RITA Intelligent Transportation Systems Joint Program Office

Real-Time Traveler Information Market Assessment White Paper

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Notice

Quality Assurance Statement

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Interviews were conducted with industry experts, with each focused on one of the four traveler information modes—traffic, transit, parking, and intermodal/freight. The Intelligent Transportation System (ITS) Joint Program Office (JPO) thanks the following experts with whom interviews were conducted:

Traffic

Name	Organization
Cy Smith	AirSage
Matt Wright	AirSage
Greg Larson	California Department of Transportation (Caltrans)
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Brian Cronin	Research and Innovative Technology Administration (RITA)

Name	Organization
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Bill Legg	Washington State Department of Transportation (WSDOT)

Transit

Name	Organization
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Matt Cluett	Battelle Memorial Institute
David Zavattero	Chicago Department of Transportation (CDOT)
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Larry Rosenshein	NextBus
Carol Schweiger	Transystems
Arjan Van Andel	Trapeze ITS
Bibiana McHugh	Tri-County Metropolitan Transportation District of Oregon (TriMet)

Parking

Name	Organization
Quon Kwan	Federal Motor Carrier Safety Administration (FMCSA)
Rod MacKenzie	ITS America
Josh Eisen	Park Assist
Rick Warner	ParkingCarma
Christian McCarick	ParkingCarma
Dennis Templeton	Port of Portland, Portland International Airport
Mike Drow	Standard Parking
Tod Dykstra	Streetline, Inc.
Wei Bin Zhang	University of California, Berkeley, Partners for Advanced Transit and Highways (PATH)
Susan Shaheen	University of California, Berkeley, Transportation Sustainability Research Center (TSRC)
Patrick Schmidt	Washington Metropolitan Area Transit Authority

Name	Organization
	(WMATA)

Freight

Name	Organization
Skip Yeakel	AB Volvo Group North America
Dan Murray	American Transportation Research Institute (ATRI)
Richard Easley	E-Squared Engineering
Crystal Jones	Federal Highway Administration (FHWA)
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16. Abstract

This report takes a multi-modal look at the "lay of the land" of the real-time traveler information market in the United States. This includes identification and characterization of the gaps in the domestic industry with respect to data coverage, data quality, data procurement methods, and data usage. Ultimately, the focus is to identify the gaps in real-time information across different modes (i.e., traffic, transit, parking, and intermodal/freight). The analysis also documents the institutional, technical, and cost issues associated with collecting real-time data from these modes; opportunities for closing the gaps; and utility of real-time data for uses beyond traveler information. Although each mode offers a unique set of challenges, an important objective of this study is to identify opportunities to best leverage resources and innovative approaches that span multiple modes.

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Table of Contents

EXECUTIVE SUMMARY

Introduction and Background

This report takes a multi-modal look at the "lay of the land" of the real-time traveler information market in the United States. This includes identification and characterization of the gaps in the domestic industry with respect to data coverage, data quality, data procurement methods, and data usage. Ultimately, the focus is to identify the gaps in real-time information across different modes (i.e., traffic, transit, parking, and intermodal/freight). The analysis also documents the institutional, technical, and cost issues associated with collecting real-time data from these modes; opportunities for closing the gaps; and utility of real-time data for uses beyond traveler information. Although each mode offers a unique set of challenges, an important objective of this study is to identify opportunities to best leverage resources and innovative approaches that span multiple modes.

US DOT Objectives

The outputs of this study will inform the Intelligent Transportation System (ITS) Joint Program Office (JPO) research agenda and strategic focus, as well as guide future investments by the United States Department of Transportation (DOT) in continued research, demonstrations, and agency initiatives to support enhancing and expanding the real-time data marketplace as well as uses of real-time data.

One of the key objectives of this study is to identify gaps in current approaches, systems, partnering strategies, and technologies relative to the real-time traveler information marketplace across the modes of traffic, transit, parking, and freight/intermodal. The rapidly evolving real-time data marketplace will require transit agencies, the private sector, and even travelers to adapt to new ways of obtaining and receiving information. With this evolution comes challenges, and through research and discussions with industry experts, this study identified several institutional, technical, and cost/resource issues.

Additional objectives include:

- Identify opportunities for closing the gaps, through emerging technologies and innovative partnerships, as well as leveraging data investments across both public and private data collection and integration capabilities, and identify the US DOT's role to support these efforts
- Document the institutional, technical, and cost issues associated with collecting real-time data from these modes
- Identify the utility of real-time data for uses beyond traveler information. New data types pose unique challenges for agencies, including traffic management personnel, transit operators, parking facility managers, and commercial vehicle operators and dispatchers. Systems and agency processes that were designed to rely on specific data types or formats may not be able to readily accommodate new types of data. Support for continued or expanded investment in real-time data needs to take these issues into account.

Summary of Key Findings

This study examined several facets of the real-time data marketplace across multiple modes and the trends and gaps relative to coverage, technology applications, partnering and procurement, data quality, usage, and cost. This section provides a summary of the key findings within the major topic areas of coverage, quality, and usage.

Real-Time Data Coverage

Coverage of real-time systems has expanded over the last decade, due largely to the availability of technology, declining cost of communications, and broader communications availability, as well as expanded business models of the private sector. The impetus for broadening coverage for real-time data collection systems for the public sector is due primarily to operational needs; data that supports agency-operated traveler information systems is typically rooted in system operations as a key or primary function. This section provides an overview of current coverage for each mode.

Traffic Data Coverage by Agency-owned Systems

Freeways continue to be the primary focus for real-time data collection throughout the country. The public sector, private sector, and industry are in agreement that there is generally good coverage of urban area freeways through public-sector-operated sensor deployment systems. Deployment has been gradually increasing over the last 5 years (as shown in **Table 1**); however, only 39 percent of urban freeways currently have agency-owned, real-time, sensor-based systems to support real-time reporting of conditions (according to the most recent statistics from the ITS Deployment Tracking Database, survey year 2007).

Table 1: Coverage Trends

Data Type	2004	2005	2006	2007
Urban centerline miles with real-time data collection technologies (%)	33%	38%	38%	39%
Metro areas with probe data technologies (%)	8%	10%	11%	9%
Metro areas reporting freeway travel times (%)	23%	41%	35%	36%
Metro areas reporting freeway speeds (%)	19%	35%	38%	32%
Metro areas reporting incident information (%)	60%	82%	83%	87%

Source: FHWA ITS Deployment Statistics Database

States indicated that there are gaps in coverage from what their systems currently provide. There are limitations in how much detection infrastructure can feasibly be deployed and maintained with current resource constraints. Arterials and rural areas were identified as key gaps/limitations of current DOT coverage capabilities.

The largest cities tend to have a higher percentage of freeway-mile flow data coverage, although even the largest cities fall significantly short of full freeway coverage. **Figure 1** shows the coverage by public sector systems. The size of the circles corresponds to the relative number of freeway miles within each urban area, and the shading indicates how many of those have real-time flow coverage by agency-owned systems. In several areas, the coverage miles do not equal the urban area freeway miles. It is also important to note that there are gaps in the current reporting system to track coverage; there are several cities that did not have any coverage reported, although they are known to have ITS deployments.

