacts		
	Direct cost of truck operation	Cargo related supply chain costs	On-dock penalties
Highway Operating Conditions			
Highway Level of Service	Trip time and direct transport costs per truck hour are higher for congested conditions, slower speeds, and unreliable travel times.	Increased probability of late arrival, incurring additional supply chain costs, where built in buffer time is exceeded.	Increased probability of incurring fixed dock penalty, where built in buffer time is exceeded.
Links and Chokepoints			
Intermodal connection	Total trip time and thus total per trip direct transport costs are higher where intermodal connections are delayed; Total trip time and direct transport costs increase where multiple stops or connections increase probability and hours of late delivery, necessitating increased buffer pad.	Late delivery can increase supply chain cost significantly for missed scheduled connections.	Increased probability of incurring fixed dock penalty where built in buffer time is exceeded.
Border crossing	Total trip time and thus total per trip direct transport costs are higher where border crossings are delayed; Total trip time and direct transport costs increase where border conditions increase probability and hours of late delivery, necessitating increased buffer pad.	Unreliable crossing time may entail higher costs at border crossings for interdependent cross border supply chains.	Increased probability of incurring fixed dock penalty where built in buffer time is exceeded.
Cargo/Supply Chain Factors			
Cargo value ($ per ton)	Cost per truck hour does not vary with cargo value; Total truck transport costs will increase with cargo value if higher buffer time pad is applied to the scheduled time for high value cargo.	Varies directly with cargo value.	Dock penalties may be higher for higher cargo value in some cases.
Expedited delivery	Cost per truck hour does not vary with cargo value; Total truck transport costs will increase with cargo value if higher buffer time pad is applied to the scheduled time for expedited cargo.	Higher for expedited shipment.	Dock penalties may be higher for expedited shipment in some cases.
Just-in-Time (JIT) production	Cost per truck hour does not vary with cargo value; Total truck transport costs will increase with cargo value if higher buffer time pad is	Higher for JIT shipment.	Dock penalties may be higher for JIT shipment.

	applied to the scheduled time for JIT cargo.		
Perishable products	Cost per truck hour does not vary with cargo value; Total truck transport costs will increase with cargo value if higher buffer time pad is applied to the scheduled time for perishable cargo.	Higher for perishable product.	Dock penalties may be higher for perishable product.

Source: TRB NCHRP Report 824 (2016)

Table 6-4. Examples of sector-specific factors for which valuation results could be differentiated

Medium trip distance, medium value (average buffer, medium time value cargo)							
Without mitigation - comparator case				With buffering			
95th percentile travel time above median travel time	95th pct. Buffer index value	95th pctl. hours above median	expected value of unreliability cost per trip without mitigation (per loaded trip)	expected value of unreliability - cost per loaded trip with buffer mitigation	implied residual economic cost per loaded trip	expected reliability cost per expected delay hour	RELIABILITY RATIO - expected cost per delay hour as pct of direct hourly transport cost
1.1	0.1	1	$ 23.95	$ 67.59	$ 43.64	$ 140.92	220.2%
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Trip Parameters	
trip length	500 miles
avg. speed	50 mph
buffer for mitigation	94th pctl.
dock penalty above buffer	$ 250.00
cargo supply chain cost per hour	$ 35.00
dock delivery window for penalty incursion	2 hours

Source: TRB NCHRP Report 824 (2016)

6. Calculate sector-specific impacts: Travel time metrics and indices and sector-valuation data are then used as inputs into the Reliability Valuation Model. The model can be automated to produce results in a manner that is informative for benefit-cost analysis and planning. The effect of a number of reliability improvement strategies and scenarios can then be studied easily.

Table 6-4 shows an example of a reliability trade-off curve (with and without a buffering strategy) based on sector-specific assumptions. The trade-off curve is an output of the RVM. Parameter values can be updated to study the effects on the reliability curve.

7. **Visualize for decision-making**: The same conflation and joining techniques that were discussed previously can be used to update map files to show how reliability estimates and values compare across different road segments in the last mile network. These maps and indicators can also be shown through interactive dashboards to deliver performance measures for decision-support.

8. **Validation**: An important final step is to compare the reliability valuation results with the implicit estimates of sector experts and participants. In this case, engaging shippers, truck drivers or fleet owners, and recipients can help confirm or adjust parameter values, cost information, and reliability improvement scenarios for benefit-cost analysis. Validation can be conducted through interviews or surveys.

7 Conclusions

Key Chapter Takeaway

This research resulted in strategies and approaches to improve last mile observability for freight planning and investment decision-making. We identified detailed approaches, data needs, and implementation steps for tool modification for the high value applications of Last Mile Flow Maps, Bottlenecks Analysis, and Travel Time Reliability Valuation.

7.1 Research Outcomes

Our early research in this study (Tasks 1 and 2) and Florida DOT feedback indicated that the Freight Fluidity opportunity area (freight observability over time) currently presents the most compelling applications for improving last mile observability for freight planning in Florida. Accordingly, later stages of this research developed the recommended strategies and implementation steps for tool modification for three applications in the Freight Fluidity opportunity area:

- **Last Mile Flow Maps** - mapping truck flows in detail to understand chosen routes
- **Bottlenecks Analysis** - identifying bottlenecks and chokepoints and estimating their impacts
- **Travel Time Reliability** - assessing the value of travel time in freight-intensive sectors

FDOT already collects and maintains a variety of data needed to develop these applications. These include traffic counts, road network and asset data, and freight facility databases. FDOT has typically pre-processed, standardized, and published these data in easily implementable formats such as GIS shapefiles.

FDOT can continue to use its best practice of **data fusion** – systematically integrating data from different sources – across these data sets to inform the three Freight Fluidity applications. Nevertheless, FDOT does currently face gaps in its datasets for last mile observability. The main gaps are the lack of precise truck location, speed, and route information at a resolution that is detailed enough to support performance estimation on the last mile network.

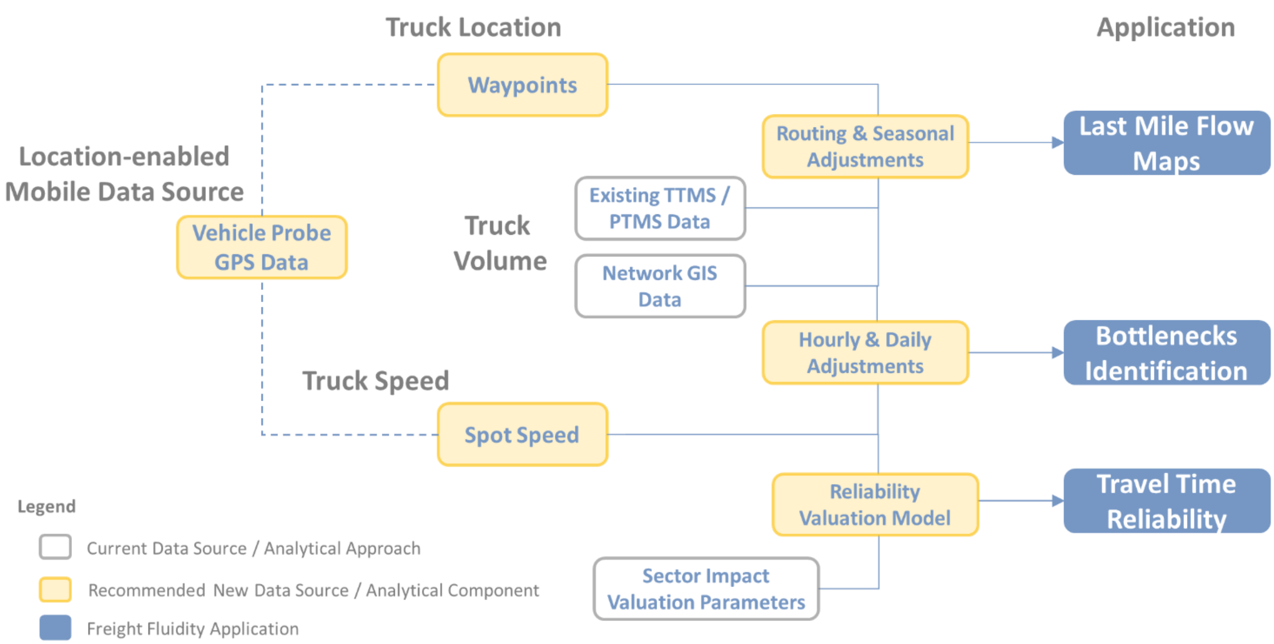
Our recommendations accordingly focus on the complementary data needed to address the gaps, and the corresponding approaches to tool modification to fully implement the Freight Fluidity applications.

Location-enabled mobile data sources can address the gaps and support the implementation of the three applications. More specifically, we recommend that vehicle probe GPS data should be combined with FDOT's existing data and tools in the following ways:

- **Recommendation 1**: Use GPS waypoint data in conjunction with current data repositories to develop a finer-grained understanding of how trucks traverse the last mile network
- **Recommendation 2**: Use GPS spot speeds along with estimated truck volumes to identify and precisely locate truck bottlenecks
- **Recommendation 3**: Use GPS spot speeds, freight facility information, and sector-specific valuation data to assess the value of improving travel time reliability in certain corridors

Figure 7-1 summarizes how these two related types of GPS data – waypoints and spot speeds – can be integrated into existing tools and transformed to produce Last Mile Flow Maps, bottlenecks analyses, and Travel Time Reliability assessments.

Figure 7-1. Data needs and analytical components for the three Freight Fluidity applications



Source: CPCS

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Appendix A: FDOT District 4 Freight Infrastructure and Freight Facilities

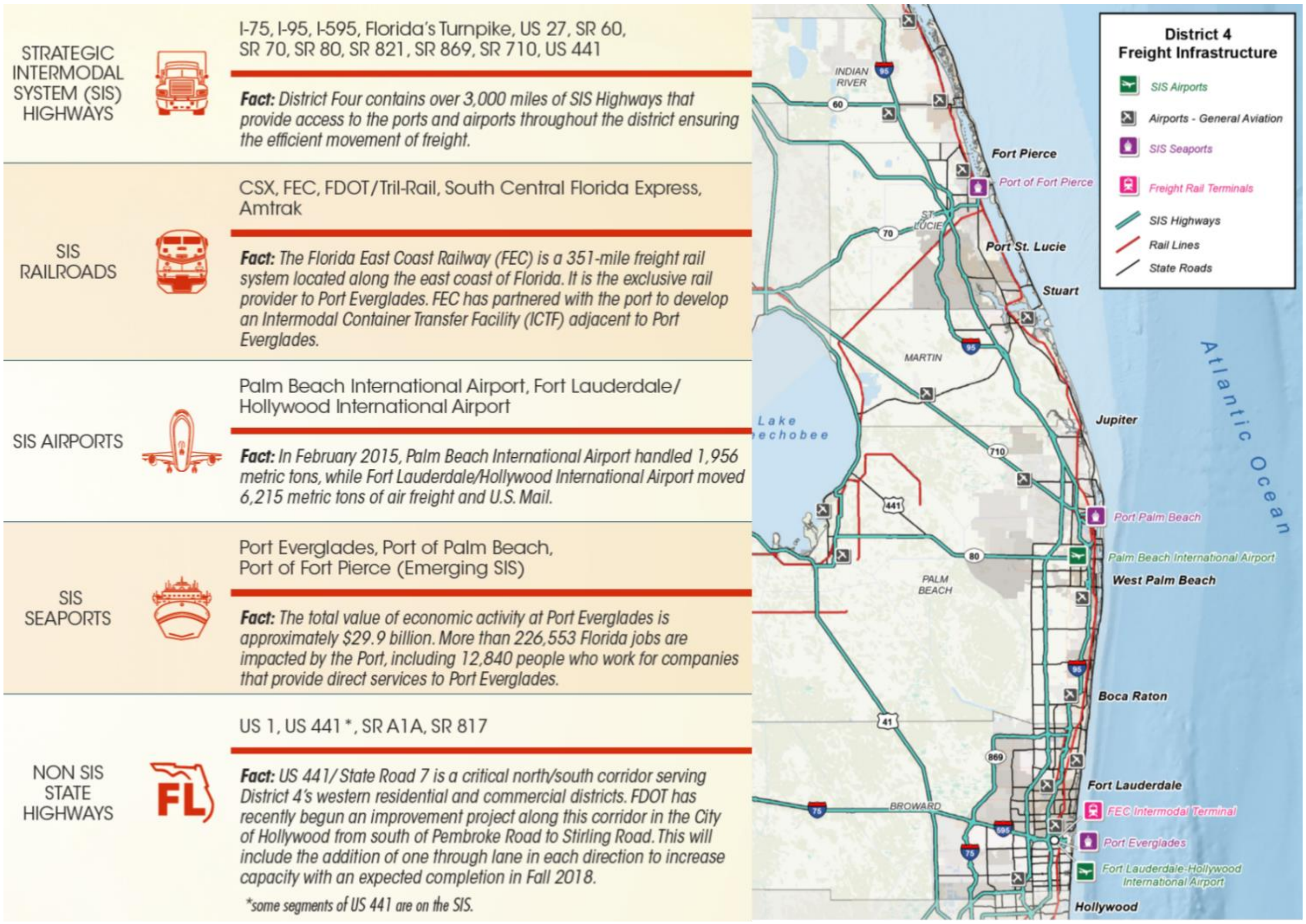
As part of our research and field visits in Broward County, we studied FDOT's existing freight infrastructure to gain a better understanding of the relationship between last mile issues and the infrastructure itself. This Appendix summarizes our observations of District 4's freight infrastructure in particular.

FDOT District 4 has a variety of freight infrastructure assets and facilities, many of which inter-operate as part of its Strategic Intermodal System (SIS). These include highways, railroads, airports, and seaports. There are also a number of state highways which help connect different parts of the region to the SIS. Figure A-1 shows key elements of District 4's SIS and non-SIS freight infrastructure and also summarizes key facts about the different modes.

District 4 also has significant freight activity as shown by the series of maps in Figures A-2 to A-5, which indicate the location, type and size of freight facilities in the following freight-intensive sectors: light Manufacturing (sector code 41), heavy manufacturing (42), lumber yards (43), packing plants (44), bottlers (45), food processing (46), materials processing (47), Warehousing & Distribution (48), and Open Storage (49).

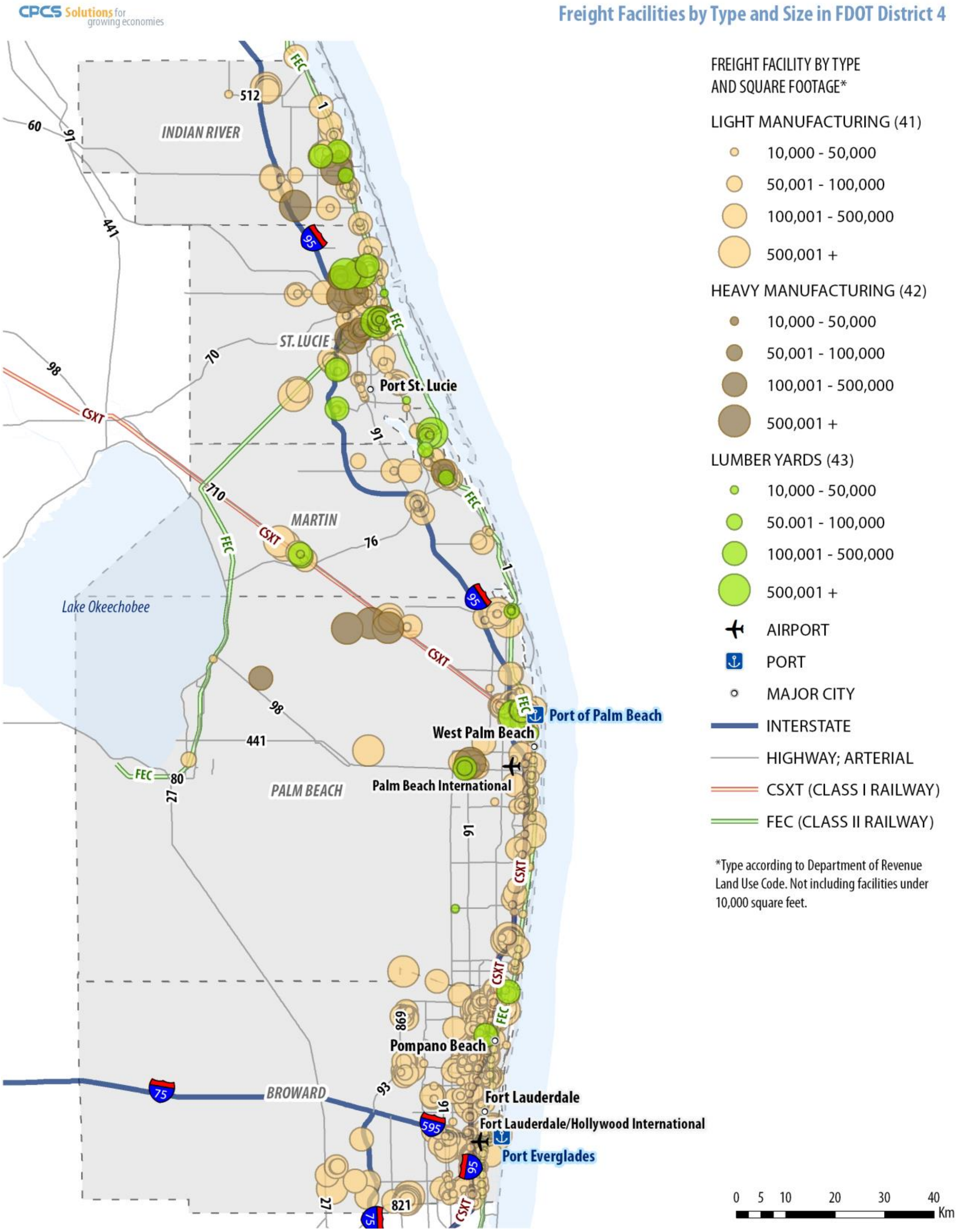
These facilities are clustered near or co-located with freight infrastructure. The activity in some freight-intensive sectors is concentrated in specific parts of District 4's five-county region. For example, St. Lucie County has a high concentration of lumber yards.

Figure A-1. District 4 freight infrastructure and key facts



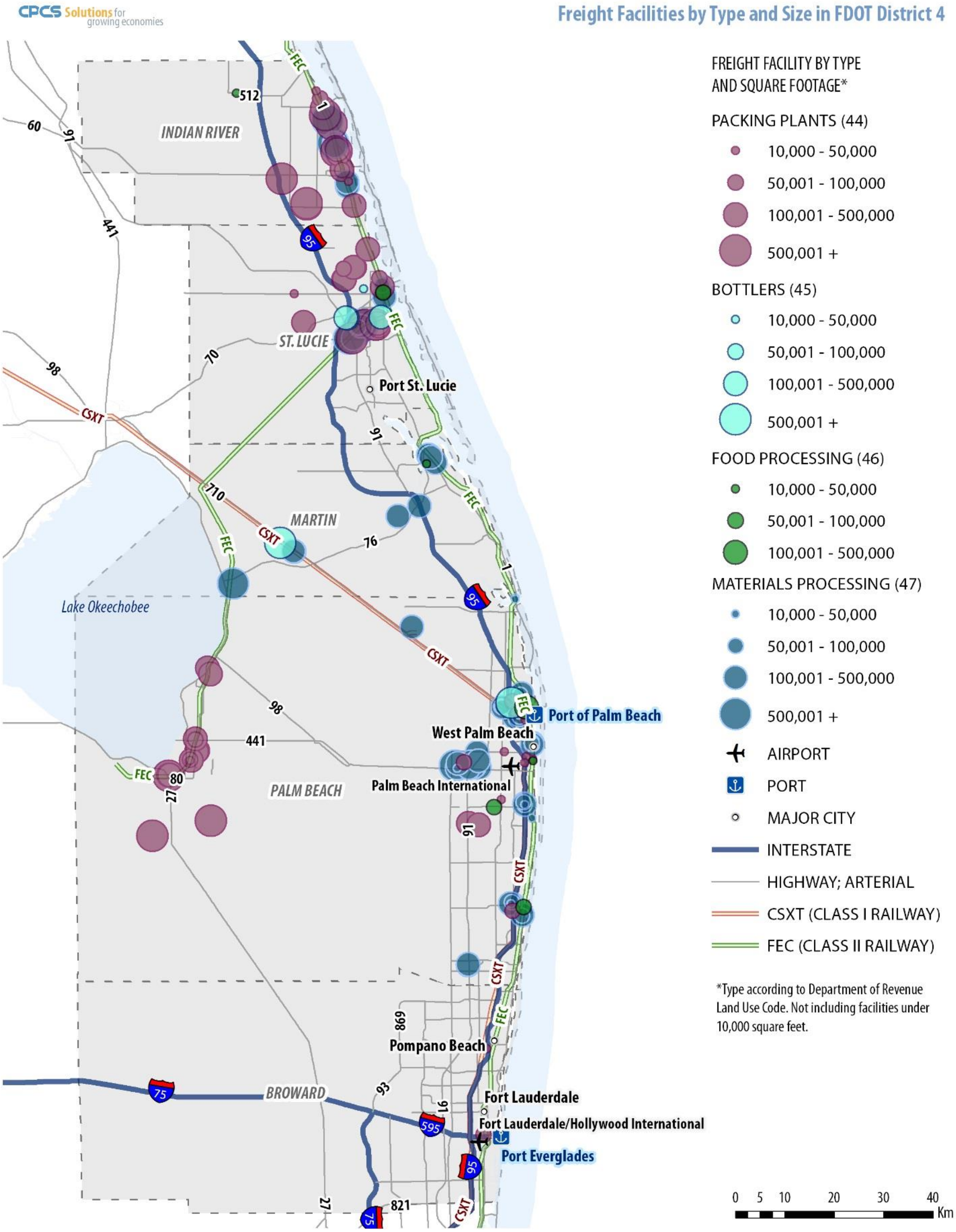
Source: FDOT District 4 Freight Mobility Implementation Guide

Figure A-2. District 4 Freight Facilities: Manufacturing and Lumber Yards



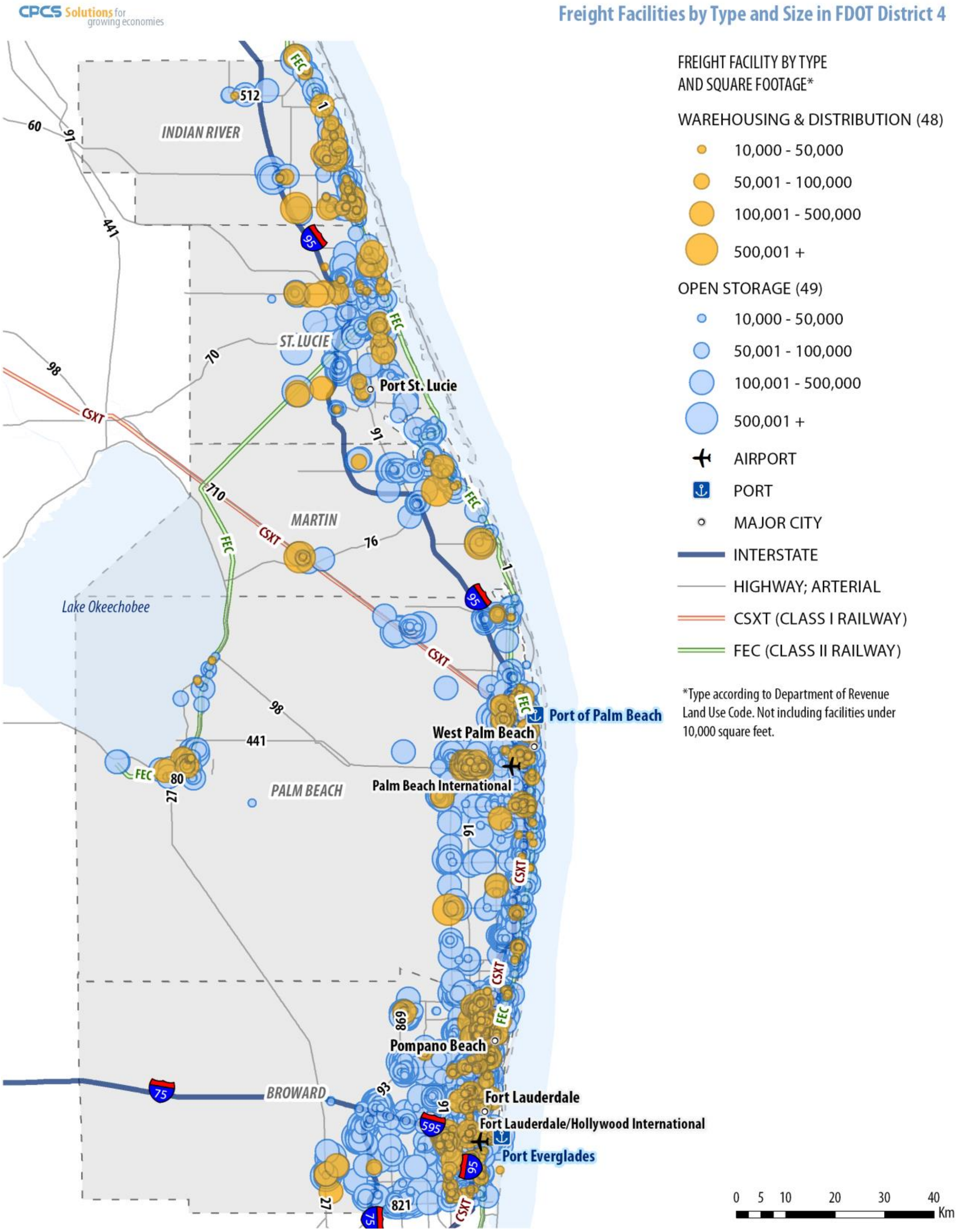
Source: CPCS analysis and mapping of FDOT's Freight Parcels dataset

Figure A-3. District 4 Freight Facilities: Packing Plants, Bottlers, Food Processing, and Materials Processing



Source: CPCS analysis and mapping of FDOT's Freight Parcels dataset

Figure A-4. District 4 Freight Facilities: Warehousing & Distribution, and Open Storage Facilities



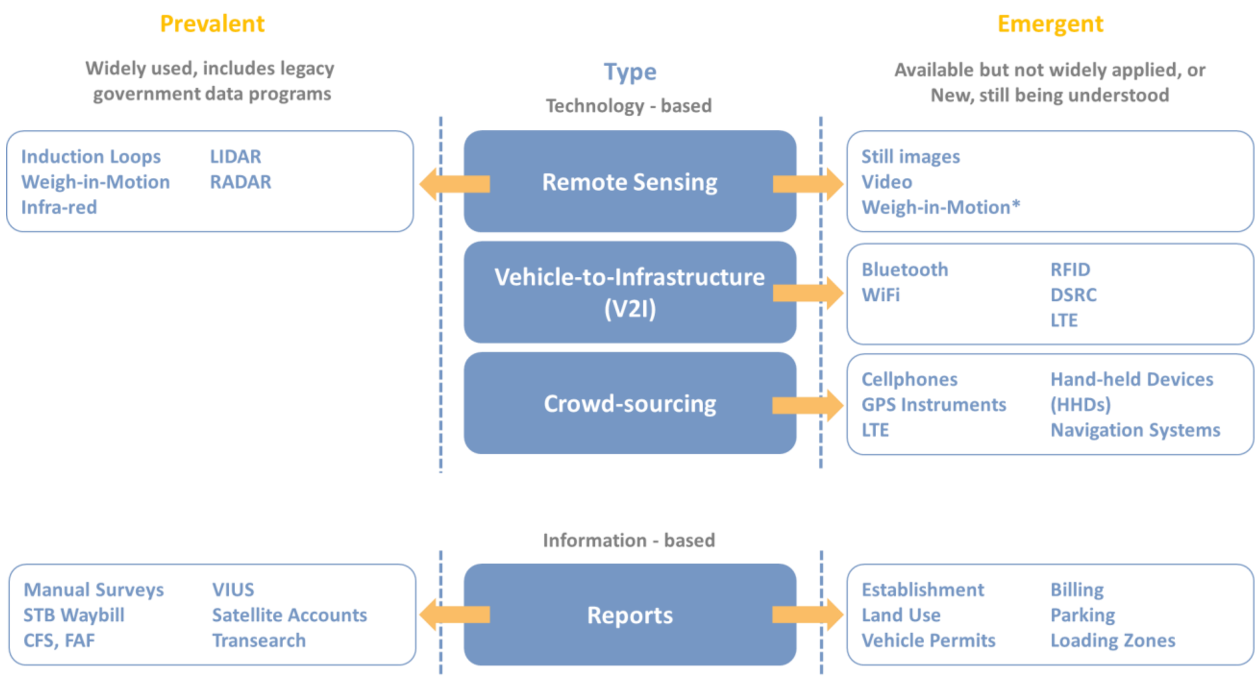
Source: CPCS analysis and mapping of FDOT's Freight Parcels dataset

Appendix B: Data, Analytics, and Business Models

The universe of freight data sources

We documented and categorized the many available and emerging sources of freight data. A subset of these can be used to develop strategies and approaches for last mile observability. Figure B-1 shows the sources categorized by Type of Source and Degree of Use.

Figure B-1. Freight data universe – categorized by Type and Degree of Use (Prevalent / Emergent)



Source: CPCS analysis

There are four broad types of relevant data sources:

1) **"Crowd-Sourced"** data such as GPS and road condition information collected and transmitted by onboard navigational devices and cellular phones;

2) **Vehicle-to-Infrastructure (V2I)** sources that query some onboard identifying element of the vehicle and receive a response, such as roadside Bluetooth, Wi-Fi, and RFID readers;

3) **Passive Sensing** infrastructure sources that do not communicate with some element of the vehicle, but collect information through observation. This category includes induction loops, and radars, weigh-in-motion sensors, and machine vision;

4) **Reports** such as oversize-overweight permit records, or surveys of shipping companies, which provide ex-post information about truck routes and volumes.

The first three of these types (crowd-sourcing, V2I, and passive sensing) are tied to the technical capabilities of sensors, vehicles and communications protocol, i.e. they are Technology-based. The fourth type, Reports, is based on processed transactions, records, and other administrative information, and is, therefore, an Information-based type.

Technology-based data sources have a number of differentiating attributes, which have implications for how freight data are collected and stored, and how data is owned and used.

Table B-1 lists the attributes for each of the technology-based types of sources in our categorization framework.

Table B-1. Main attributes of Technology-based types of freight data sources

Attributes	Type: Crowd-sourced	Type: V2I	Type: Passive sensing
Recording Device?	Cell Phone Navigation System GPS Tracker	Bluetooth Detector Wi-Fi Reader RFID Reader DSRC	Induction Loops IR Detectors Radars Weigh-in-Motion Still images Video
Communication with vehicle / responder?	Yes	Yes	No
Recording Location?	Anywhere / Mobile	Fixed Location	Fixed Location
ID Obtained?	Automatically	Automatically	Through calculations
Active Transmission?	Automatically	After query	After observation
Sensor Ownership?	Distributed Private	Distributed Private	N/A
Collector Ownership?	Mostly Vendor	Public / Vendor	Mostly Public
Data Ownership?	Variable	Variable	Public
Storage Paradigm?	Vendor, Cloud	Mostly Vendor, Cloud	Public or vendor servers

Source: CPCS analysis

Freight-relevant Analytics for "Big Data"

Analytics for big data have different possible goals, based on the nature of the data, the type of information that can be extracted, and the usefulness of that information for a particular application. The four main goals are:

→ **Descriptive** – This goal answers the question "what is going on in the data?" It helps understand variables, the degree of variation, and sensitivity.

→ **Diagnostic** – This goal addresses questions like "how does X relate to Y?" or "does B depend on A?" In other words, diagnostic analyses focus on establishing statistical and causal relationships

→ **Predictive** – This goal uses information from both descriptive and diagnostic analyses, as above, to help observe conditions and anticipate events and trends. It answers questions of the nature "what is likely to happen, given current conditions?"

→ **Prescriptive** – The goal of this type of analytics is to develop recommendations for decisions and behaviors. It suggests choices in response to questions like "what should be done when…?" Prescriptions also build on descriptive and diagnostic analyses.

Table B-2 below shows relevant transportation applications and specific last mile examples for each type of goal. Most often, decision-making involves the use of more than one type of analysis and multiple sources of data.

Fully addressing each last mile freight challenge will require a combination of different analytical approaches leveraging a fusion of different data sources

Table B-2. Goals, Applications and Examples of analytics for freight-relevant big data

Analysis Goal	Transportation Applications	"Last Mile" Example
Description	Model parameter selection, calibration	Freight Trip Generation models
Diagnosis	Factors, Statistical Relationships, Pattern Recognition	Alerts, Route Violations, Exceptions
Prediction	Anticipating abnormal behavior, interventions, maintenance	Crash prediction, Hazard detection
Prescription	Optimization-based recommendations	Dynamic routing, scheduling

Source: CPCS analysis, based on Tom Davenport's Framework – Deloitte University Press

Freight-relevant business models for data acquisition

New opportunities are now available for how public agencies can obtain data relevant to the last mile of freight. These move agencies away from the traditional model of asset investment, towards more "asset light" approaches for data acquisition through service agreements.

Agencies have traditionally invested in the assets (technologies, sensors, software, and servers) to enable data collection and analysis. A common variant of the traditional model is the use of vendors either as Original Equipment Manufacturers (OEMs) or asset providers. The use of vendors may extend beyond the asset procurement phase, and into the operations and management of data collection systems, and software or web-interface improvement. In many cases, these assets are owned by the procuring agencies.