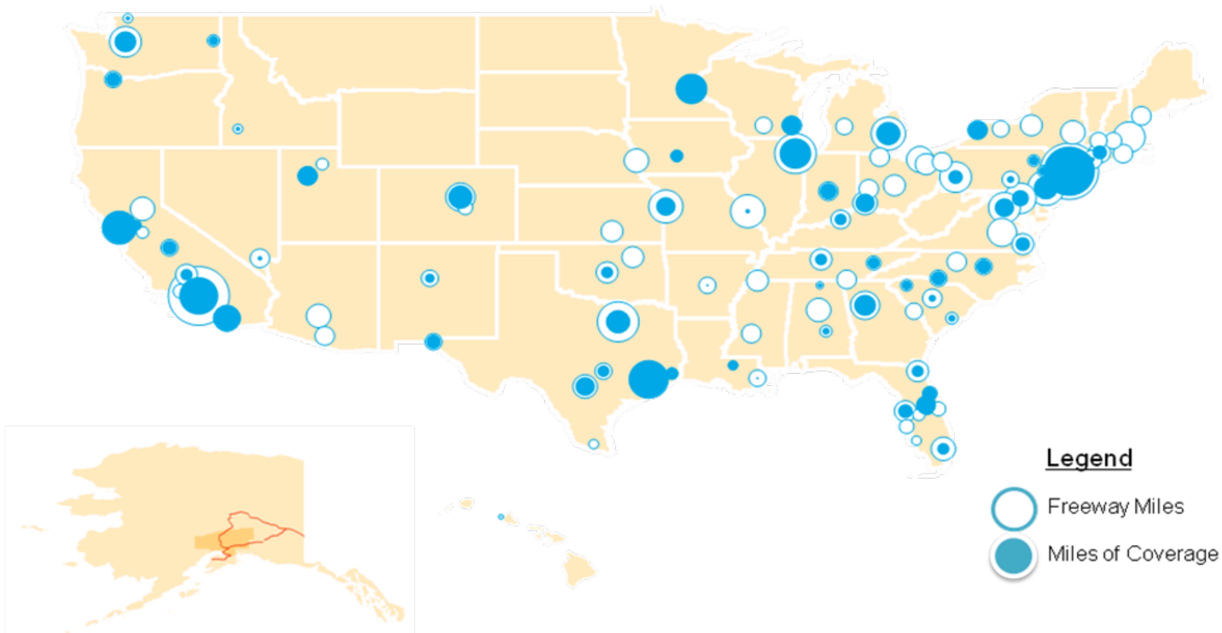


Figure 1: Real-time Flow Coverage

Statewide real-time speed and flow coverage (to include rural area Interstates, state routes, US routes, or others) does not occur. Rural corridors have, to date, been a lower priority for real-time data, so it has been difficult for some states to justify the investment. Available data on a statewide basis includes incidents, construction, and planned events, although this information is not always provided in real time.

Available data for arterials is primarily intersection detection data, but it is used exclusively for signal control; information usually does not leave the controller. When there is instrumentation to provide arterial conditions data, it is typically only on major arterials, rather than the entire arterial network. This limits the usability of this data to support arterial congestion information or travel times.

Road Weather Information Systems (RWIS) are a common ITS application, especially in cold weather states with snow and ice. Most areas do not have sufficient RWIS density to provide route-specific road-weather information. Weather data is also an area where DOTs can obtain information from other sources (such as the National Weather Service, universities, US Army Corps of Engineers, or others), which could limit states' interest in making significant investments in their own data collection infrastructure.

Traffic Data Coverage by Private Sector Systems

With the growth in mobile computing power and mobile communications, the private sector is now obtaining traffic conditions data from in-vehicle sources, including global positioning system (GPS) devices (on-board or consumer-provided) or cellular phones. Over the past several years, the private sector has greatly expanded its geographic coverage of both urban and rural areas, and has the ability to collect flow/speed data on corridors beyond what is currently collected by public-agency, sensor-based deployments on urban area freeways.

Coverage of private-sector systems is represented in a number of ways. National providers (such as INRIX, NAVTEQ and AirSage) may represent "coverage" in terms of an urban area, corridor segment, or regional coverage (such as coverage linked to a cellular provider range/service area). However, their focus continues to be on Interstate routes in and near major metropolitan areas because this data is most in demand by their customers, including in-vehicle application developers; private-sector, Web-based traveler information systems; and media.

Other statistics of coverage reports by private sector providers include:

- XM Satellite Radio provides traffic data from NAVTEQ in 80 metropolitan markets.
- Total Traffic Network, the traffic information arm of Clear Channel, provides navigation data to in-vehicle devices in 95 markets.
- INRIX provides incident data through a partnership with Clear Channel in 113 markets.
- AirSage provides real-time, historical, and predictive traffic information for 127 US cities.
- TrafficCast provides flow data in 28 markets, incident data in 138 markets, and construction data in 146 markets.
- SpeedInfo, a private infrastructure-based provider, is a partner in 14 metropolitan areas. SpeedInfo provides data to both the public sector and other private sector clients. In some cases, SpeedInfo supplements or extends current data collection strategies already in place by the public sector.

Transit Coverage

Transit agencies of all sizes, even smaller agencies, are utilizing real-time traveler information to increase overall customer satisfaction. Each year, the US DOT Research and Innovative Technology Administration (RITA) surveys transit agencies across the United States to ascertain their use of transit systems management and operations tools and their deployment of ITS.

In 2007, 94 transit agencies across 6 types of transit vehicles (fixed-route buses, heavy or rapid rail, light rail, demand-responsive vehicles, commuter rail, and ferry boats) responded to the survey. For each vehicle type, agencies indicated the number of vehicles they possessed, whether these vehicles were equipped with automatic vehicle location (AVL) technology to track transit vehicle movements, and whether they electronically display automated or dynamic traveler information to the public. **Table 2** summarizes the results of the survey**.** The table also describes information from a similar survey in 2004 to which 80 transit agencies responded regarding the number of transit vehicles that have automatic passenger counters (APCs), which track the number of passengers aboard a vehicle at any given moment, even if the information is not shared with the public.

Table 2: Transit Coverage Deployment Summary

Transit Types	Measurement	Equipped with AVL	Display Real-Time Traveler Information	Equipped with APC
Fixed-Route Buses	Number of Metro Areas Reporting Use of Technology	60	28	41
	Vehicles with Technology	26,381	11,569	6,323
	Total Vehicles	43,233	43,233	43,233
	Percent	61%	27%	13%
Heavy or Rapid Rail	Number of Metro Areas Reporting Use of Technology	5	3	0
	Vehicles with Technology	2,013	454	0
	Total Vehicles	10,812	10,812	10,812
	Percent	19%	4%	0%
Light Rail	Number of Metro Areas Reporting Use of Technology	7	5	6
	Vehicles with Technology	452	264	134
	Total Vehicles	1,317	1,317	1,317
	Percent	34%	20%	8%
Demand-Responsive Vehicles	Number of Metro Areas Reporting Use of Technology	49	7	2
	Vehicles with Technology	5,260	198	9
	Total Vehicles	10,938	10,938	10,938
	Percent	48%	2%	0%
Commuter Rail	Number of Metro Areas Reporting Use of Technology	3	3	1
	Vehicles with Technology	1,348	397	100
	Total Vehicles	4,710	4,710	4,710
	Percent	29%	8%	2%
Ferry Boats	Number of Metro Areas Reporting Use of Technology	3	0	0
	Vehicles with Technology	30	0	0
	Total Vehicles	48	48	48
	Percent	63%	0%	0%

Source: RITA, ITS Joint Program Office

Figure 2 exemplifies the diverse range of transit agencies across the United States that provide some form of real-time traveler information to their customers. However, the map also shows the large disparity in terms of agencies that have deployed AVL systems to their transit vehicles but are not fully utilizing their data by providing real-time transit information to the public. The map also shows that only two metropolitan areas (San Francisco Bay Area, California and Chicago, Illinois) have the capability to provide real-time information across multiple agencies and transit modes. Even these two agencies have yet to fully deploy these pioneering systems.

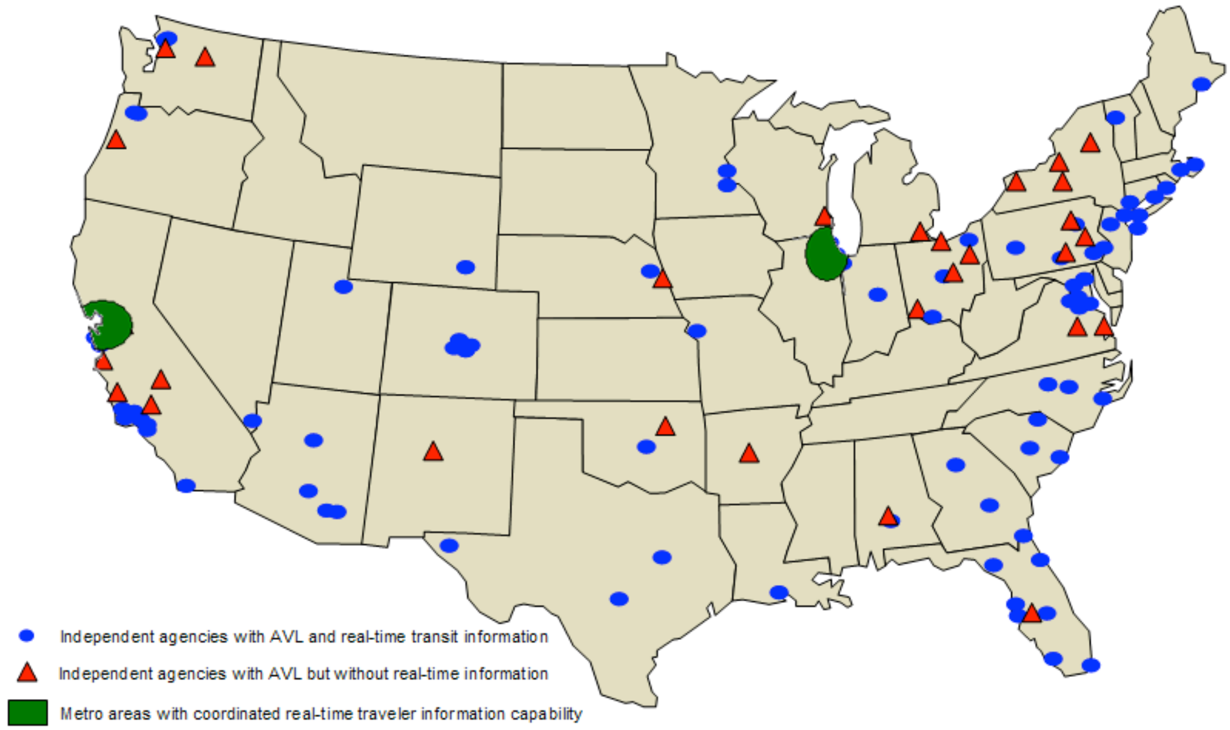


Figure 2: Transit Real-Time System Coverage (Metropolitan Areas)

Parking Coverage

There are a limited number of real-time parking information deployments in the United States (shown in **Figure 3**). Parking systems are concentrated in areas where parking is often scarce including transit station park-and-rides, airports, and central business districts. To date, most of the parking information systems (including detection) have focused on revenue applications; the introduction of parking locations or availability as a modal data point is relatively new. Most parking facilities are run by individual operators, resulting in a fragmented industry with limited inter-operator coordination. The figure also shows two metropolitan areas in California that are developing regional real-time parking information systems, including on-street systems, that will allow customers to locate a facility closest to them within the broad regional network. While real-time information is available for a limited number of deployments, advanced static facility information is more readily available across many facilities in major cities nationwide.

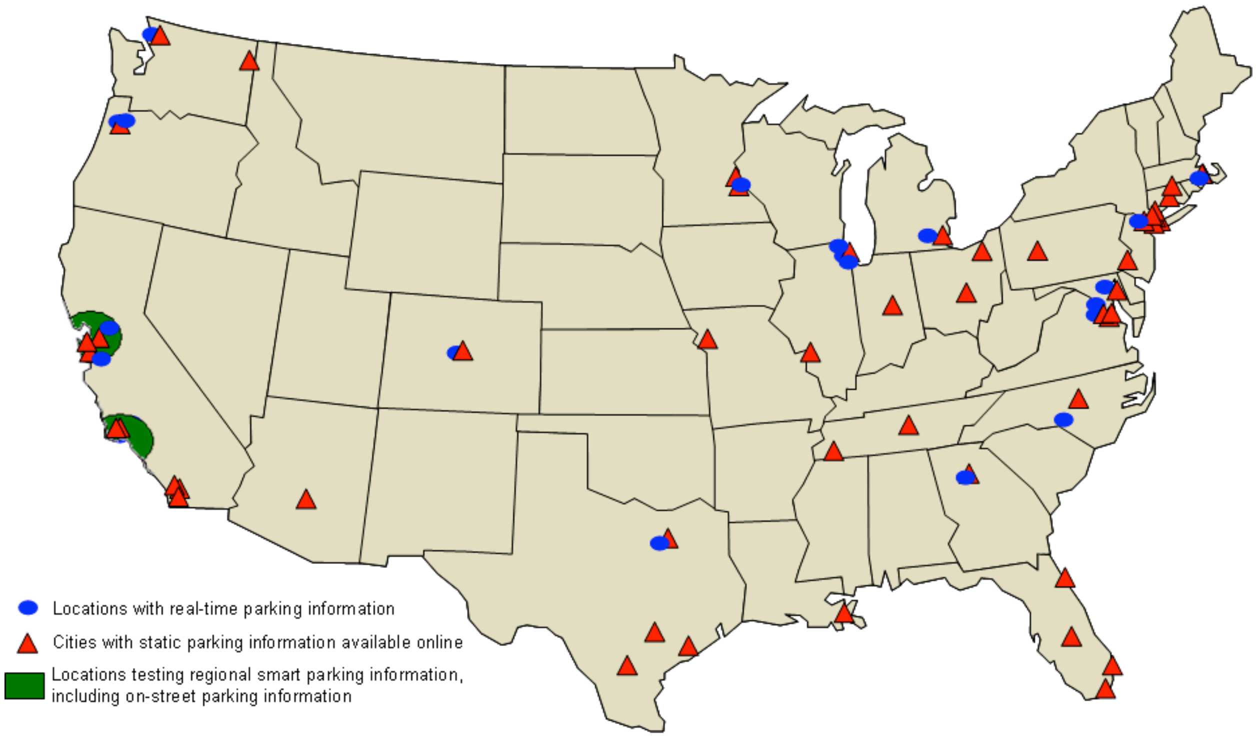


Figure 3: Real-Time Parking System Coverage

Freight Coverage

Both public and private sector data and traveler information applications for freight vary in scope and delivery. Privately run systems use onboard communications systems to track and provide information to a vehicle along its entire route. These systems provide information, of at least some detail, for the majority of roads in the United States.

Conversely, public systems are most often deployed by individual agencies and are more limited in scope. Some public sector systems seek to add freight-specific information to existing traveler information systems. Others' systems focus on specific regions or locations where freight traffic is particularly high, such as border crossings and intermodal facilities. Much of the focus for publicly sponsored real-time freight information systems has centered on these types of facilities, which are choke points for the freight industry. Currently, many of these areas lack a centralized switchboard for truckers to receive information, and trucks often lack adequate communication links with ports because there is such a vast quantity of data points. Information, particularly intermodal information, often does not flow well at such hubs due to the size of the systems, the substantial capital costs, and the fact that companies are hesitant to share their proprietary freight information.

Data Quality

Quality encapsulates several parameters, including accuracy, timeliness, reliability, and granularity. For real-time traveler information to be effective, travelers must trust the information being provided to them. While the public does not expect information to be perfect, highly accurate data is necessary. It is also imperative to consider that the level of accuracy required will vary depending on who is requesting the information. There is a difference between the accuracy that is desired and the accuracy that is tolerated. Ultimately, however, users are the key measure of quality, both for agency traveler information systems and for private-sector data collection and dissemination systems.