A number of trends in technology, software and IT have turned the traditional business model on its head, and have in fact created an opportunity for more cost-effective and reliable data acquisition and analytics. The opportunity is driven by:

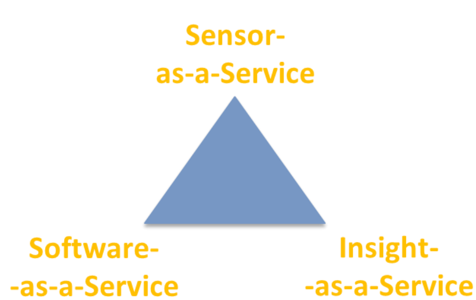
- the proliferation of cheap sensors due to commoditization
- cost-effective cloud-based storage
- robust and high-powered computational and analytics capabilities (ex. Cloud computing)
- high-quality interface designs and visualizations, and
- a preference for customized "on-demand" reports and analytical conclusions to support real-time decision making

Both established firms, as well as start-ups, have taken advantage of this opportunity to offer service-oriented business models (Figure B-2) for data acquisition and analytics.

The emphasis of these new business models is on providing public agencies with a turnkey solution to data acquisition or analytics.

Through "as-a-service" arrangements, public agencies can avoid lock-in to rapidly evolving technology assets and mitigate the need for expensive software and database development, while the private vendor bears the risk of upgrading sensors, and maintaining software and tools to meet stipulated performance requirements. These new business models mean that FDOT does not necessarily have to invest in new sensors or assets to collect last-mile freight data; the department can develop a subscription/services agreement with a vendor to provide data that meets specifications for performance measurement.

Figure B-2. Service-oriented business models for the provision of data to public agenices



Source: CPCS analysis

Appendix C: Last Mile Data and Analysis — Best Practices Framework

Last Mile Data Best Practices Framework

We developed a three-part framework to evaluate new strategies and methodologies for addressing the last mile of freight activity, as shown in Figure C-1. This framework is based on our synthesis of last mile challenges in Florida, and opportunities identified in our research on freight data sources, analytics, business models, and applications, as discussed in preceding sections.

Figure C-1. Proposed three-part framework for evaluating last mile data and analytics solutions

Source: CPCS analysis

To apply the framework, three questions must be asked for each solution being evaluated, which directly address persistent last mile challenges or leverage opportunities:

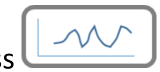
→ **Does the approach improve vehicle observability, and if so along which dimensions?**

- **Vehicle Type or Classification**, ex. For truck counts
- **Vehicle ID**, ex. Keeping track of a vehicle for re-identification or route tracking, O-D information
- **Vehicle Purpose**, ex. Understanding the nature of the trip either based on commodity or freight generation activity, for freight fluidity insights

→ **Does the approach allow the public sector to mitigate the need to obtain commercially sensitive or otherwise proprietary data?**

- **Access**: there are no access restrictions based on current rules and regulations for the public sector's collection and use of this data Access
- **No access**: this obstacle to last mile freight data collection is unmitigated ~~Access~~

→ **Does this approach enable/require collection of raw data or directly provide insights?**

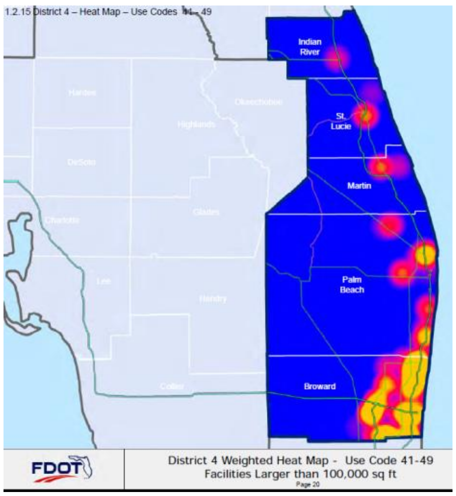
- **Data**: the solution implies raw data collection with some pre-processing, with transformation and detailed analytics required, and can be used for multiple applications ...10010..
- **Insight**: the solution implies a turnkey approach for specific applications through an "as-a-service" agreement to speed up the decision-making process 

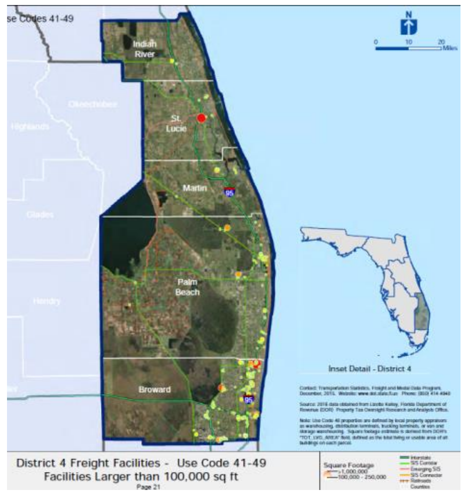
The framework is intended to be a qualitative screen for the potential value of a new solution or approach to last mile data collection. The indicators are not intended to be binary or summative. For example, a particular approach may only check two out of three Vehicle Observability criteria and could still help advance the state of practice. Similarly, the availability of raw data must be evaluated in the context of the application(s) for which it is being considered, as some data sources can be useful for more than one application.

We apply this framework to case studies of solutions addressing last mile freight challenges. We include two FDOT case studies to show how FDOT is among those using state of the art techniques and to demonstrate our best practices framework with FDOT's internal projects.

Best Practice Case Studies

Case Study 1: FDOT Freight Facilities Data Set





Source: FDOT 2016

What was the last mile problem/project objective?	To identify freight facilities for distribution of consumer and other goods that generate moderate to high levels of truck traffic
What were the data used?	FDOR parcel data based on tax records, fused with map scans using GIS
What analysis was performed?	Descriptive – to understand facility location for Freight Generation / Freight Trip Generation model calibration
What was the best practice/advantage?	Publicly available FDOR data that were available by request, no access restrictions
What was accomplished, and what last mile gaps still remained?	The approach identified facilities but did not focus on vehicles, only freight facilities. The data were raw and needed substantial transformation. Commodity or trip purposes were inferred from facility meta-data

Framework Scoring Indicators

Vehicle Observability?

ID X

X Type

X Purpose

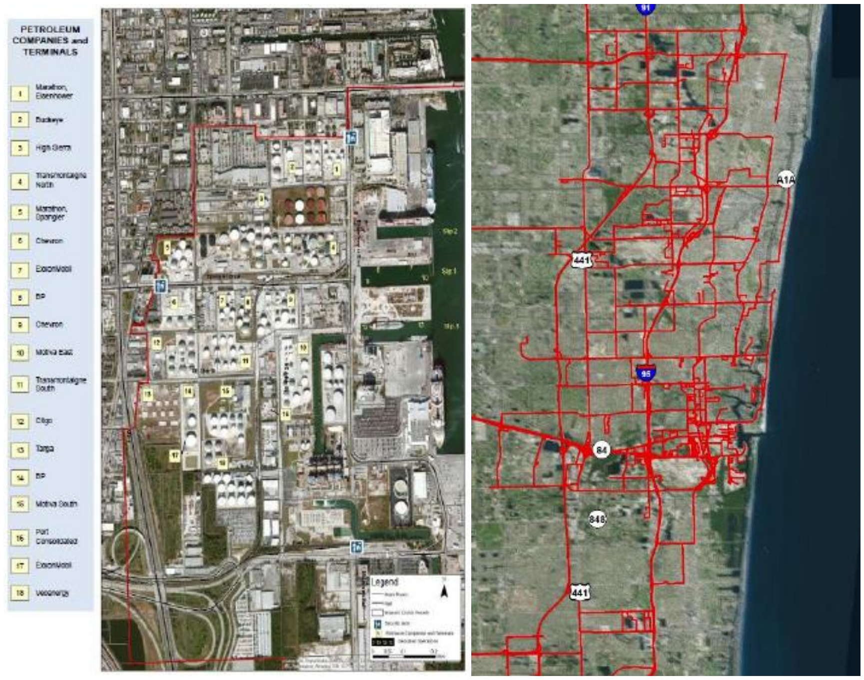
Data Access?

Access

Insight?

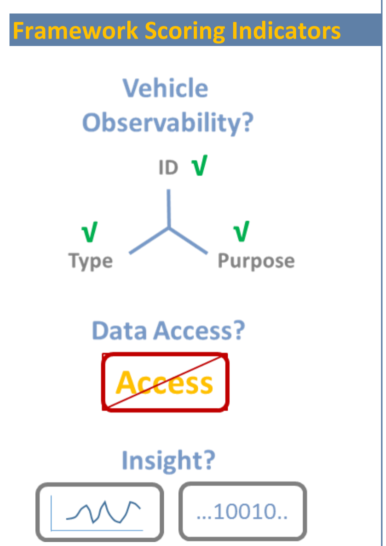
...10010..

Case Study 2: FDOT Port Everglades Study



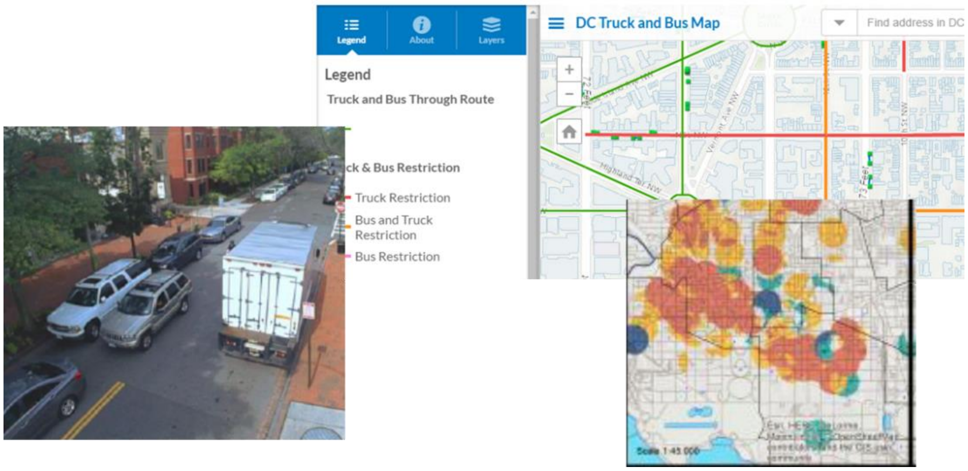
Source: FDOT 2016

What was the last mile problem/project objective?	To understand the supply and demand chain for petroleum commodities distributed from Port Everglades (PEV) to the 12 counties of southern Florida.
What were the data used?	A fusion of data sources including FDOR transaction data, ATRI GPS data, video imagery of truck movements
What analysis was performed?	Diagnostic – for commodity flow and trip/tour tracing to understand O-D and truck movement
What was the best practice/advantage?	Specific commodity information from transaction records, unique vehicle types, and IDs from video imagery-based classifications and license plate information, partial public data access
What was accomplished, and what last mile gaps still remained?	Petroleum commodity O-Ds and vehicle types were successfully identified, but the approach required intensive analysis and not easily replicable, with only partial access to publicly available data



We include seven case studies of efforts from urban and metropolitan regions who are addressing last mile challenges.

Case Study 3: DC Urban Truck Sensing



Source: DC DOT 2016

What was the last mile problem/project objective?	To improve urban freight sustainability through Waze-like routing for regular and OS/OW vehicles; real-time loading zone and parking management
What were the data used?	A fusion of meter transactions, vehicle permit records, opt-in pay by cell identifiers, and still and video images
What analysis was performed?	Descriptive analysis of commercial loading zone usage, Diagnostic of parking violations, Predictive (modeling) of potential usage
What was the best practice/advantage?	Inventory of specific locations, matched to automatic pay by cell data collection, with unique vehicle ID and types, ownership obtained from program registration
What was accomplished, and what last mile gaps still remained?	Initial pilot can push out information to commercial users, and track registered vehicles/fleets that opt into the management program, but little understanding of violation behavior, trip purposes, or effects of policies such as variable pricing or automatic parking enforcement (violation penalties)

Framework Scoring Indicators

Vehicle Observability?

ID √

√ Type

√ Purpose

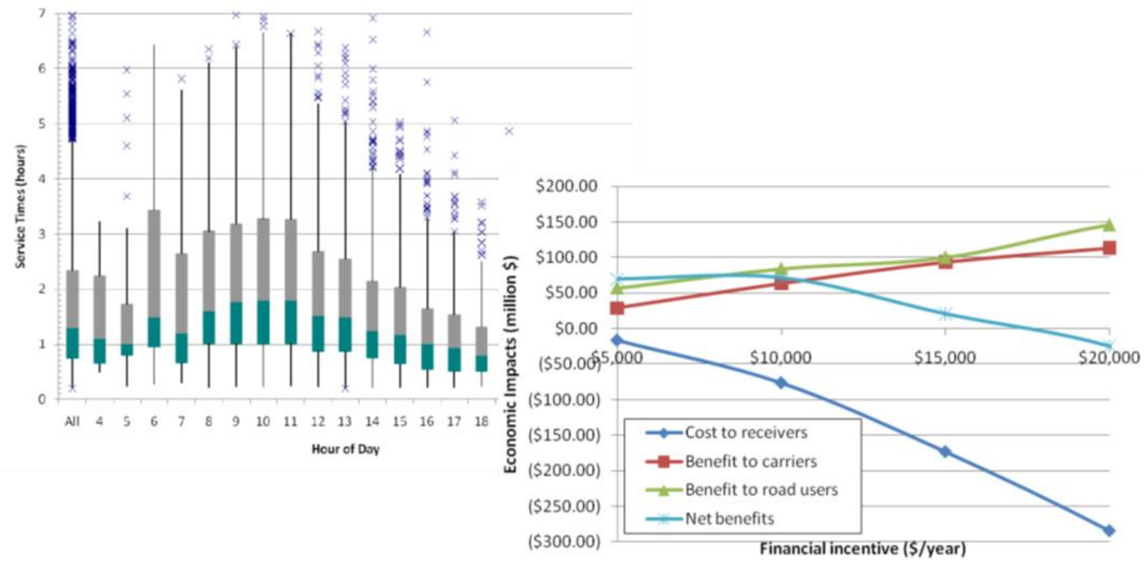
Data Access?

Access

Insight?

...10010..

Case Study 4: New York City Off-Hour Deliveries



Source: NYMTC 2016

What was the last mile problem/project objective?	To implement an urban freight traffic management system for the New York City metro area with a focus on moving loading/unloading to off hours
What were the data used?	A fusion of GPS data from fleets, economic data on costs and cost savings/benefits, receiver order data
What analysis was performed?	Descriptive – to understand carrier behavior, Diagnostic – to understand relationship with receiver preferences, Prescriptive (modeling) – to test the effect of program and policy changes
What was the best practice/advantage?	Small group of volunteers opted into the program with no data restrictions to provide complete vehicle observability and raw data
What was accomplished, and what last mile gaps still remained?	Detailed understanding of costs and benefits to carriers and receivers under different program designs, obstacles to scaling up across city and including small carriers

Framework Scoring Indicators

Vehicle Observability?

ID √

√ Type

√ Purpose

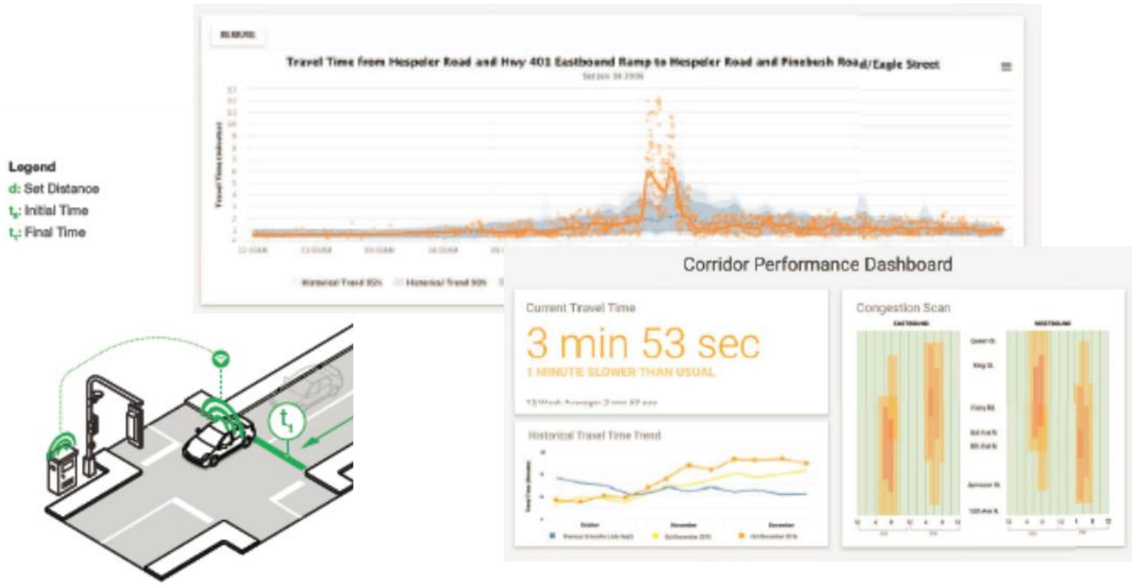
Data Access?

Access

Insight?

...10010..