Historically, the quality of traveler information data is not often formally measured and published, especially for the public sector. Rather, most internal assessments have focused on customer satisfaction and feedback. Past research has attempted to define reasonable standards for data quality for different applications, but actual reports on whether these standards are met are rare. Furthermore, there are no consistent standards on what makes for high quality data. Quality is a very subjective aspect of traveler information; some customers may have different quality expectations depending on their needs or current situation, and establishing a monetary aspect to real-time data (such as through subscription revenue models) may create even higher quality expectations.

Transit agencies are working to improve real-time information systems to reflect real-time conditions in response to customer demands. Transit schedule adherence is inherently variable, so real-time information tracking vehicle location and arrival times must be highly accurate in order to be useful. GPS AVL generally allows for extremely accurate data in real time, usually to within 30 feet of actual vehicle location and seldom more than 100 feet. Most agencies strive for data that is accurate at least 95 percent of the time, often striving for numbers as high as 98 percent. As agencies implement systems that provide real-time arrival and departure information, customers will become more dependent on higher quality data.

From the traffic perspective, various thresholds for data quality have been proposed in different contexts. The Real-Time System Management Information Program (RTSMIP) proposed rule (set to go into effect in 2010) includes the real-time information data quality targets listed in **Table 3**. This will be the first formal quality/latency requirement linked to traffic systems, with a focus on timeliness. It also requires attention to coverage with the metropolitan and non-metropolitan area designations.

Table 3: RTSMIP Real-Time Information Data Quality Targets

Category of Information	Timeliness for Delivery			
	Metropolitan Areas (in minutes)	Non-Metropolitan Areas (in minutes)	Availability (in percent)	Accuracy (in percent)
Construction Activities:				
Implementing or removing lane closures	10	20	90	85
Roadway or lane blocking traffic incident information	10	20	90	85
Roadway weather observation updates	20	20	90	85
Travel time along highway segments	10	NA	90	85

Source: Real-Time System Management Information Program Notice of Proposed Rule Making

With the growth in private firms providing traffic data to the public sector, measuring data quality is becoming more important. New, innovative data collection techniques rely on combining traffic data from multiple sources to arrive at real-time estimates. Because many of these methods are new and unproven in all conditions, public agencies cannot rely on their familiarity with known technologies (e.g., point sensors) to understand the quality of this data. Therefore, public sector agencies must validate the data they are buying against the levels specified in the contract documents.

Some agencies typically measure the quality of data that is used to communicate traveler information to the public by:

- Validating travel times generated by detection systems (spot-check travel-time runs using GPS to calculate point-to-point times)
- Verifying incident accuracy by field devices and during travel-time runs
- Linking contractor fees for data supplied to the objective measure of quality resulting from private-sector validation efforts
- Considering the feedback received from phone and Web-based comments (particularly with 511 systems).

The system reliability of sensors can challenge the effectiveness of the data that is disseminated to the public. In California, according to the California Department of Transportation (Caltrans) Performance Monitoring System (PeMS), between 60 percent and 80 percent of Caltrans sensors are functioning at any given time. This is typical, if not good, for the industry. Some agencies actively assess the downtime of sensors (public-agency-owned or private-sector-owned) to ensure that the data they are receiving is reliable. Agencies also use the downtime information to determine private sector contractor fees, in that some contracts include metrics such as system uptime, downtime, or contractor response times, and link those metrics to monetary incentives or penalties (as in the case with system downtime that exceeds a specified threshold). Most states have successfully established sensor reliability standards on limited access freeways and incident data, although they need to improve the standards for planned event data/construction data.

A current lack of standards can diminish data quality across all modes. Data and communications protocols exist that support data formats (to a degree) and information exchanges, but there are several attributes unique to the various modes that require uniform standards in order to enhance the usefulness and overall quality of information provided to the traveler. Traffic managers can rely on the Institute of Electrical and Electronics Engineers (IEEE) 1512 standards to support incident reporting, although there is no consistent severity index that is uniformly applied. Similarly, there is also a lack of standardized information in determining and sharing incident reports for transit. Developing systems that use a standardized structure would allow for increased interoperability and improved real-time incident reporting to travelers.

Methods and processes need to be developed and utilized that will support data validation. With the growth in private firms providing data to the public sector, measuring data quality is becoming more important. Because probe-based and aggregated data are new and unproven in all conditions, public agencies cannot rely on their familiarity with known technologies (e.g., point sensors) to understand the quality of the probe-based data that they procure from the private sector. Early deployments such as the I-95 Corridor Coalition and Michigan Statewide Data Procurement will provide valuable insights to agency validation processes for probe (or consumer-generated) data, factoring in parameters such as data latency, densities or volume of data points, aggregated data from multiple sources, and other variability factors such as location or weather conditions.

Usage

Providing information to system users allows customers to make better decisions regarding the scheduling and routing of their trips to increase safety and reduce stress. In addition to providing users with information, the data stemming from real-time information applications can be utilized internally and allow agencies to improve their systems operations and performance. How the real-time data is used can influence quality requirements and thresholds, availability, coverage, and cost.

Traveler Information Uses

A variety of media exist to provide real-time traveler information. While each is at various stages of development, providing information through as many media as possible promotes information dissemination to the widest group of customers. **Table 4** shows the various methods that public agencies can use to provide real-time traveler information.

Table 4: Public-Sector, Real-Time Information Dissemination Methods

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
Dynamic Message Signs (DMS)	All	Medium	• Provide high-quality information at site • High profile	• Expensive • Not useful for advanced planning • Americans with Disabilities Act (ADA) issues • May require permits
Website	All	High	• Useful for pre-trip planning • Low expense • Highly customizable • Aggregate information from other sites	• Not accessible on site • Users may not have access on both ends of journey
Email Alerts	All	Low	• Low expense • Highly customizable	• Only available to limited number of customers that sign up for service

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
Smartphones/ wireless	All	Low	• Accessible pre-trip and on site • Third parties develop applications	• Only available to limited number of customers • Limited understanding of how to utilize
511	All	High	• Can be customizable and interactive • Highly accessible • Popular with older, less tech-savvy users	• User-friendly interface can be difficult to develop, especially in multiple languages • Requires active promotion of transit agencies • May require memorization of commonly used routes
In-vehicle telematics (including personal navigation devices)	Traffic, Parking, Freight	Low	• Expanding segment • Multimodal information	• Demonstrated, not widely deployed • Marketing and software integration difficulties
Radio	All	Low	• Low expense • Accessible pre-trip and on site • Popular with older, less tech-savvy users • Service provided by third parties	• Limited information available at all times
TV	Traffic, Transit	Low	• Service provided by third parties	• Not accessible on site • Users may not have access on both ends of journey
Automated Service Announcements (ASA)	Transit	High	• Provides peace of mind for riders • Transfers/ connection information	• Provides little real-time choice

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
Kiosks and Display Signs	Transit	Medium	• Popular with older, less tech-savvy, and ADA users • Provides peace of mind for riders • Transfers/ connection information	• Only available in terminal or at stop

Individual agencies track usage of their systems (511 phone, Web, e-mail alerts) as an important activity-based measure. At the national level, the 511 Coalition aggregates call volumes from 511 systems across the country. Usage has grown since the inception of 511 (shown in **Figure 4**), due to increased awareness as well as the number of deployments now active.

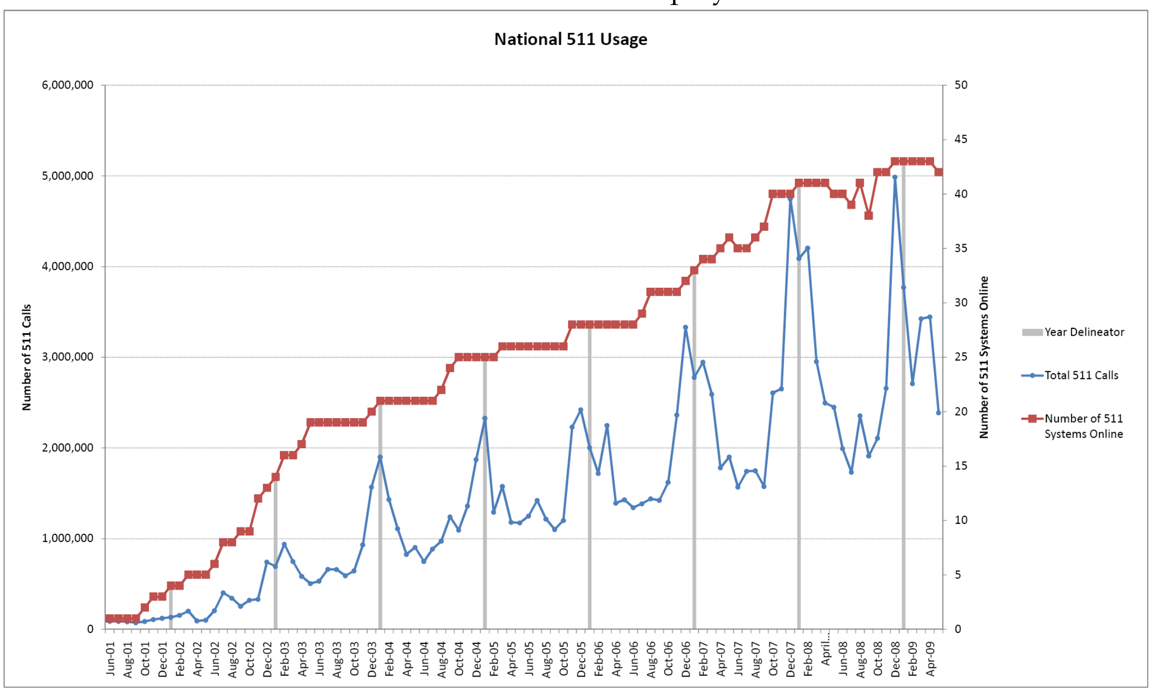


Figure 4: National 511 Deployment and Usage Trends

System Management and Operations

In addition to providing real-time traveler information to customers, transportation agencies can leverage the information stemming from real-time applications to improve their own internal operations, including management of their own fleets and infrastructure. For example, information can be used to monitor conditions, increase the accuracy of transit schedules, or improve the utilization at a parking facility. Additional systems management uses for real-time information include:

- Traffic management centers utilize sensors, cameras, and incident responders to provide the operators with information to manage traffic. Freeway management is more prevalent than arterial management due to the greater availability of information for major highways.
- In addition to real-time traveler information, many transit agencies use AVL for improvements in vehicle fleet management and operations. Even if it is not disseminated to users, tracking schedule adherence can indicate whether vehicles are behind or ahead of schedule, to allow for improved spacing that avoids platoons of clustered vehicles.
- Commercial vehicle operators, particularly larger carriers, use real-time applications to improve their operations, including improved routing, scheduling, and driver efficiency. Instruments on the truck can also serve to diagnose the vehicle's en-route operating efficiency, including fuel efficiency, mechanical specifications, and software updates.
- Once data is obtained from parking sensors, it is possible to build information models on arrivals, departures, occupancy, duration, and availability, as well as information reflecting demand. Networked meters can deliver information regarding current operational and payment conditions and historical transactions, which can be used to produce a complete real-time and historical view of compliance, violations, actual versus potential revenue, and options for improving pricing and policy.

Performance Measurement

The same data that is used to generate real-time network conditions information is also used to monitor and measure system performance and trends over time. An effective performance measure and reporting program requires a robust data archive. To effectively support evaluations and performance monitoring, archived data generally needs to be of a higher quality than real-time data to be useful for all of its possible applications such as transportation planning and performance monitoring.

Near-Term Influences on the Real-Time Data Marketplace

Several key events and factors are envisioned to influence the collection, delivery, and partnership strategies within the real-time data marketplace over the next 5 to 10 years. This section summarizes some of the major trends and influences.

Real-Time Data Collection

Shift toward More Ubiquitous Data via Probe-Based Technologies

Probe-based sensors provide much broader coverage than can be achieved through traditional DOT/agency-owned infrastructure-based/stationary sensor deployments. Data from probes is currently limited to speed and flow, which works well to support many traveler information applications such as travel times and speed maps. The challenge is that other operations and planning functions that also rely on occupancy and volume data cannot utilize the probe data in the same way they could with the traditional fixed-sensor data.

Real-Time Data Generated from Consumer Devices and Applications

Several private sector providers use this model, known as "crowd sourcing," to bolster other fleet/probe data and increase the amount of data points for real-time speed and flow information for freeways as well as arterials. Some approaches rely on an "opt-out" model; if users allow GPS with "my location" features enabled, they will be providing anonymous location data. Crowd sourcing is not a new phenomenon with GPS, but applying user-generated location data to develop a consolidated picture of traffic conditions in real time opens enhanced potential for broadly expanding current data collection capabilities. Unlike onboard systems, mobile devices go with the user, and it can be difficult to validate data points on arterials (for example, bikes versus automobiles on a congested arterial roadway), although firms such as Google and NAVTEQ are already providing arterial speed information on a limited number of routes in some cities. One of the Safe and Efficient Travel through Innovation and Partnerships (SafeTrip-21) projects in the San Francisco Bay area is using this user-provided content as a data source.

Expansion of AVL Capabilities to Support Transit Operations and Traveler Information

Vendors are developing more efficient AVL systems and communications infrastructure. This includes AVL with more frequent vehicle position updates and improved accuracy and/or reliability. Vendors are working with transit agencies to bring such new systems online, often as part of periodic technology refreshes, and ensuring compatibility with existing systems. The proliferation of high-bandwidth wireless networks including WiMAX and 4G cellular networks will provide additional real-time information opportunities. Furthermore, the number of transit agencies that have deployed AVL systems has nearly doubled over the last 10 years. Agencies are leveraging AVL to both improve system management and performance as well as provide their customers with real-time transit information.

Improved Sensors That Enable Real-Time Parking Information

Parking sensor vendors are developing more accurate and affordable infrastructure-based sensor technologies. Sensors are rapidly becoming cheaper, smaller, and more ubiquitous, allowing more systems to use the more granular vehicle presence detection method and increasing overall accuracy. In particular, vendors are close to developing sensors appropriate for usage in commercial vehicle parking facilities, allowing expansion into this additional market where the variable sizes of commercial vehicles have previously limited deployment.

Demand for Real-Time Data

Providing Travelers with Situational Awareness Information, Not Just Corridor or Route-Specific Information

Situational awareness is expected to encompass multi-modal information, not just corridor or route conditions. As more travelers become reliant on dynamic content delivered through mobile devices, real-time information will need to support a range of decisions for the traveler, including current route conditions, options for changing routes, modal options if they decide to change their trip or route, destination information (such as available parking or wait times). Expanding this concept to focus on freight-specific situational awareness would need to factor in multi-state corridors, ports, and intermodal facilities, as well as private-sector services (such as truck stops). The data and integration needs to support situational awareness information could be significant.

Substantial Growth in Subscribers to Real-Time Traffic Services

A recent article based on an electronics/automotive industry research study (iSuppli, July 2009) predicts the number of subscribers to real-time traffic services will double in 2009 (4.6 million in

2008 to 8.1 million in 2009), and is expected to reach over 50 million by 2014. The global trend is envisioned to be similar, with a prediction of 184.9 million in 2014. This prediction translates to a projected $1.28 billion industry in the United States by 2014. Real-time services include both portable and fixed devices as well as mobile phones. This indicates continued market demand for vertical supply chain partnerships among data and content providers, as well as enabling applications for vehicle-based and mobile communications devices.