Case Study 5: City Traffic Sensing



Source: Miovision 2017

What was the last mile problem/project objective?	To improve urban traffic sensing and signal operations, for arterial and corridor performance management
What were the data used?	A fusion of video imagery for vehicle classification, Bluetooth for vehicle IDs, and DSRC / LTE communication
What analysis was performed?	Descriptive – to understand vehicle behavior in intersections and arteries, Diagnostic – to evaluate turning patterns, driver choices, signal operations
What was the best practice/advantage?	Multiple data sources are fused through automated analytics and dashboard visualization for customer/stakeholder decision making in near real-time
What was accomplished, and what last mile gaps still remained?	Observe vehicle flows and patterns using classification and IDs, in processed form for input into decision-making. Trip purpose must be inferred through routes, land use; grid of sensors needed

Framework Scoring Indicators

Vehicle Observability?

ID √

√ Type

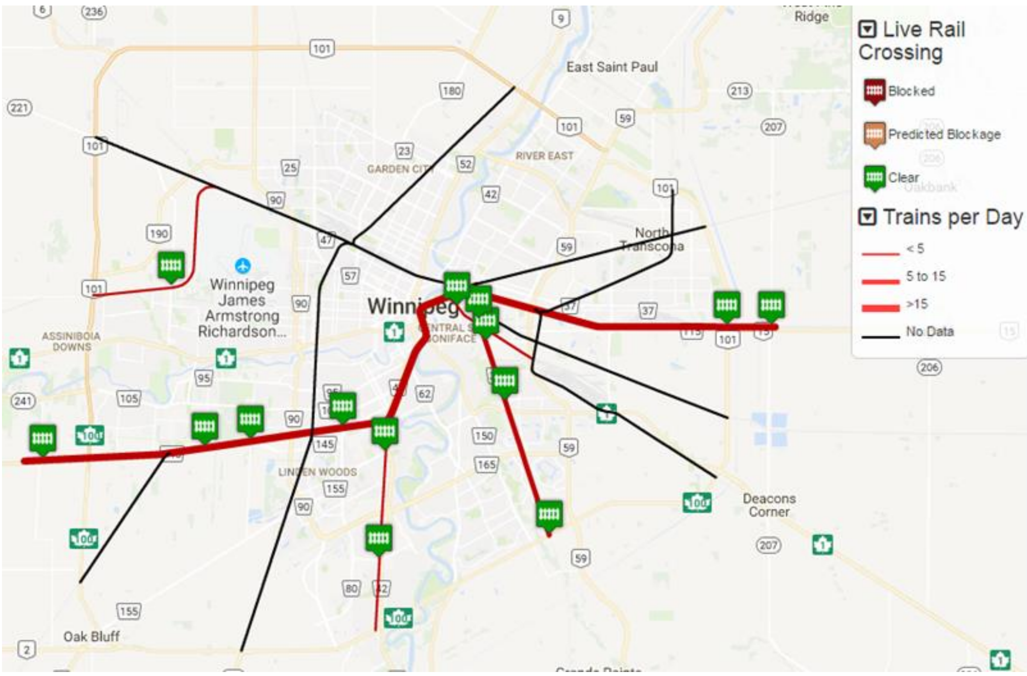
x Purpose

Data Access?

~~Access~~

Insight?

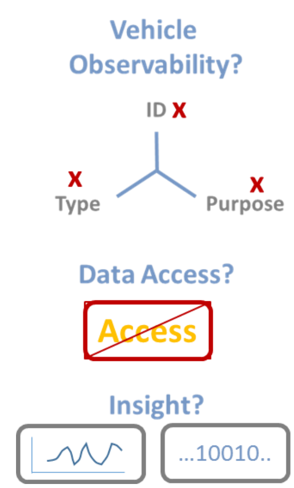
Case Study 6: Railway Track Crossings



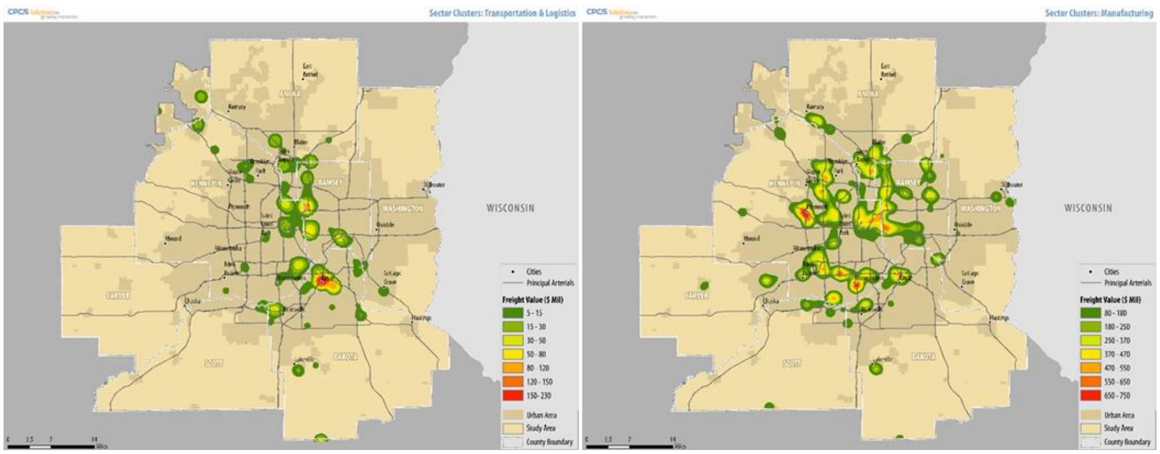
Source: Trainfo 2017

What was the last mile problem/project objective?	To predict the time and location of train crossings in real-time for use by commuters, emergency vehicle operators, and commercial vehicles
What were the data used?	A fusion of video imagery, Bluetooth, schedules information from train operators, multiple
What analysis was performed?	Diagnostic – train crossing patterns, Predictive – for use with Traffic Systems Management centers, and emergency dispatch systems for vehicle routing and signal timing
What was the best practice/advantage?	Automated analytics on fused data sources presented in a transformed state through dashboard visualization, input into decision-making
What was accomplished, and what last mile gaps still remained?	Predictive train crossing accomplished in areas where data is available, shared, and high density of sensors. A Little insight into a truck or commercial vehicle behavior at crossings. Both transformed raw data and insights available, but no access to private data

Framework Scoring Indicators



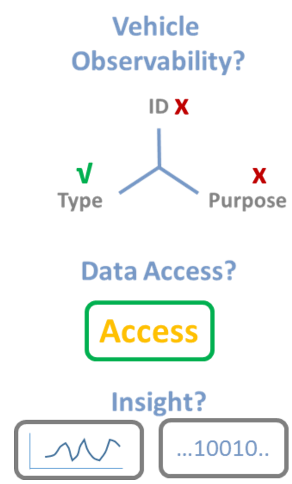
Case Study 7: MetCouncil Regional Freight Corridors



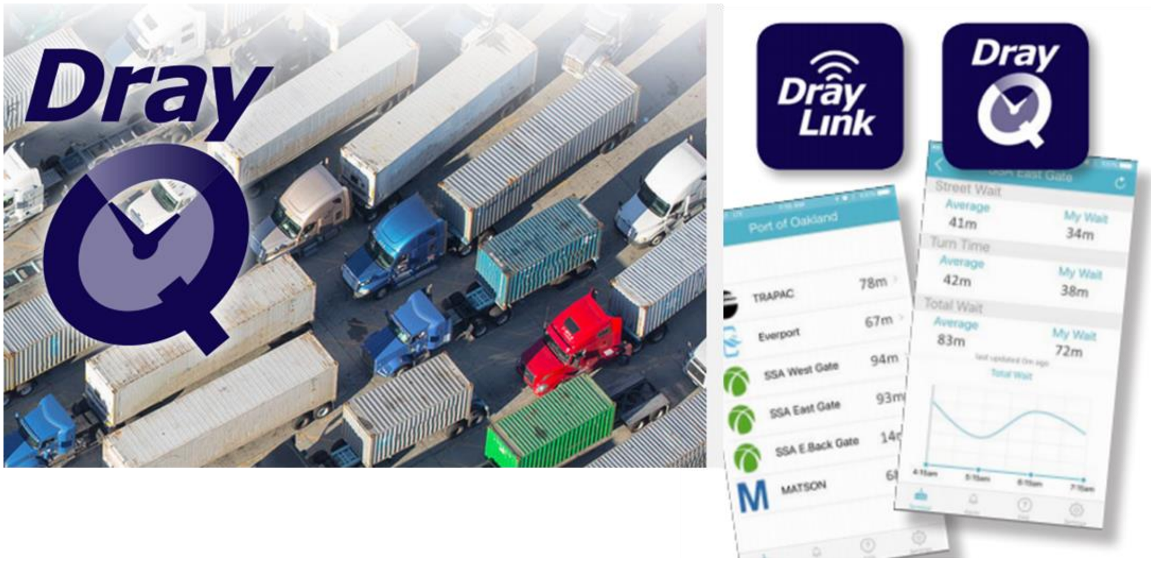
Source: CPCS 2016

What was the last mile problem/project objective?	Understand freight activity and truck tours in relationship to economic sectors and land use, for eventually prioritizing freight projects
What were the data used?	A fusion of truck counts, GPS, land use, and establishments data
What analysis was performed?	Descriptive – to understand vehicle tour patterns in relation to land use
What was the best practice/advantage?	Fusion of data already collected by the agency and used in new ways including visualization and mapping, systematic regional focus instead of specific location, or corridor
What was accomplished, and what last mile gaps still remained?	Enabled sector based distinctions of freight activity and value of flows, cannot provide last mile resolution without finer grained data, needs intensive analysis and transformation

Framework Scoring Indicators



Case Study 8: Ports of Seattle and Tacoma Drayage Activity



Source: Leidos 2017

What was the last mile problem/project objective?	To predict port servicing operations performance for trucks, including wait times, queue lengths, and other parameters
What were the data used?	A fusion of sources including on-board device Bluetooth, WiFi, GPS, and port system transactions
What analysis was performed?	Descriptive – in terms of performance statistics, Predictive – calculating wait times and other performance measures
What was the best practice/advantage?	Phone / device-based application (app) to display performance metrics through automated analytics and visualization, using data from a variety of private sources
What was accomplished, and what last mile gaps still remained?	This approach increases predictability of operations for on-port and commercial carriers but offers little to no visibility into vehicle observability or performance outside of the port envelope

Framework Scoring Indicators

Vehicle Observability?

ID √

√ Type

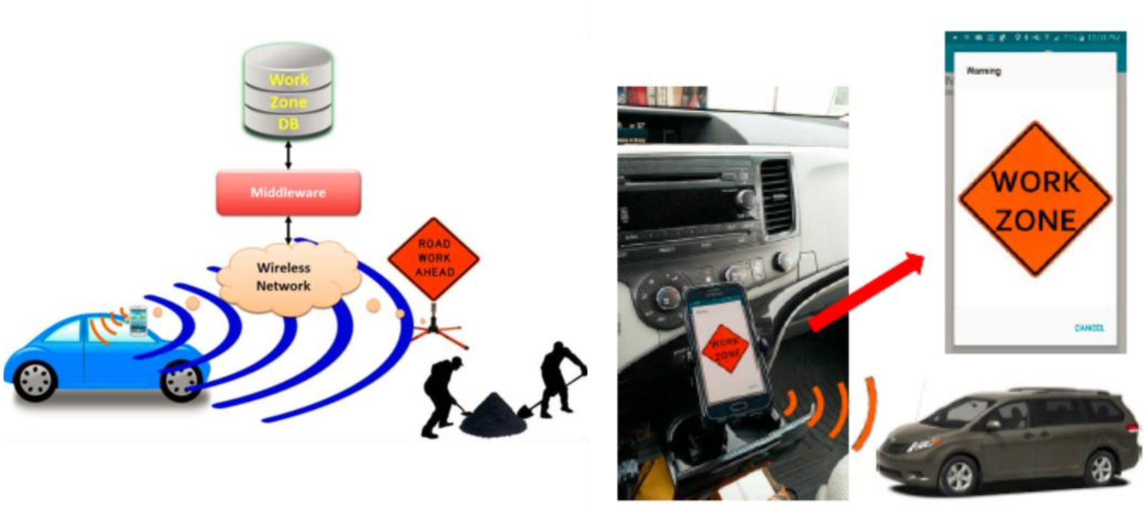
√ Purpose

Data Access?

~~Access~~

Insight?

Case Study 9: MnDOT Work Zone Alerts



Source: MnDOT 2017

What was the last mile problem/project objective?	To alert drivers of passenger and commercial vehicles of work in progress near work zones to protect workers
What were the data used?	Two-way data between vehicles and receivers using Bluetooth, GPS, and messaging
What analysis was performed?	Diagnostic – reporting work zone activity to approaching / nearby drivers
What was the best practice/advantage?	To provide specific and targeted messaging to affected nearby drivers based on vehicle type and identifier in relevant zones through automated DMS systems through a smartphone app
What was accomplished, and what last mile gaps still remained?	Pushes out the information to vehicles based on type and location, and allows for reverse data collection, but does not study driver response or behavior near work zones after drivers receive the message

Framework Scoring Indicators

Vehicle Observability?

ID √

√ Type

x Purpose

Data Access?

~~Access~~

Insight?

Appendix D: Real-Time Corridor Management — Concept and Recommended Solution Architecture

Real-Time Corridors

This section discusses real-time arterial management for Freight Signal Prioritization and Dynamic Two-Way Messaging, as state of the art applications for freight-related operations under the banner of "Real-Time Corridors". Computer Vision, MAC address recognition, and cloud-based software are the main innovative technologies that support these specialized applications (see Appendix A for a general discussion of the "universe" of freight data sources and analytical approaches). A guide to potential solution architectures and data needs for real-time corridors is included here in this Appendix.

Challenge: Understanding last-mile freight behavior in real time

Some of Florida's last mile challenges are associated with the movement of trucks through signalized arteries and corridors, and near chokepoints such as bridges, ramps, and railway crossings. The most relevant observed challenges during traffic operations that create frictions for the safe and efficient movement of trucks and their interactions with other traffic modes are:

- Long truck wait times at busy signalized intersections to access/leave freight facilities
- Frequent stops and starts, accelerations and decelerations
- Wide or difficult turns that create traffic slowdowns, especially during peak travel periods
- Queuing on or near ramps to enter signalized arteries, facilities, or near railway crossings
- Potential conflicts and interactions with other vehicle types, including cars, bicycles, or trains at crossings

The common thread linking many of these challenges is the lack of an operations feedback loop between field conditions and the traffic management center, i.e. between freight traffic behavior at granular time intervals or activity at chokepoints such as railway crossings, and operations decisions such as signal timing, control, or information-based to notifications to drivers to influence their behavior (speed, routes, etc.).

The freight operations-related opportunity area ("real-time corridors") involves the ability of public agencies to sense and respond to, and perhaps influence freight behavior in real time.

Public sector implications for last mile freight operations

According to the Federal Highway Administration, there are more than 330,000 traffic signals operating in in the U.S. Most agencies re-time signals on a 3- to 5-year cycle at a cost of about $4,500 per intersection unless there are signal-related malfunctions, failures or incidents, or dramatic changes in traffic patterns (Federal Highway Administration, 2017). In the absence of real-time data about the need for retiming or maintenance, and given the prohibitive cost of manually collecting traffic data to frequently update signal timing, retiming and signal maintenance schedules are based on models and simulations. Further, many agencies use between three to seven signal timing plans per day and different plans for weekends. An agency's choice of plan may not be calibrated or updated to coordinate with real-time traffic conditions (Transportation Research Board, 2010).

The benefits of optimizing traffic flows through frequent retiming, re-phasing, and advanced signal control are well documented (Transportation Research Board, 2010; Federal Highway Administration, 2015). New traffic data collection, vehicle classification approaches, and signal network connectivity have made it possible to not only automatically monitor signal performance, but also close the feedback loop between traffic conditions and signal operations. Feedback is accomplished through Adaptive Signal Control (ASC). ASC is not a cure all for traffic congestion overall, but it gives traffic system operators more tools to create a more responsive infrastructure network.

Adaptive Signal Control (ASC) is a suite of applications that uses a variety of approaches, including data collection, communications, instrumentation, and controls, to alter the operations of traffic signals. Specialized applications include dynamically changing signal behavior to prioritize buses, i.e. Transit Signal Priority, or pre-emptive actions to allow the free flow of emergency vehicles.

Freight Signal Priority is an extension of these concepts to dynamically manage signals and intersections to increase the fluidity of freight and simultaneously mitigate externalities such as pollution and greenhouse gas emissions.

Anticipating the increasing connectedness and automated communications ability of vehicles with embedded sensors (Vehicle-to-Infrastructure and Infrastructure-to-Vehicle communications), real-time arterial management approaches are now closer to reality. The final report for NCHRP 20-102(03), Challenges to CV and AV Applications in Truck Freight Operations, suggests that:

"Once automated freight becomes a reality, large amounts of data will be available…therefore there is a need to prepare and plan for managing and processing huge data sets that will be coming from CV and AV enabled trucks in order to increase their usefulness for planning and operations needs as we transition from the age of data scarcity to data abundance."

Many technologies and approaches making use of new data sources are close-to-mature or rapidly approaching readiness and can be deployed to manage arteries and signalized corridors in real-time.

Freight Signal Priority Concept and Related Applications

An important freight-relevant application making use of Vehicle-to-Infrastructure communications approaches is Freight Signal Prioritization (FSP) – modifying signal timing and traffic flow control to prioritize the flow of freight and commercial vehicles. This application was formalized by the Federal Highway Administration's (FHWA) Connected Vehicle Reference Implementation Architecture (CVRIA) in mid-2015. FSP is officially defined by CVRIA as:

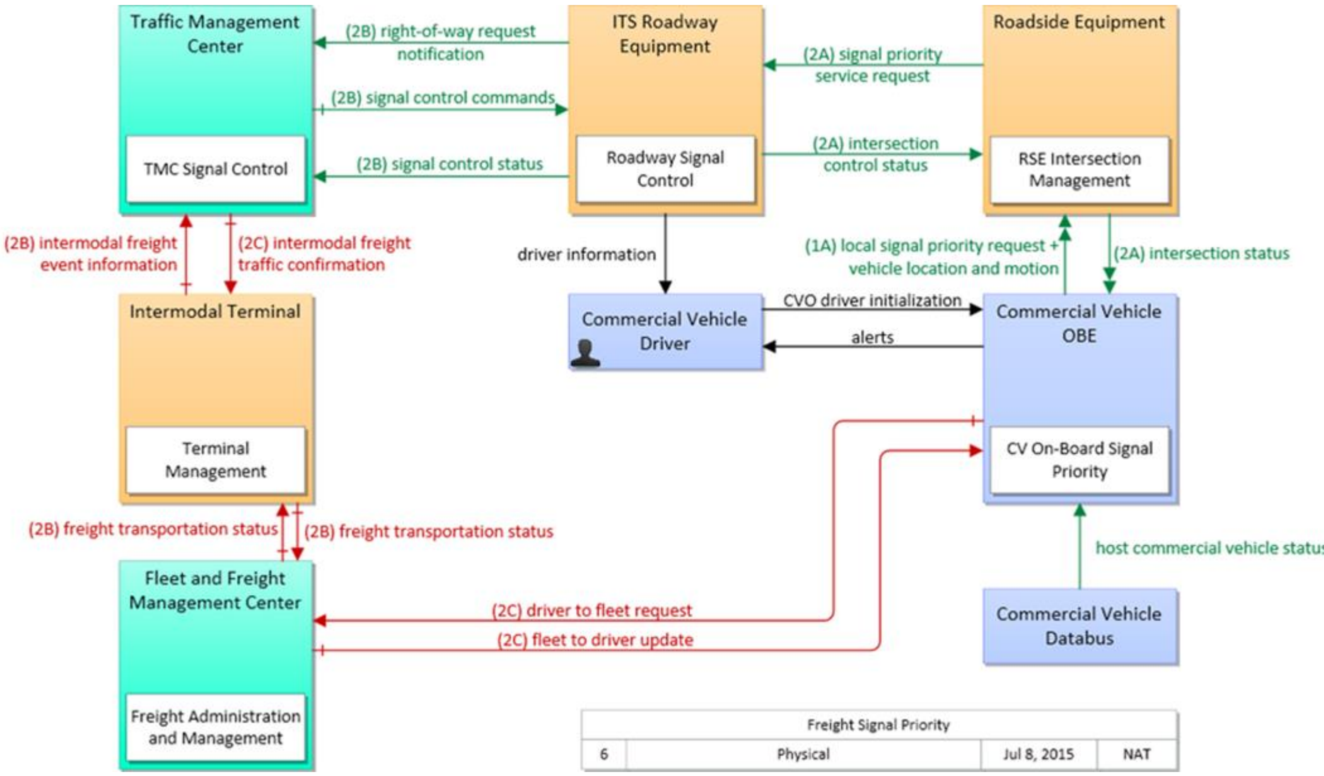
The Freight Signal Priority application (FSP) provides traffic signal priority for freight and commercial vehicles traveling in a signalized network. The goal of the freight signal priority application is to reduce stops, delays, to increase travel time reliability for freight traffic, and to enhance safety at intersections.

FHWA's FSP architecture envisions using various sensors to acquire and use data from vehicles identified as trucks as they move through signalized intersections by adjusting signal cycles to accommodate truck movements through the intersection without stopping. FSP's other aspirational benefits include:

- **Time savings** due to reduced travel time for adjacent/following vehicles traveling in the same direction within the signalized corridor,
- **Environmental benefits** from reductions in truck fuel use and emissions, and
- **Economic benefits** derived from improved freight flows related to specific cargo types/characteristics.

Figure D-1 shows how the FHWA CVRIA envisions that an FSP system could be applied. The architecture defines physical system components of an FSP application at a single intersection. Extending the framework to multiple signals located closely together in a corridor adds to the complexity of the approach. For example, pre-signaling inputs from an upstream detection location to a downstream signal prior to vehicle arrival needs additional sensors upstream and downstream (hardware), communication protocols, and software to manage sensing and trigger actions. The approach is further complicated if trucks were to turn into or out of a corridor, or additional trucks were to enter a corridor mid-stream from other freight facilities or from crossing roadways. For these reasons, FSP implementation corridors must be carefully selected and meet certain design and performance standards.

Figure D-1. FHWA CVRIA Freight Signal Prioritization Architecture



Source: FHWA CVRIA

Even though the CVRIA architecture describes FSP at a single arterial intersection, the approach can be extended to special locations such as railroad crossings that have both freight and train activity. This specialized application has particular relevance in Florida because of the large number of at grade rail crossings. Instead of adjusting signals, however, trucks and commercial vehicles could receive recommendations to adjust their speeds or take alternative routes to avoid crossing blockages. These actions may rely on applications such as dynamic two way messaging to provide in-vehicle alerts based on real-time system conditions.

Technologies such as Dedicated Short Range Communication (DSRC) Basic Safety Messages (BSM) and Media Access Control (MAC) address recognition (through WiFi and Bluetooth) have enabled real-time automated communications between vehicles and infrastructure. When individual truck identification information is registered in the communications systems and recognized by embedded sensors, FSP related actions are more likely and workable. In addition to FSP, the BSM can also provide other useful information to the controller regarding truck location, vehicle attributes, and traffic conditions that can be passed back to freight managers/dispatchers so they can more effectively anticipate, plan, and track truck movements through the system. Truck identifiers such as Bluetooth signals or other emitters identifying truck maintenance info or other parameters could also be incorporated to advantage in this process as well.

Proposed solution architecture and data sources for real-time corridors

The opportunity area of real-time corridors is promising, as it represents the application of a number of best practices, including some related to freight. However, the solutions are extremely system specific; each local multi-modal transportation network has its own set of assets, attributes and behaviors, and transportation management and operations performance objectives. Nonetheless, the techniques of traffic sensing and dynamic control are also general and can eventually be customized and adapted to suit the precise needs of a local system.

Under the broader area of real-time corridors, the specific applications include:

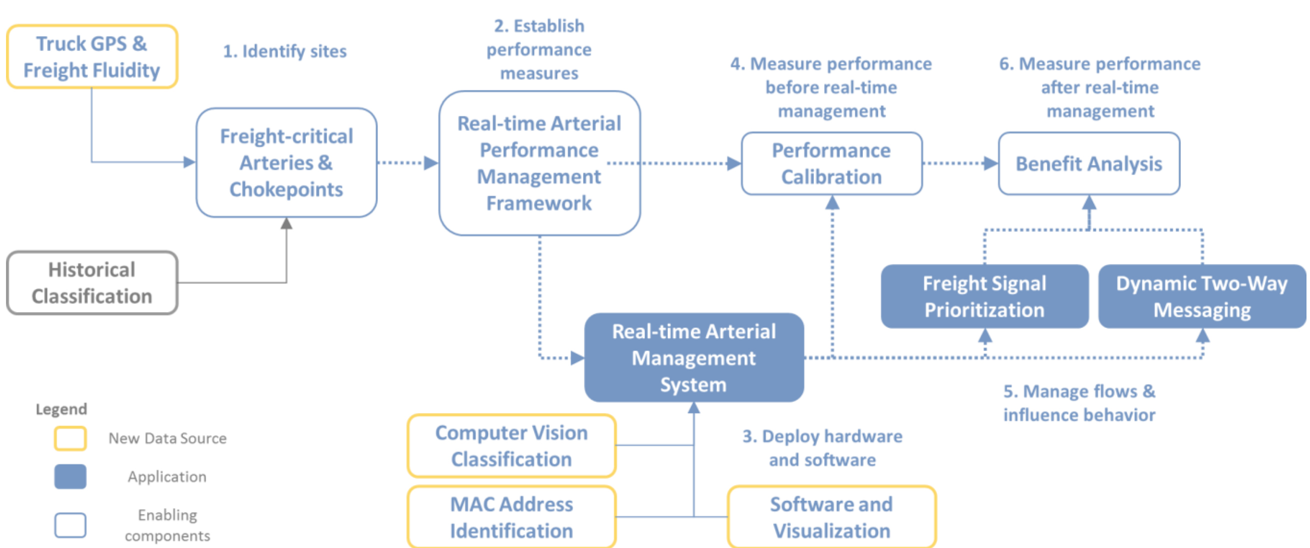
- Freight Signal Prioritization
- Real-time Alerts and Dynamic Two-Way Messaging
- Other applications extending to freight "interactions" (such as with transit, bike & ped, cars) under the architecture of the Real-time Arterial Management System

Some of these applications are closer to "readiness" than others. At the same time, the technologies and approaches will continue to evolve in the near-term, while the solutions will take longer to implement. The deployment must be therefore also be thought of in terms of investment time-cycles, in addition to tactical operations.

Real-time corridors must be carefully architected up front, because they will be gradually built out over time, and the pieces must complete a bigger picture.

Our recommended stepped approach in Figure D-2 can help develop a framework to accomplish the objectives of real-time corridors.

Figure D-2. Stepped Approach to the Real-time Corridors opportunity area, and its specific applications

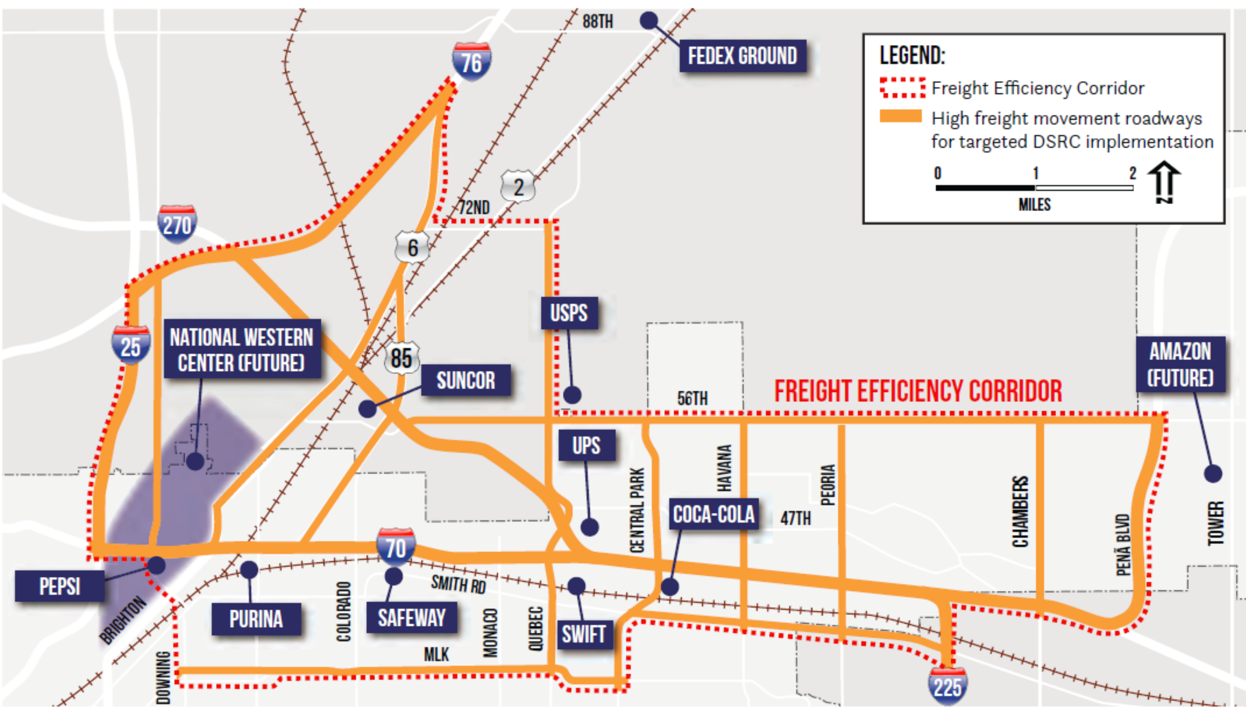


The steps are as follows:

1. Identify high-priority arterial corridors and sites: This first step for identifying freight-critical arteries and locations can leverage some of the same vehicle GPS data as recommended for the Freight Fluidity analysis, notably the freight Flow Map and identification of critical chokepoints such as railway crossings. While there are many potential corridors and crossings, the prioritization approach could make use of multiple criteria such as volumes, incidents, complaints, sector based impacts, and proximity to critical facilities such as Port Everglades, for example. Vehicle GPS data can be supplemented by historical vehicle classification and other traffic data. The highest priority arteries and sites should be those where freight flows are critical *and* improvement in flows towards real-time coordination will be most beneficial.

FDOT has rich data on the location and attributes of freight facilities in different sectors, in its Freight Facilities dataset (see Appendix C – Case Study 1). This can inform the freight fluidity map described above, and also assist with identifying freight-critical corridors. Figure D-3 below shows an example of a freight efficiency corridor concept in the Denver metropolitan region. The site was chosen by Denver for pilot tests because of the high degree of private freight activity, intermodal interactions, and last-mile access challenges in this corridor.

Figure D-3. Freight efficiency corridor site in the Denver metropolitan area



Source: US Department of Transportation, "Beyond Traffic – Smart City Challenge", City and County of Denver

2. Establish performance measures: The second step is the choice of performance measures in the context of a real-time performance management framework. In other words, many different performance measures should be evaluated and those most relevant to the arteries and sites must be chosen prior to developing the specifications of a pilot approach or project (including hardware and software). The framework should clearly link the metrics established with the overall goals of the program. Table D-1 lists some relevant performance measures, and some empirical observations corresponding to these are depicted in Figure D-4.

Table D-1. Examples of simple and complex Signal and Arterial Performance Measures

Category	Performance Measures
Simple Signal Performance Measures (SPMs)	Vehicle volumes Wait times Hardware problem / malfunction detection
Complex Signal and Arterial Performance Measures (APMs)	Red/Green Allocation Red / Green Occupancy Ratio Purdue Split Failure Arrival Volumes Movement Progressions, i.e. Arrivals-on-Red vs. Arrivals-on-Green Purdue Coordination Diagram Transit and Emergency Vehicle Pre-emption
Performance Measures with additional real-time and historical data analytics and visualizations	Point-to-Point Travel Time Congestion Plots Corridor Travel Time Reliability Measures Freight congestion impacts

Source: CPCS analysis of literature, reports, and vendor materials

Figure D-4 Examples of simple and complex Signal and Arterial Performance Measures