Competitive Private-Sector Market

The private-sector market competition influences real-time information capabilities in nearly all modes. There are already competitive influences in the probe data marketplace for highway-based segment speed data. The commercial vehicle industry, already fairly mature in its deployment of in-vehicle telematics applications, is projected to increase in terms of proliferating onboard communications devices. Initially, only the large long-haul operators were able to fund the substantial capital costs associated with implementing on-board systems, but with the addition of new vendors to the market, as well as the improvements to wireless communications, costs have decreased. Smaller and short-haul companies are able to migrate from radio-based communications systems to public carrier push-to-talk services and in-vehicle telematics that include integrated AVL and data applications. Furthermore, more trucking companies are using telematics systems for proscribed routing and geofencing for their vehicles to track and monitor shipments, particularly for high-value and hazardous materials cargo.

Expected Implementation of Real-Time System Management Information Program

The parameters of this program include traffic and travel condition information for all interstate highways, which includes incidents as well as construction and weather advisories. Urban areas (metropolitan statistical areas with over 1 million in population) will have stricter requirements (for latency), as well as a requirement for provision of travel times on interstate and non-interstate highways, which will require real-time speed data in order for agencies to meet these requirements. For those urban area freeways not already instrumented with public-agency-operated detection systems, agencies will need to seek alternatives to obtain this data, such as through private-sector initiatives. It will also serve as an impetus for improved information sharing between public safety and transportation management agencies about incidents, particularly for non-urban area corridors.

Development of Integrated Multimodal Information

As users of real-time information do not segment their journey by mode, they therefore need integrated information across various modes. State DOTs are partnering with transit agencies and other local transportation agencies to integrate real-time traveler information. Likewise, some transit agencies operating within a single metro area are working to provide seamless real-time interfaces. For example, an integrated system would permit a suburban user to drive to a transit station, park his car, and ride light rail downtown, while receiving real-time traveler information updates throughout the journey.

Delivery of Real-Time Traveler Information

Social Networking and User-Generated Content for Traveler Information

Online applications like Facebook, Really Simple Syndication (RSS) feeds, and Twitter can share information related to congestion, incidents, and construction and are especially popular with younger users. Several state DOTs, regional transportation agencies, and transit operators use Twitter to provide alerts of incidents, delays, or service enhancements. One of the challenges with Twitter and other social networking sites is that they are open to allow users to also post content, so agencies have very little control over user-generated content. Agencies should be aware of the potential legal issues that surround their use, including restrictions regarding a municipal organization being part of a public forum. Twitter and Facebook represent current tools, but social networking is a rapidly evolving market. Their impact on traveler information needs further research to determine the risks and viability of social networking as an information delivery strategy.

Safety Concerns with Mobile Devices

As the methods and means to obtain and share real-time information via mobile applications increases, so do the safety concerns about distracting users. Many states and regions are implementing legislations that ban texting while driving. An important question many transportation agencies face as they make increased use of mobile-focused tools such as Twitter or enhanced mobile Web applications is whether they are actually encouraging the use of these devices by travelers while en route, thereby promoting unsafe driving. There needs to be a concerted outreach effort to promote the safe use of mobile delivery systems, as well as increased focus on developing applications and systems that do not cause distraction while travelers are obtaining and processing information.

Data Gaps Influencing the Real-Time Data Market

Traffic Data Coverage Gaps:

- Only 39 percent of urban freeway miles have sensor coverage to supply real-time traffic flow data, and even the largest cities fall significantly short of full freeway coverage.
- Flow and incident data for rural highways and arterials remains a significant gap in achieving "all roads" coverage for real-time information.
- Route-specific weather also poses an information gap. There is a significant disparity in RWIS coverage between states, even in states with mature RWIS programs. There are wide swatches of area in adverse weather areas with no RWIS sensors.
- Statewide reporting systems that have been established for interstate and highway corridor events do not readily handle arterial/local road information without substantial modifications.
- There is a gap in reporting on public-sector data coverage and concise and consistent reporting on private-sector coverage as well. The ITS Deployment Statistics database has gaps in its reporting due to a lack of survey response from different agencies, and it does not include any reports from private-sector data entities.

Transit Data Coverage Gaps:

- Approximately 62 percent of transit vehicles are not equipped with the AVL systems necessary to provide real-time vehicle location information. Some agencies that have deployed AVL on a substantial portion of their transit fleet to support operations have yet to leverage AVL information to provide real-time traveler information.

- There is a lack of system coverage at the regional level, including providing consolidated real-time information from multiple transit agencies operating within a single region.
- Communications infrastructure is often insufficient to provide real-time information, including networks that are unable to support the amount of data sent by large fleets.
- Within transit agencies that operate a variety of types of transit vehicles (light rail, bus, ferry, etc.), there is a lack of integration of real-time information across various vehicle types, preventing customers from receiving end-to-end trip information.

Parking Data Coverage Gaps:

- Currently, the parking industry is fragmented in both its operation and sharing of information, especially between public and private operators. There is a substantial gap in the mapping of parking spaces and parking information across metropolitan areas and regions.
- The deployment of real-time parking information systems has been relatively sparse. While it is only practical to deploy in parking facilities frequently at or near capacity, such as transit station park-and-rides, airports, and central business and entertainment districts, many congested areas lack any parking information.
- Due to the variability of their size and shape, current sensor technology does not allow for monitoring the presence of commercial vehicles. While real-time parking information could improve safety by alerting commercial drivers of available parking at rest areas, a useable system has yet to be deployed.

Freight Coverage Gaps:

- Cost remains a significant factor in freight operators adopting new technology; for cost reasons, devices and communications (beyond traditional radio communications) may remain out of the reach of carriers and industry sectors operating on thin margins, including drayage operators in ports and intermodal facilities.
- Few agencies have implemented freight-specific add-ons to their 511 and agency-operated traveler information systems. Most freight-specific systems are third-party provided, which may mean subscriptions or additional equipment is needed for truckers to obtain information.

Gaps in Data Quality:

- To promote seamless sharing of information and integration of dynamic multimodal data into traveler information systems, there is a need to develop and promulgate standards for both the public and the private sectors. These include content, naming conventions, mapping, attribute references, incident reporting, and data structures among others. Parking is one area in particular that lacks well-defined and adopted standards.
- Even within a single mode (such as transit), there are potentially many inconsistencies in how information is reported or in the data structures. This limits the ability to consolidate information from multiple sources, such as transit operators within a region, between states for contiguous corridor information, or among different parking facilities. This is further complicated when proprietary information is involved, such as for freight.

- Probe-based data as an option for arterials is still emerging, due to the challenges with validating data points off of the well-defined freeway network. This data collection approach continues to evolve rapidly.
- Processes to validate purchased traffic flow and speed data have been enacted by a few public agencies with private-sector data contracts, but there is not yet consensus on the appropriate validation methods.
- The impact of data latency on real-time information is an issue. Improved polling rates for AVL and probe vehicles (commonly now every 3 to 5 minutes) would greatly improve the quality of data for real-time information systems. Polling frequency for freeway sensor networks also varies. There is an inherent latency from the time information is transmitted to an operations/dispatch center to when it can be verified and distributed.
- The ability of state DOTs and regional transportation agencies to maintain effective data collection systems is directly linked to resources. Maintenance of sensor networks (including preventive maintenance) might not be as high of a priority as other funding demands within an organization. Similarly, reporting systems that rely on staff to enter data and update information require that staff resources have time, access to the database, and access to the information. This impacts the accuracy of non-real-time data such as work zones or planned events.