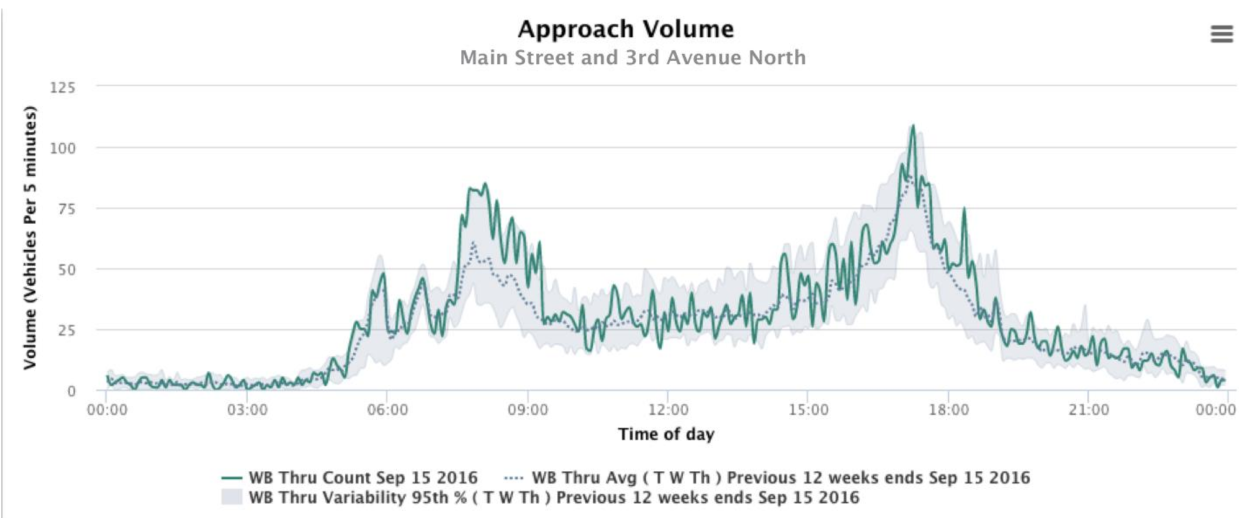
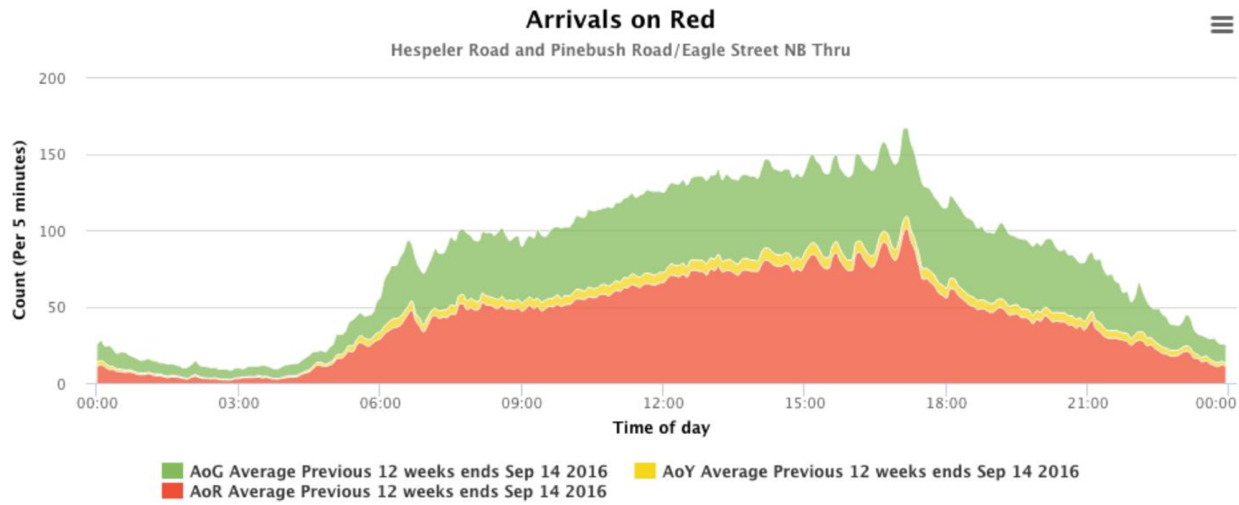
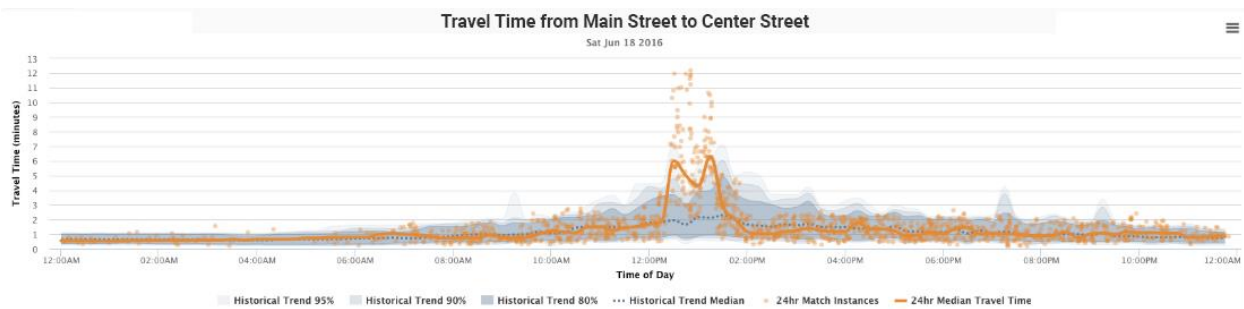


Figure D-5 Examples of simple and complex Signal and Arterial Performance Measures (Continued)





Source: Miovision

Performance measures for the more specialized applications within this opportunity area, such as railway crossing performance, real-time information alerts, and dynamic two-way messaging will likely have additional performance measures.

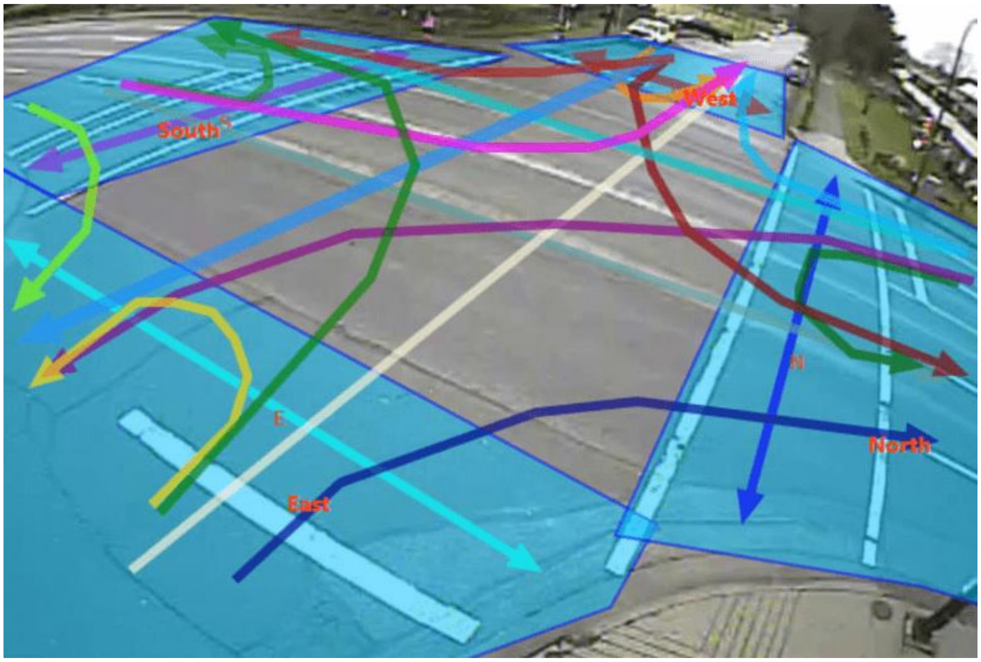
3. Select and deploy hardware and software: The choice of hardware and software and the architecture of the program will depend on the framework and performance measures of interest. For example, if real-time truck turning counts at intersections are desired, then the hardware must accommodate data collection to support both vehicle classification and path analysis, and the software must be able to process the data feed and visualize it for decision-makers. Depending on the maturity of the approach the analysis may lag, i.e. the results will be post-processed, but analysis may eventually be available in real time as the technology matures further.

Computer Vision

Figure D-5 shows an example of computer vision, i.e. the use of automated analytics on a video feed, to classify vehicles and show their turning movements at an intersection. This approach requires integration between cameras, communications assets, analytics software, and visualization capabilities.

Other types of sensors such as advanced upstream detection units and stop-bar detectors can supplement basic signal controllers and cameras at intersections in a full build out for a wide range of performance measures.

Figure D-5. Intersection turning movements based on path analysis and vehicle classification using video imagery

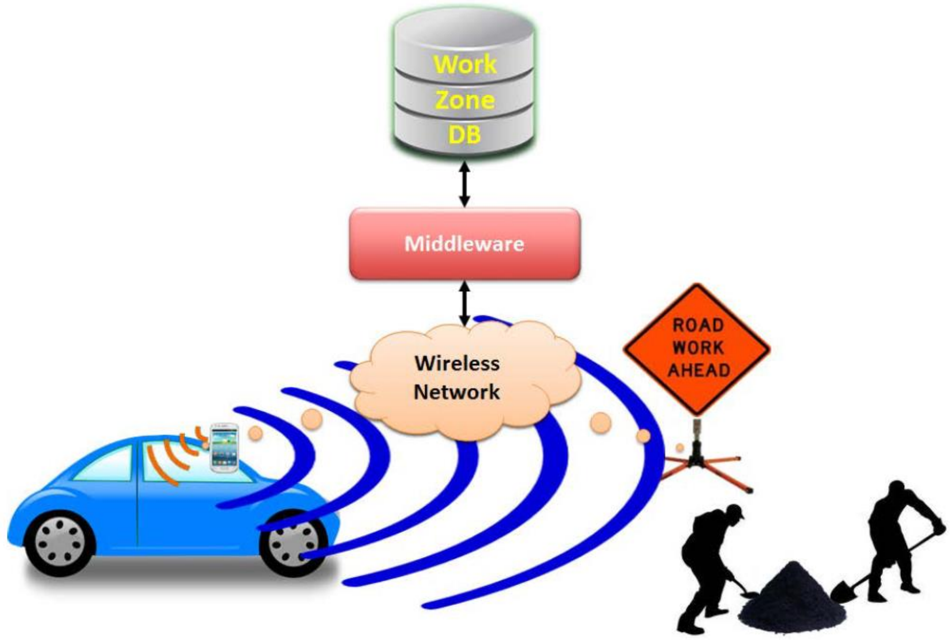


Source: Miovision

Media Access Control (MAC) Address Identification

A full buildout could also include Bluetooth or WiFi-based MAC address identification to assess proximity to hazards and work zones, travel speeds, and routes. These technologies can support Infrastructure-to-Vehicle and Vehicle-to-Infrastructure communications. Dynamic two-way messaging for work zones is one specialized application using this technology, which may require additional architectural components as shown in Figure D-6.

Figure D-6. Dynamic Two-Way Messaging for work zone safety using Bluetooth



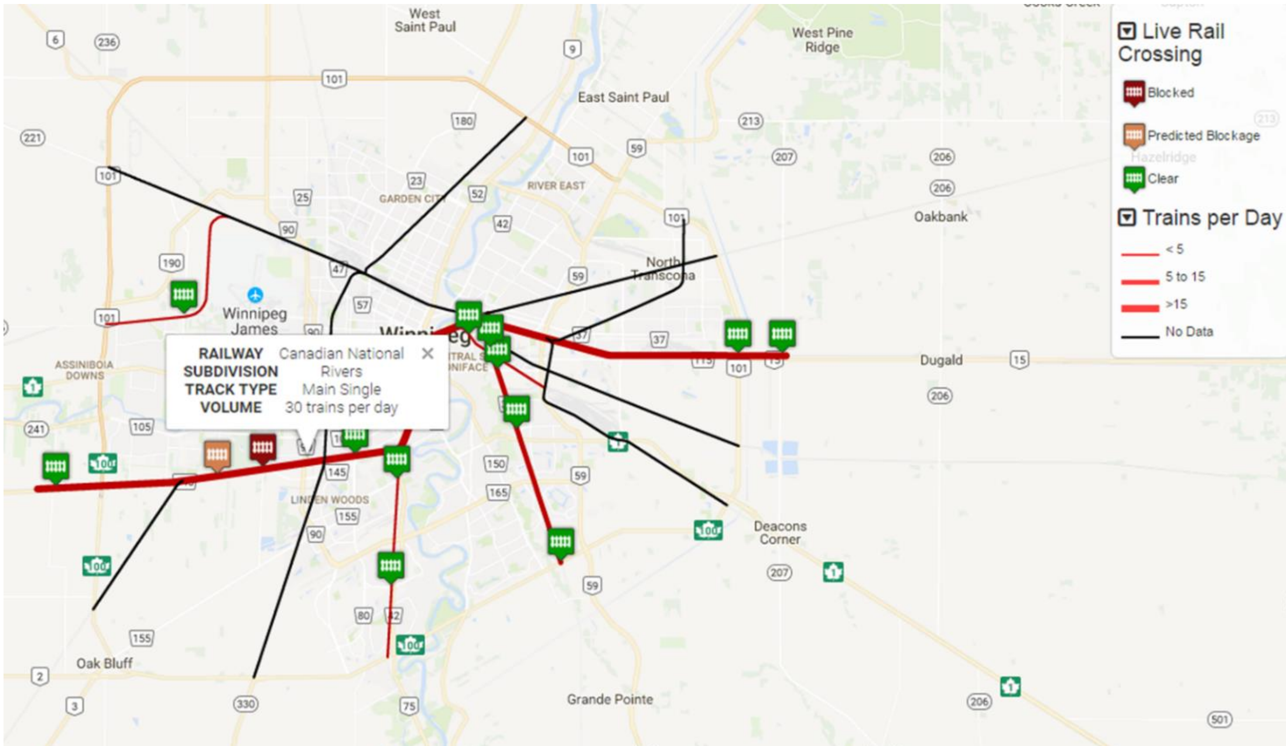
Source: Minnesota Department of Transportation

Software Dashboards

Specialized software could leverage the very same data feeds being generated for truck identification and classification at arterials and combined with other sources, such as railway schedules to anticipate blockages at crossings. The snapshot of a real-time dashboard in Figure D-7 shows the current and predicted blockages at crossings as well as clear crossings in a region. The same visualization also charts the average number of trains on the respective lines based on historical data.

The large number of at grade rail crossings in Florida, and in District 4 in particular, could imply that there are some freight critical corridors that contain crossings. The opportunity to include data collection and relevant to truck behavior at crossings should be considered at the site selection stage in above in Step (1). Some of the traffic related performance measures discussed above in Step (2) could be applied at rail crossings so that a “truck + train” activity map of crossings can be generated through data collection over time.

Figure D-7. Real-time and historical awareness of train activity at regional crossings in Winnipeg, Canada

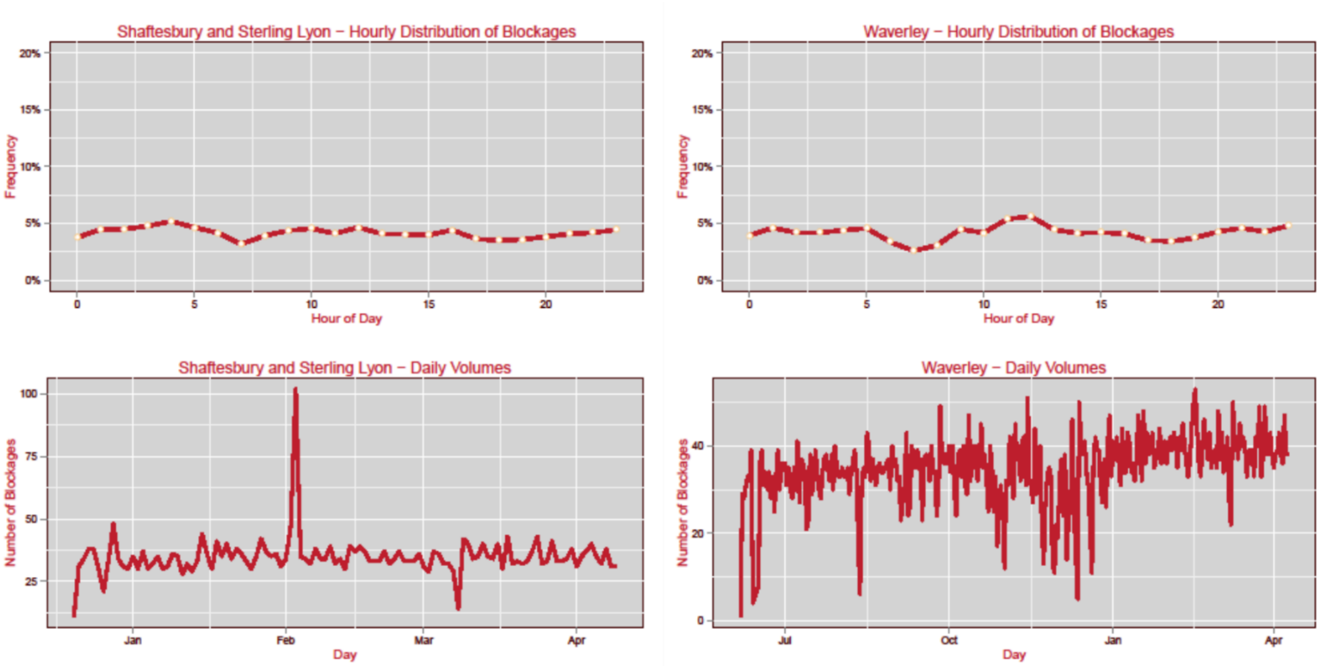


Source: TRAINFO, MORR Consulting

4. **Measure performance before implementing changes**: This step is critical for two purposes - generating a historical benchmark and "current" profile that will be necessary to understand the effect of an intervention (change in approach to signal timing, for example), and for calibrating any new sensors, hardware and software in the anticipated architecture of the real-time corridor. In other words, the pre-intervention performance measurement should be conducted using both current as well as the new data collection techniques for calibration.

Developing a current profile of the sites in question is important because there are variations in behavior at different locations even within the same area. Figure D-8 shows two railway crossings that have a very similar profile in terms of the frequency of hourly blockages but very different levels of magnitude and variation in the number of blockages within those hours. These profiles would be useful while evaluating the specific effects of re-routing trucks as an intervention, once a change has been implemented. Site-specific profiles can also inform the choice of sites in future, where benefits could be expected to be most significant.

Figure D-8. Establishing the "current" profile of daily blockages at rail crossings



Source: TRAINFO, MORR Consulting

The importance of calibrating the proposed data collection techniques and recognizing the possible sources and types of measurement error is reinforced by a completed MnDOT Freight Signal Prioritization study (SEH, 2012). The study used in-road loop detectors to identify trucks at a single relatively low truck-traffic intersection (i.e., approximately 1800 trucks per day). Traditional 6-foot by 6-foot loop detectors separated by 24-feet were located in the roadway upstream on the approach prior to the standard cycle extension loop detectors that were in-place at the intersection. When a vehicle longer than the 24-feet was detected, it was determined to be a "truck" and the protocol for a green signal extension was activated so that the "truck" would not have to stop before clearing the upcoming intersection. Truck detection validation for this detector set-up had mixed results—trucks and several non-trucks were identified as trucks requesting priority. At the same time, several trucks/freight vehicles were not identified as trucks by the loop detectors in this configuration. While this example certainly indicates the need for an appropriate choice of technology, it also reveals that there will be "false positives" and false negatives" and these must be factored into the framework and also the post-evaluation of benefits.

5. **Manage flows and influence behavior**: Among the many possible specialized applications in real-time corridors, this discussion envisions two: Freight Signal Prioritization and Dynamic Two-Way Messaging. As discussed above, there is a wide range of performance measures and choices of hardware and software that could apply to the real-time arterial management framework broadly, so this step of the solution architecture process would focus on establishing the types of interventions for these two applications.

Freight Signal Prioritization

There are four possible actions when a truck approaches a signal – doing nothing, and three types of changes to signal cycle. Signal controllers can change signal cycles in three ways once a truck seeking priority treatment is detected: extension of the green signal, early green, or phase insertion (Ioannou, 2015). Figure D-9 shows the four actions (including no action required) in FSP signal operations to accommodate a truck once detected and a signal priority request is made.

Figure D-9. Four cases for signal priority action upon detecting a truck

Source: METRANS (2015)

→ **Case 1 - No Action**: Anticipated truck arrival is during a green cycle, and no action is required.

→ **Case 2 - Cycle Extension**: Anticipated truck arrival would require truck to stop and re-accelerate. The green cycle is extended to avoid truck stopping.

→ **Case 3 – Early Action**: Anticipated truck stoppage can be addressed by advancing the following cycle. Include an early green phase on next cycle to accommodate truck movement.

→ **Case 4 – Phase Insertion**: Anticipated truck arrival is during yellow cycle. To accommodate the truck, Phase 3 (i.e. additional phase) is skipped at signal and Phase 1 is used to allow the truck priority in through movement.

The premise of this approach is that FSP for commercial trucks can improve their throughput and those of other corridor vehicles adjacent or following the commercial trucks. However, extending green cycles or advancing/skipping cycles as shown above can have negative impacts on cross-traffic vehicles of all types by shortening their cycle times. As a result, planning and policy choices to facilitate truck movement will likely have to be made prior to adoption of FSP in a busy corridor, as part of the framework design in Step 2.

There have only been a few demonstrations of FSP, and it is also likely that future simulations and field studies of FSP implementation would need to determine a methodology to properly balance competing interests between freight and other traffic throughout the daily travel cycle. The calibration of the solution will depend on local conditions.

Dynamic Two-Way Messaging

In addition to safety messages and traveler information alerts, two-way messaging applications can be used to passively observe vehicle behavior within a geo-fenced region. In other words, the message that is passed from an in-vehicle device to an embedded transponder can either be communicated in the form of text, audio, or visual cues (meaningful to a human) or as a passive signal to detect presence, location or device ID. Security and encryption protocols can be used to de-identify the data such that a device cannot be linked to a vehicle's or driver's identity, and only to behavior, unless a fleet operator has opted in to sharing vehicle identity in a registered data base. This approach can therefore be used to both monitor as well as communicate with vehicles in a corridor.

6. Measure performance after real-time management: The final step of implementing a solution for real-time arterial management in a corridor is to evaluate the benefits captured. Although this step comes last, the requirements of benefit analysis (structuring the pre/ post test) must be understood and detailed as early as steps (1) and (2) in relation to site selection, and selecting performance measures as part of the real-time management framework.

Freight Signal Prioritization

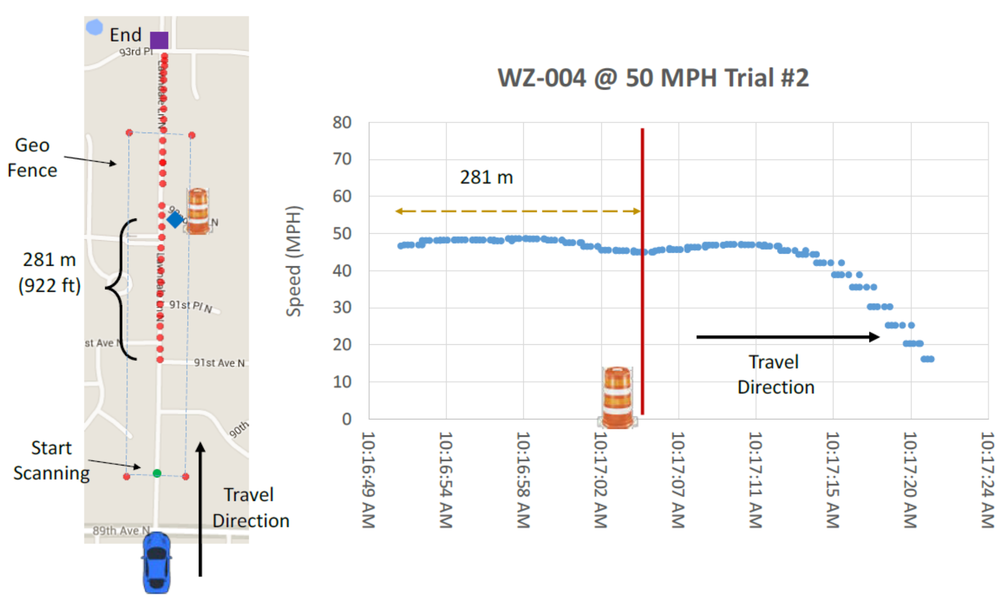
One completed FSP study has documented some success, and the results of field testing are consistent with what computational simulations of the solution architecture might show (Federal Highway Administration, 2015). The study evaluated the potential network-wide impacts of a Multi-Modal Intelligent Transportation Signal System (MMITSS) based on a field data analysis utilizing data collected from a MMITSS prototype and a simulation analysis. The Intelligent Traffic Signal System (I-SIG), Transit Signal Priority (TSP), Freight Signal Priority (FSP), and the combination of TSP and FSP applications were evaluated. FSP simulation results indicated the approach successfully reduced travel times at some locations for trucks equipped with sensors to request priority, but that these requests for priority also increased system-wide delay, due to increased delays on side streets. The results of the field test demonstrated that MMITSS applications effectively improved the travel time and the delay of the equipped vehicles. In particular, FSP reduced the delay of connected trucks by up to 20% and I-SIG improved travel time reliability by up to 56%, compared to the base case (pre-intervention), but the trade-off is that the approach may produce overall system-wide negative impacts.

Dynamic Two-Way Messaging

The experimental results of MnDOT's two-way messaging study between a device with Bluetooth Low Energy (BLE) tags and an in-vehicle app was successful and shows promise for applying this approach in situations beyond work zone safety, such as real-time corridors. Several experiments were conducted to validate the system performance under different roadway geometry, traffic, and weather conditions (Minnesota Department of Transportation, 2016). The results indicated that the in-vehicle smart phone app could systematically detect a long-range BLE tag placed over 410 feet (125 meters) away on a traffic barrel on a roadway shoulder, while travelling at 70 mph (113 km/h).

The behavior of the vehicle (ex. speed) could also be successfully tracked through the study corridor, as the messaging system could track vehicles and register the observations in the system database within a radius of 50 miles. Figure D-10 shows the observation and tracking of a vehicle that is limited to a geo-fenced study corridor. The profile shows the speed of the vehicle throughout the section of the geo-fenced area that is within the detection range of the Bluetooth module. In other words, as the module communicates its presence and message alerts to the in-vehicle app, the app returns its speed and location to the database.

Figure D-10. Corridor study results of a test of two-way messaging using Bluetooth LE MAC ID recognition



Source: MnDOT (2016)

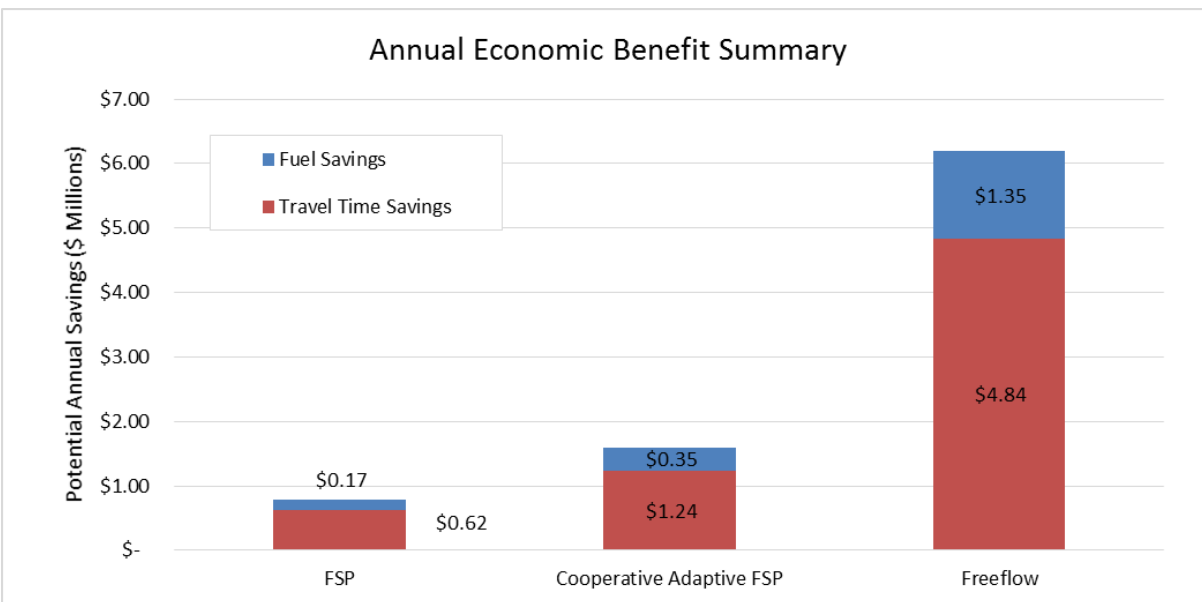
To account for privacy concerns, the messaging system and app only detected those tags that were registered in the system database, and ignored all other Bluetooth devices. This flexibility suggests that specialized approaches could be developed to only track and communicate between freight vehicles and devices in participating fleets. This approach can extend to a range of different alerts and message types including but not limited to work zone safety, rail crossing blockage status, recommended speed suggestions, hazard alerts, etc.

Combined FSP and Two-Way Messaging

The freight component of the Florida's Automated Vehicle Initiative estimated the benefits of real-time corridor management for the perishable freight industry in the Miami region (Florida Department of Transportation, 2017). This study envisioned both specialized applications – both FSP, and two-way messaging (Cooperative-Adaptive Signals with FSP, CA-FSP). In the latter case, messages recommend travel speeds to the vehicle in addition to signal actions, which are triggered upon truck arrival. The study compares benefit estimates to that of an ideal case of free flow truck movements, in which there is no delay to freight vehicles.

The economic benefit estimates of the two applications and ideal scenario are summarized in Figure D-11. Cooperative-adaptive FSP is estimated to provide greater benefits from both time and fuel savings because of the coordination between signals and vehicles through two-way communication. The results of this study are based on simulation models and some field data collection to establish the current profile of travel conditions. This approach is yet to be tested in the field.

Figure D-11. Summary of Annual Economic Benefit Estimates of FSP and CA-FSP



Source: FDOT (2017)

Appendix E: Location-enabled Mobile Data Sources

Table E-1. High-Precision Global Navigation Satellite Systems

High-Precision Global Navigation Satellite Systems	
What is the new data source?	Satellite receivers can provide global geolocation and time information to users in all weather conditions by connecting to four or more satellites.
Why is it new?	The technology is not new, however, it is being applied in new ways to understand truck movements.
What challenges does the new data source help solve?	**GPS vehicle data** can provide real-time measures of travel speeds (de Boer 2012, Obuhuma 2012), road operating conditions (Huber et al. undated) and, by tracing GPS device paths, average travel times across segments. **GPS trace data** can also provide OD information (Lin 2013). However, because GPS trace data is likely more intensively employed by certain classes of road users, such data may not provide a representative OD sample suitable for more general use. When combined, these two types of data can show a vehicle's speed along its route. Data from multiple vehicles can reveal common OD points and infrastructure bottlenecks, helping agencies alleviate congestion and improve last-mile, last 50-feet issues, and improve synchronization of land use and transportation planning.
How is the new data applied?	GNSS user equipment provides the computed position and time to the end user application, for example, navigation, surveying or mapping.
What is required to use the new data source?	To fully extract value from high-resolution GPS / GNSS data, organizations need a way to streamline the acquisition and storage of large data sets, and develop capabilities to analyze and visualize these data to inform performance measures. Many of these routines are automated using GIS and other analytical software, and decision-makers can rely on visual dashboards. Agencies interested in minimizing hardware, software, IT, and analytics capabilities can subscribe to services from specialist vendors.

Table E-2. Cellular/Wireless Communication

Cellular/Wireless Communication	
What is the new data source?	Cellular wireless communication (cellular) is a communication technology that allows for the wireless transmission of data and voice between mobile devices and other mobile devices, the internet, or other services across long distances. Data is transmitted between devices using various bands of the radio spectrum, depending on the particular technology and service provider.
Why is it new?	New advances in lower cost cellular technology and high bandwidth networks such as 4th Generation Long Term Evolution (4G LTE), and now 5th Generation have made cellular based communications all but ubiquitous. When cellular devices and their real-time data streams are correlated with the movement of vehicles, they take the form of both spatial and time series data.
What challenges does the new data source help solve?	Cellular-derived data's ability to identify common origin and destination points can help planners determine where freight generators and receivers may be located, and the routes that trucks take between origin and destination. These location-based data can also indicate dwell times, and speeds by interpolating between observations. The data can be applied to multiple freight challenges.
How is the new data applied?	Cellular communications are a source of origin-destination (O-D) data. Cellular O-D data are a measure of estimated device movements between pre-defined geographic areas/zones. The movements are developed based on analysis of mobile device sightings and activity locations over a set time period, ranging from weeks to months. The trips developed from cellular O-D data do not reflect actual trips, but rather the estimated trips derived from analysis of the device's movements and patterns over the subject time period. Proprietary algorithms impute the estimated trips of a device based on its patterns between its home, work, and other activity locations. The movements of each sampled device in the study area are estimated individually and then expanded and aggregated to develop the total number of cell based O-Ds for the study area's pre-defined geography.
What is required to use the new data source?	Agencies and organizations typically only need an acquisition/subscription agreement with a data aggregator and vendor to obtain the data, but they may need GIS, and databasing capabilities to analyze and visualize the data as with other mobile data sources. Cellular data may be less precise or prevalent (sampling distribution) than GPS / GNSS data sources, so the choice of cellular data involves a trade-off.