Gaps in Promoting Increased Usage of Real-Time Data:

- Similar to the data integration gap identified above, there is also a critical gap in the usage of data among and between different departments and agencies. Data sources (such as AVL or sensors) might be deployed with a primary purpose to support operations. While there has been good progress in utilizing that data to support real-time traveler information, there is not yet widespread leveraging of real-time information to support mode shift, planning, evaluations, performance monitoring, or policy development.
- There is also an opportunity to use real-time data to better understand how travelers use, interact, and seek out information sources to support more informed trip planning and decision making. A better understanding of the needs of different users and how travelers use information will lead to improved ways of collecting and providing information to them, as well as elevating the priority of utilizing real-time information to affect driver behavior.

Cost to Fill Gaps and Address Real-Time Data Needs

The deployment of real-time traveler information systems throughout the country provides the opportunity for millions of travelers to make informed decisions about their routes and schedules. But, needless to say, this deployment comes at a cost. While costs for traveler information systems are not easily isolated because much of the detection infrastructure is deployed to support other operations programs, this section seeks to provide several example capital and operating cost estimates for various field technologies, communications, and central systems that could be used as a starting point in the planning stages of real-time traveler information systems deployment.

Traffic

Cost data is readily available for dissemination technologies and systems, such as 511. Costs for private sector probe-based data will evolve with this relatively young market. Currently, there are limited data points for cost information or comparison. For now, the best available cost data is from the I-95 Corridor Coalition, which published its contractual initial and recurring costs.

Table 5 presents a general, high-level cost estimate for deployment of the RTSMIP previously described in **Table 3**), including central system costs/upgrades, interfaces for incident/closure systems, road weather information, and provision of travel times. The assumptions used to arrive at these estimates follow the table.

Table 5: General Cost Estimate for RTSMIP Deployment

Subsystem			Initial Costs	Recurring Costs (Annual)
Central System				
Advanced Traffic Management System (ATMS) Upgrades – new systems	$3 million per system	10 systems	$30 million	(5%) $1.5 million
ATMS Upgrades – Integration of new devices	$200,000 per system	40 systems	$8 million	(5%) $0.4 million
		Subtotal (Central System)	**$38 million**	**$1.9 million/yr**
Traffic Incident and Construction Lane Closure Information				
Database Operator	$150,000 per year per state	50 states	$7.5 million	$7.5 million
		Subtotal (Lane Closure Management)	**$7.5 million**	**$7.5 million/yr**
Roadway Weather Observation Updates				
RWIS Coverage in 61 Metropolitan Areas	(See *Weather in the Infostructure*)	61 metro areas	$38.8 million	(5%) $1.9 million
RWIS Coverage in Non-Metro Areas	$38,000 per RWIS sensor	360 sensors	$13.7 million	(5%) $0.7 million
		Subtotal (Road Weather Information)	**$52.5 million**	**$2.6 million/yr**
Travel Time Along Highway Segments				
Urban Area Detection	$8,000 per sensor	3,450 sensors	$27.6 million	(5%) $1.4 million
Metro Area Mileage without Detection*	$900/$750 per centerline mile	10,800 miles	$9.7 million	$8.1 million**
		Subtotal (Travel Times)	**$37.3 million**	**$9.5 million/yr**

Subsystem	Initial Costs	Recurring Costs (Annual)
NATIONWIDE SYSTEM TOTAL	$135.3 million	$21.1 million/yr

Notes:
*Probe-based method of data collection was assumed for the non-metro roadways; $900/mile/yr includes first year startup costs.
**Recurring costs for probe data are assumed to be $750/mile/yr according the to the I-95 Corridor Coalition contract.

Assumptions

Central System

- It is assumed that each state would require a central Advanced Traffic Management System (ATMS) for the consolidation of data and that each state has one major system to consider, although that is clearly not always the case.
- If systems last approximately 10 years, it may be assumed that five states would need to upgrade their systems in any given year. If five additional systems would need upgrading ahead of schedule to accommodate new major deployment, 10 states would need to completely upgrade their ATMS software platforms. The cost of a full replacement is assumed to be approximately $3 million.
- It is assumed that the remaining 40 states have a system in place that can accommodate significant expansion of devices. It is assumed the integration cost for these systems would average $200,000 each.
- It is assumed that all other costs such as system maintenance and operators are already reflected in existing systems and are not additional costs.

Incident Information

- It is assumed that incidents can be collected from existing sources but that additional database management staff would be needed to maintain the system.
- It is assumed that maintenance of construction information would be handled by the same database management staff as for incidents, or that these two roles together would equate to one full-time equivalent staff person.

Roadway Weather

- It is assumed that the existing roadway weather data provided by public and private entities would need to be supplemented with a nationwide deployment of RWIS stations. Cost estimates were developed using the Federal Highway Administration's (FHWA's) *Weather in the Infostructure*.
- It is assumed that the metropolitan area needs would be addressed by the cost estimate provided in FHWA's *Weather in the Infostructure* (based on composite scoring and road miles), but with 2003 costs escalated to current estimates.

- It is assumed that 10 percent of the non-metro roadway miles have RWIS sensors deployed requiring coverage on the remaining 90 percent of non-metro mileage, which would require RWIS sensors at an average of one per every 100 miles.

Travel Times

- It is assumed that existing sensor deployments would be maintained up to one per mile but not expanded geographically.
- It is assumed that all future geographic expansion of real-time travel time data would come from probe-based data sources. The total mileage to be covered by future expansion is equal to 10,800 centerline miles, which is 61 percent of the freeway mileage in the 50 largest metropolitan areas, given the remaining 39 percent are covered as per deployment tracking statistics.

It is assumed that 50 percent of all existing sensors need to be replaced, but that replacement costs include the sensor, planning and installation costs only, not infrastructure that would be existing such as pole, cabinet, communications, etc. The total number of sensors to be replaced is 3,450, which is half of the current deployment total.

Transit

The public sector has captured some information regarding the costs of deploying real-time traveler information to transit systems, although detailed information is not always available. The following section estimates the costs associated with deploying full real-time information to the 94 transit agencies that responded to the 2007 RITA ITS Deployment Survey. **Table 6** shows the estimated total capital costs to deploy AVL and real-time information to the 31,664 buses and 26,512 other vehicles currently unable to display real-time information to travelers. The table shows a simple calculation of the number of vehicles multiplied by the assumed AVL deployment cost of approximately $8,000/vehicle and an incremental cost of real-time information application deployment cost of approximately $4,000/vehicle, based on the *RITA Benefits, Costs, Deployment, and Lessons Learned: 2008 Update*. The total costs also include the capital cost for transit real-time information signage, which is estimated at $18 million for 3,000 signs. (A cost per sign of $6,000 is assumed, with one sign deployed for every 20 transit vehicles and approximately 60,000 total transit vehicles).

Table 6: Total Deployment Capital Costs

Transit Types	Incremental Cost to Equip with AVL	Incremental Cost to Display Real-Time Travel Information	Incremental Cost to Deploy Signage	Total Incremental Cost
Fixed-Route Buses Only	$135 million	$125 million	$10 million	$270 million
Other Transit Vehicles	$150 million	$105 million	$10 million	$265 million
All Transit Vehicles	**$285 million**	**$230 million**	**$20 million**	**$535 million**

Source: RITA Benefits, Costs, Deployment, and Lessons Learned: 2008 Update

Table 7 estimates the average annual operating costs associated with real-time information for transit, including the software and communications costs associated with deployment. Assumptions are based on values found in the *FHWA Benefits, Costs, Deployment, and Lessons Learned: 2005 Update*.