Appendix F: List of Florida DOT Data Sources Evaluated

Data Source	Type	Format	Frequency	Coverage	Data Owner in FDOT	Data Developer	Notable Data or Metrics	Acquisition Technique, Vendor (if applicable)	Access Mechanism for Districts, etc	Current Uses and Applications	Known Issues (e.g. Privacy, Data Quality, etc.)	Link	Latest Year	DOT Person to be contacted for validation (if necessary)
FreightSIM	Demand Model	CSV, Access, Cube, GIS	5 Years (Forecasts for 2010 and 2040)	Statewide	Transtat (TDAA)	Transtat (TDAA)	Daily vehicle trips estimated by mode, route, commodity and OD	Estimated at TAZ level using various freight data inputs	By request	Studies and reports	Provides information for heavy and medium trucks. Doesn't capture local truck traffic movement	http://www.fsutmsonline.net/index.php?/model_pages/comments/updated_florida_statewide_model_flswm_version_60_passenger_and_freight/	2010-base year and future 2040	Thomas Hill / Frank Tabatabaee
FAF	Commodity Flow	CSV	5 Years	National	N/A	FHWA	Value, tons, ton-miles by mode, route, commodity and OD	Database developed based predominanty using Commodity Flow Survey	Downloadable f rom FHWA	FreightSIM, trends and studies	The spatial resolution of origin and destination is very low. Florida is divided in 5 FAF zones	http://www.ops.fhwa.dot.gov/freight/freight_analysi s/faf/	2012 - base year and 2045 future year	Not applicable
HPMS	Infrastructure	GIS	Annual	National	Transtat (TDAA)	Transtat (TDAA)	Road extent, condition, performance, characteristics	Transtat submits HPMS data	Downloadable from FHWA	RCI	Limited to NHS mainly	https://www.fhwa.dot.gov/policyinformation/hpms. cfm	2014	Eric Brickner and Tina Hatcher
NPMRDS	Truck/Car	GIS, CSV	Monthly	National	Transtat (TDAA)	FHWA	Travel time in 5 min increments off the National Highway System	Collected by HERE (mobile devices, connected cars, commercial fleet, others) for NHS; free for DOTs through FHWA	By request	FDOT performance reports, studies	Large data storage, FDOT sharing agreement only allows usage for FDOT projects. No knowledge about sample size	http://www.ops.fhwa.dot.gov/freight/freight_analysi s/perform_meas/vpds/npmrdsfaqs.htm	2016	Joel Worrell
BTS NTAD	Infrastructure	GIS	Variable	National	N/A	BTS	Location of facilities	County-level, collected by BTS (free)	Downloadable from BTS	Mapping, visualization, studies and reports	Some datasets have not been updated for many years. For example intermodal terminal facilities was last updated in 2003	http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/fil es/publications/national_transportation_atlas_datab ase/index.html	2016	Not applicable
FDOT Multimodal Performance Measures Source Book	Various	Excel, pdf	Annual	Statewide	Transtat (TDAA)	Transtat (TDAA)	Performance measures for the SHS	Compiled by Transtat	Downloadable from FDOT	FDOT performance reports		http://www.fdot.gov/planning/statistics/sourcebook /	2016	Doug McLeod
ATRI GPS data from SHRP2 C20 Research	Truck	CSV, GIS	Monthly	National	Transtat (TDAA)	ATRI	Location, spot speed, heading	ATRI collects via GPS from its sample of trucks (Class 8-13). Licensed from ATRI.	By request	SHRP2 C20, 2014 Systems Planning Office study	Data is only usable for FDOT projects, Temporal coverage is for a couple months.	http://www.fsutmsonline.net/images/uploads/reports/PINJARI_FDOT_BDK84_977_20_Final_Report_All_Chapters_Aug2014.pdf	2010	Thomas Hill / Frank Tabatabaee
Rand McNally GPS data	Truck	CSV	1 Time	Statewide	Transtat (TDAA)	Rand McNally	Location, spot speed (every 10-20 min)	RM collects via GPS from its sample of trucks (Class 5-13). Licensed from RM	By request	Mapping, visualization, studies and reports	No unique vehicle identifier, double counts are possible, sample size unknown. Currently only a sample of data is available	Not applicable	2014	Joel Worrell
FDOT Traffic Database	Truck/Car	GIS, CSV, SQL, txt	Annual	Statewide	Transtat (TDAA)	Transtat (TDAA)	Volume, classification, vehicle weight, speed	Pavement sensors - 300 TTMS sites, 12,000+ PTMS sites, special counts. Collected by FDOT (free)	Florida Traffic Online, FDOT Transtat Website. Disaggregate data can be acquired by data requests.	Online and mobile display, traffic studies and maps, forecasting	PTMS sites collect data for 2-7 days only which is later estimated for computing AADT and AADTT numbers	http://www.fdot.gov/planning/statistics/trafficdata/	2016	Steven Bentz
INRIX speed data	Truck / Car??			National	Transtat (TDAA)	INRIX	Spot Speed	Available for purchase from INRIX	By request	Bottleneck Studies, Congestion Analysis	Sample Data	Not applicable	2010	Thomas Hill / Frank Tabatabaee
Roadway Characteristic Inventory	Various	CSV, GIS, SQL DB	Continuous	Statewide	Transtat (TDAA)	Transtat (TDAA)	Roadway characteristics	Data collected by FDOT/Districts	LRS downloadable from FDOT website, GIS Shapefiles from FDOT website, Data Analysis and Reporting for Transportation Systems (internal reporting tool) Specific roadway data available by request	HPMS, Work Program Projects, FDOT LRS, Travel Demand Modelling inputs, MOVES	Data is updated frequently throughout the year.	http://www.fdot.gov/planning/statistics/rci/	2016	Joel Worrell
FDOT Rest Area / Service Area Locations	Infrastructure	GIS	Annual	Statewide	Transtat (TDAA)	FDOT Office of Maintenance	Locations	Facility location data freely available from FDOT Office of Maitenance	Downloadable from FDOT by request	Inventory, Asset Management	Actual rest areas are currently fluctating due to remodeling of state rest areas.	http://www.fdot.gov/maintenance/RestAreas.shtm	2016	Deanna Hutchison
FDOT Weigh Stations	Infrastructure	GIS	Weekly	Statewide	Transtat (TDAA)	FDOT Office of Maintenance	Locations, Weight of trucks	Data available from Office of Maintenance	Location information downloadable from FDOT	Inventory, Asset Management, Commercial Vehicle Weight Enforcement and Research studies	Data is not retained from Weigh Station WIMs, or Scales. WIMs are used for commercial vehicle enforcement at weigh stations and are part of a different system that Transtat's WIM locations.	http://www.fdot.gov/maintenance/weighstationlisti ng.shtm	2016	Paul Clark

FDOT Transtat WIM Stations	Truck	CSV, GIS, SQL DB	Weekly	Statewide	Transtat (TDAA)	Transtat (TDAA)	Speed, volume, classification, Weight of trucks	Collected by Transtat independent of MCSAW weigh stations	Location information downloadable from FDOT by request.	traffic forecasting and performance measures	30 WIM stations are often confused with the 20 weigh station WIMs in the state.	http://www.fdot.gov/planning/statistics/trafficdata/	2016	Joey Gordon
Jason's Law Survey	Infrastructure	GIS	One-time	National	Transtat (TDAA)	FHWA	Public and private parking facilities, number of parking spaces	Collected by FHWA, published as report	Downloadable from FHWA	Parking Demand and supply studies	Assimilation of different parking facilities inventories. Missing parking facilities if any are unknown. The parking facility data currently available is for one year alone. For other years, private parking facilities inventory has to be bought through commercial data sources like Trucker's Friend	http://www.ops.fhwa.dot.gov/freight/infrastructure/truck_parking/jasons_law/truckparkingsurvey/	2015	Not applicable
Permit System for OSOW	Truck	Online tool	Variable	Statewide	Maintenance	FDOT Office of Maintenance	Vehicle configuration, routes, loads	Collected by Office of Maintenance	By request	Studies and reports	Data provided for blanket permits and routing permits.	https://gis.dot.state.fl.us/OneStopPermitting	2016	Veronica Martin
Crash Analysis Reporting System (CARS)	All Surface Modes	CSV, GIS, SQL DB	Annual	Statewide	FDOT Safety Office	FDOT Safety Office	Crash locations and data	Collected by Safety Office and DHSMV (free)	By request	Safety analysis studies	Data is collected and analyzed for a given year and is not available until the following year.	http://www.fdot.gov/safety/11A-SafetyEngineering/SafetyEngineering1.shtm	2014	Joseph Santos / Benjamin Jacobs
VIUS	Truck/Car	-	Discontinued	National	Transtat	U.S Census	Vehicle characteristics	Collected by US Census Bureau	Downloadable from U.S Census Bureau	Demand Models	Latest release of data was in 2002	https://www.census.gov/svsd/www/vius/2002.html	2002	Not applicable
Container Number Database	Truck	Online tool	Daily	Statewide	FDOT Traffic Engineering and Operations	MCSAW and DACS	Real-time commercial vehicle data	Developed by MCSAW and DACS - free but licensed. Includes 36 LPR cameras	By request	Commercial Vehicle Enforcement	Data stored is exempt from public records request		2016	Marie Tucker
Transearch	Commodity Flow	GIS, CSV	Annual	National	Transtat (TDAA)	IHS Markit	Tons, value and units at county or TAZ level, with commodity, mode, route and OD	Purchased from IHS Global Insight, which combines numerous sources	By request for FDOT Projects	FreightSIM, studies	Data is only usable for FDOT projects		2011	Thomas Hill / Frank Tabatabaee
Commodity Flow Survey (CFS)	Commodity Flow	CSV	5 Years	National	N/A	U.S Census	Tons, value at BEA level with commodity, mode, OD. Also public use microdata	Collected by US Census Bureau as part of Economic Census (free)	By request from U.S Census Bureau	FAF, FreightSIM	Sample Data	https://www.census.gov/econ/cfs/	2012	Not applicable
County Business Patterns (CBP)	Business Establishment	CSV	Annual	National	N/A	U.S Census	Zip-code or higher level employment and establishment data by NAICS	Collected by US Census Bureau (free)	Downloadable from U.S Census Bureau	FreightSIM, others		http://www.census.gov/programs-surveys/cbp.html	2014	Not applicable
DOR Tax Parcel Data	Business Establishment	GIS, CSV	Biannual	Statewide	Surveying and Mapping	Department of Revenue (DOR)	Parcel boundaries, tax information	Collected by FL Department of Revenue (free)	Downloadable from DOR website and FDOT. DOR and FDOT have an agreement for data access.	Land Use analysis, geospatial analysis, travel demand modeling	Several releases of data occur several times in a given year. Final releases occur near the end of a year for approximate county parcel assessments.	http://floridarevenue.com/dor/property/gis/	2016	Joel Worrell / Jared Causseaux
Infogroup	Business Establishment	CSV	Annual	National	Transtat (TDAA)	InfoUSA	Business establishment data - sales, employment as per industry codes	Available for purchase from Infogroup	By Request for FDOT Modeling related projects or through Florida Statewide Model	Modeling only	Restricted to modeling efforts, information can extracted through Florida Statewide Model	FSUTMSonline.net	2014	Thomas Hill / Frank Tabatabaee
BEA Economic Accounts	Industry	Excel	Annual	National	N/A	Bureau of Economic Analysis	GSP, IO by industry	Free from BEA	Downloadable from BEA	FreightSIM, others		http://www.bea.gov/	2015	Not applicable
Association of American Railroads (AAR)	Rail	Excel	Annual	National	N/A	Association of American Railroads	Economic, financial, policy, traffic, safety indicators	Purchased from AAR	Purchasable from AAR	Studies and reports		https://www.aar.org/		Not applicable
Public Use Waybills Sample (PUWS)	Rail	CSV	Annual	National	Rail Office	Surface Transportation Board	Rail OD, commodity, tonnage, revenue, line miles, car type	Collected by STB (free)	Free Waybill data is available from the public. The Confidential Waybill Sample is accessible to only FDOT approved consultants which are then to the STB for FDOT projects only.	Studies and reports	Data is scrambled and requires manipulation to work with.	https://www.stb.gov/STB/industry/econ_waybill.htm l	2014	Ed Lee / Rickey Fitzgerald
Strategic Intermodal System (SIS)	Intermodal	GIS	Annual	Statewide	Systems Planning	Systems Planning	Intermodal facility locations	Collected by Transtat (free)	Downloadable from SIS / RCI	SIS projects		http://www.fdot.gov/planning/sis/default.shtm	2016	Chris Edmonston
Airport Council International (ACI)	Air	Excel	Monthly	Global	Aviation	ACI	Traffic (tons, mail), economics metrics	Purchased from ACI	By request for FDOT projects	Studies and reports		http://www.aci.aero/		Aaron Smith / Todd Cox
BTS Form 41 Traffic	Air	CSV	Monthly	National	N/A	BTS	Passengers-freight-mail enplaned, aircraft type, hours, capacity and seats.	Collected by BTS (free)	Downloadable from BTS	Studies and reports		http://www.transtats.bts.gov/Tables.asp?DB_ID=111	2016	Not applicable

FAA Database	Air	Excel	Annual	National	Aviation	FAA	Location, service level, hub size, landed weight	Collected by FAA (free)	Downloadable from BTS	Scheduling and delay analysis studies	FAA often	https://aspm.faa.gov/opsnet/sys/Main.asp	2016	Aaron Smith / Todd Cox
Flightaware Data	Air	CSV, Others	Real-time	Global	N/A	Flightaware	Flight tracking	Purchased from Flightaware	Not applicable, Not acquired	Studies and reports		https://flightaware.com/		Not applicable
OAG Database	Air	XML	Daily	Global	Aviation	OAG	Airline schedules, analytics	Purchased from OAG	By request	Studies and reports		http://www.oag.com/	2016	Aaron Smith / Todd Cox
Automated Identification System	Maritime	Geodatabase	Annual	National	N/A	Marine Traffic	Vessel location, vessel speed, vessel identifier and characteristics	Free from US Coast Guard	Not applicable, Not acquired	Anchoring studies	Large dataset	http://www.marinetraffic.com/	2016	Daniel Fitz-Patrick
Navigation Data Center	Maritime	CSV, GIS, SQL DB	Annual	National	N/A	U.S Army Corps of Engineers	Vessels, facilities, waterways	Collected by US Army Corps of Engineers (free)	Donwloadable from USACE	Studies and reports	The update rate is slow	http://www.navigationdatacenter.us/	2014	Not applicable
PIERS	Maritime	Excel	Annual	National	Seaport & Waterways	IHS Markit	Imports/exports from Bills of Lading @ US ports - commodity tonnage, value, TEUs	Purchased from JOC Group (IHS)	Subscription access by request	Plans, Demand Models	Data is only usable for FDOT projects	https://www.ihs.com/products/piers.html	2016	Daniel Fitz-Patrick
National Pipeline Mapping System	Pipeline	GIS, CAD	Annual	National	Transtat (TDAA)	PHMSA	Location and other information, tank data	Collected by USDOT PHMSA (free)	FDOT requests access from the NPMS	Studies and reports	Data is only usable for FDOT projects	https://www.npms.phmsa.dot.gov/	2016	Joel Worrell
BTS Transborder Freight Data	Commodity Flow	Online tool	Monthly	National	N/A	BTS	Cross-border flows by commodity and mode	Free from BTS	Downloadable from BTS	Reference		https://transborder.bts.gov/	2016	Not applicable
Colography National Survey of US Expedited Cargo	Commodity Flow	CSV	Annual	National	N/A	Colography	Shipment volume and weight by establishment; mode	Purchased from Colography Group	Not applicable, Not acquired	Not applicable		http://www.colography.com/files/press/2014%20National%20Survey%20Primer_030714.pdf		Not applicable
Transportation Services Index (TSI)	Economic	Graphs / Tables	Monthly	National	N/A	BTS	Multimodal activity index	Published by the BTS (free)	Downloadable from BTS	Reference		http://www.rita.dot.gov/bts/transportation_services _index	2016	Not applicable
US Census Foreign Trade Data	Economic	CSV	Annual	National	N/A	U.S Census	US import/export - commodity, quantity, value, mode, OD, port	Developed by US Census Bureau (free)	Downloadable from U.S Census Bureau	Studies and reports		https://www.census.gov/foreign-trade/index.html	2016	Not applicable
Electronic Freight Theft Management System	Truck	Online tool	Unknown	Statewide	N/A	DHSMV	Freight-related theft information	Developed by FDOT/Florida Highway Patrol	By request	Studies and reports		https://services.flhsmv.gov/ReportCargoTheft/login.aspx?ReturnUrl=%2freportcargotheft		Marie Tucker
Department of Health Data	Other	GIS	Annual	Statewide	N/A	DOH	Health establishment data	Collected by FL DOH (free)	Currently do not have access	Not applicable		http://www.floridahealth.gov/statistics-and-data/		Not applicable
USDA Economic Research Service	Other	CSV	Annual	National	N/A	USDA	Agricultural data	Collected by USDA (free)	By request	Studies and reports		http://www.ers.usda.gov/data-products/		Not applicable
USDA NASS	Other	GIS, CSV	Annual	National	N/A	USDA	Agricultural data	Collected by USDA (free)	By request	Studies and reports		https://www.nass.usda.gov/Data_and_Statistics/	2017	Not applicable
Bluetooth Statewide Screenline Project	Truck/Car	CSV	1-Time	Statewide	Transtat (TDAA)	Transtat (TDAA)	Truck/Cruise Traffic Speed and distribution from ports	Field collected through task work order for Transtat	By request	Studies and reports	Dataset is in raw form and fairly large. Temporal coverage is only for a month of data.	Not applicable	2016	Thomas Hill / Steven Bentz
Port Everglades local traffic counts	Truck/Car	XLS, SHP	1-Time	Local	Transtat (TDAA)	Transtat (TDAA)	Link and intersection counts and movements	Field collected through task work order for Transtat	By request	Model Development	Data collected during non-typical, seasons variation issues	Not applicable	2014	Thomas Hill / Terry Corkery
Port Everglades Petroleum Study	Petroleum Trucks		1-Time	Local	FDOT District 4	FDOT District 4	Tax receipt data, GPS Location, spot speed, heading	ATRI collects via GPS from its sample of trucks (Class 8-13). Licensed from ATRI	By request	Studies and reports	Data is only usable for FDOT projects. Temporal coverage only covers a few months of data.	http://www.fdot.gov/research/Completed_Proj/Sum mary_PL/FDOT-BDV25-977-17-rpt.pdf	2015	Min Tang Li / Frank Tabatabaee
Virtual WIM Station Locations	Truck	Tabular	Real-time	Statewide	MCSAW	MCSAW	Overweight trucks, Carriers in violation, Weight measurements	Collected by MCSAW	By request	Enforcement	Image quality, readability issues,	https://vwim.fltrucksizeandweight.com/vwim/index. htm	2016	Craig Wilson