Table 7: Transit Real-Time Information Annual Operating Costs

	Annual Costs/Vehicle	Approx. Number of Vehicles	Annual Costs
Software			
Buses Only	$400	32,000	$12.8 million
Other Transit Vehicles	$400	28,000	$11.2 million
All Transit Vehicles	$400	60,000	$24 million
Communications			
Buses Only	$700	32,000	$22.4 million
Other Transit Vehicles	$700	28,000	$19.6 million
All Transit Vehicles	$700	60,000	$42 million
Total Annual Operating Costs			
Buses Only	$1,100	32,000	$35.2 million
Other Transit Vehicles	$1,100	28,000	$30.8 million
All Transit Vehicles	$1,100	60,000	$66 million

Source: FHWA Benefits, Costs, Deployment, and Lessons Learned: 2005 Update

Parking

Assessing the cost to fill the gaps of real-time parking information is complicated by the limited number of deployments currently in existence and the inability to assess the total number of spaces that would benefit from real-time information. Unlike other modes, where complete coverage would be beneficial to travelers, many parking facilities are never full, meaning that real-time information is unnecessary. Of the systems that have been implemented, costs vary greatly depending on the granularity of information being provided. Systems that measure only the total number of available spaces in a facility typically cost several hundred-thousand dollars. Similarly sized systems that identify individual open parking spaces often cost several million dollars. **Table 8** estimates typical per-space costs for these various types of systems.

Table 8: Typical Per-Space Smart Parking Costs

Parking System	Costs	
	Capital	Annual Operations and Maintenance
Entry/exit	$40	$2
Space-by-space	$600	$30

Freight

The ability to estimate the costs of public-sector freight information systems is also limited by the number of systems that have been deployed and the difficultly in isolating real-time information costs. Systems that provide freight-specific information to existing 511 systems can be developed for as little as $10,000, such as the Washington State DOT system that aggregates freight relevant information from the DOT's existing system and disseminates it to commercial vehicle companies via email. Deploying real-time freight information to ports and intermodal facilities can cost several million or more. Private-sector systems can be calculated on a per-vehicle basis. Entire after-market telematics packages can now be installed and maintained for approximately $500 to $2,000 per truck per year.

Roles for the US DOT

The US DOT plays a crucial role in coordinating the efforts of the state and local government and private-sector partners. Based on the research conducted for this report, the following conclusions represent actions that will further the development of real-time information systems to continue to improve transportation safety, security, and efficiency.

Standards

Develop National Standards on Real-Time Information

Every state/region is doing something different with 511 and other real-time information applications, although a majority of them follow the same concepts. The US DOT/FHWA has an opportunity to develop national standards for 511 implementation beyond what is currently provided in the 511 Implementation Guidelines. This would support the interoperability of systems and seamless transition for the traveler between system areas.

Help to Improve Data Quality and Define Quality Standards

Public agencies are interested in support from the government to better ensure data quality. This support can be in the form of white papers, proof of concept, research, or analysis of existing systems. Quality standards can be developed on the national level to ensure that the amount of infrastructure-based data collection devices or probes would satisfy a basic level of quality for the dissemination of that data to the public. Linking the quality of data with the revenue provided to collect that data would help increase the standard for quality.

Help to Improve Data Exchange Standards

The US DOT could and should do more in the arena of real-time data exchange and traveler information standards. To date, many standards are not as widely used as they should be, and this hinders the ability to widely share and use information, which improves data quality. The US DOT should make standards freely available, push for key existing standards to be completed to eliminate ambiguities, provide a more open forum for sharing lessons learned as well as a more open process for standards development, and provide clear test procedures or validation processes so that accurate implementations of the standards can be confirmed.

Standardize Approaches to Collect and Share Information with the Public

There are gaps in information gathering and dissemination that could be mitigated if there were a standard methodology applied to:

- *Construction data* – Real-time data collection for actual lane closures, delays, and other impacts to traffic from the construction activities can be shared with the traffic management agencies to disseminate more accurate information to the traveler.
- *Communications protocol for sharing data* – The methods for collecting, storing, and sharing data can be in multiple forms/protocols, which makes sharing information with new agencies and new users a challenge to overcome. The information that is important to active traffic management and traveler information can be standardized on a national level to be able to share data more easily and potentially provide interoperability between local or state systems.
- *Sharing additional information with third-party companies to disseminate to the traveler* – This would include dynamic information on managed lanes or pricing information as an example of information that the consumer would benefit in knowing prior to entering the managed lane.
- *Attribute information* – When choosing a parking space, customers benefit from increased knowledge of facility attributes including hours of operations, security features, entry/exit, and cost.

Resources

Understand the Implications of Section 1201 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)

The private sector is supportive of these real-time requirements, but the public sector has some reservations for the federal requirements due to funding and resource implications.

Fund ITS Programs

States and local agencies continue to need funding support to implement ITS to collect data on roads, fleets, and parking facilities, and for more than just traveler information purposes. If the direction of the market remains that the public sector deploys detection devices to collect public data, then funding will continue to be required for maintaining and enhancing programs.

Improve the ITS Deployment Tracking Database

Although it remains the best source of information available on the national level, the ITS Deployment Tracking Database has notable gaps. The uniformity (lack of) of survey results is an issue. Ensuring the survey gets to the right people who have access to the right information is crucial. This is particularly true for arterial information. It is recommended that efforts be focused on maintaining contacts within key agencies who can provide the needed information. Further, data can be obtained from other sources. Vendors are knowledgeable of where their systems are deployed and what their capabilities are. In particular, there are far fewer signal system vendors than there are signal systems. Gathering information from these firms could garner a good return for the effort.

Research and Development

Research and Evaluate the Benefits of Investing in Data

Define the benefits of investing in real-time data. While there are numerous agencies and areas in the country that are educated on the opportunities for collecting data in the market today, there are some areas that are not yet thinking about how they can use that data.

Facilitate the Development of Technologies and Applications

Supporting the development of technologies through funding and partnerships with the private sector, such as is occurring with IntelliDrive^{SM}, SafeTrip-21, and Mobile Millennium in California, allows the government to show support and new use of innovations and allows the private sector to implement the value-added applications. Emerging market segments like parking and freight are further behind in the development of effective and affordable technologies. Helping agencies to understand what innovations are available and testing those innovations to determine benefits and justifications for widespread use would benefit agencies looking for new opportunities in providing good quality data to their customers.

Encourage the Development of Additional Communication Methods

Funding for research in the areas of digital short-range communication (DSRC), WiFi, WiMAX, and other open-air communication networks for obtaining real-time data also can support the development of real-time information across all modes.

Conduct Research to Improve Understanding of Real-Time Information Usage

Additional understanding of how travelers use real-time information is needed, including how the information they receive affects the decisions they make. This is especially crucial in developing market segments like transit, parking, and freight. This information can be used to focus outreach efforts, broaden the usage of information, and promote market sustainability.

Partnerships

Encourage Partnerships

Partnerships that utilize interagency deployments and coordination should be promoted. The relationships should focus on multi-modal regional real-time information and involve coordination between agencies and the private sector. Such partnerships can include the modal integration of real-time information for interagency coordination to consolidate data between state DOTs (traffic) and transit agencies (transit). In addition to public sector partnerships, commercial vehicles need to be an active partner in the development of real-time freight information, including through incentives that encourage participation.

Provide a Qualified Vendor List and Qualified Methods List for Public Agencies to Receive Data

Work to provide a qualified vendor list for providing data and possibly partner with ITS America to develop this. Recommended data collection methods for public agencies to consider implementing would be beneficial for local agencies.

Encourage the Public Agencies to Leverage the Private Sector Strides in Data Collection Techniques and Technologies

The private-sector data is broader in geographic scope than what the public-sector-operated systems can collect. The private-sector competition will keep prices reasonable, which may be able to demonstrate that they are equivalent or lower than the cost for public agencies to deploy data collection devices and provide traveler information services such as 511. There needs to be a bigger market and more demand from customers in order to make prices competitive.

Negotiate Data Collection Activities at a National Level

The US DOT/FHWA should explore the idea of negotiating with the private sector on a national level (perhaps similar to the General Services Administration [GSA] Schedule) that would provide data on a local or state level. This could not only provide a standardized method for distributing the data to public agencies, but could also support the reliability of that data due to the larger-scale application.

1 INTRODUCTION AND OVERVIEW

1.1 Background

A decade ago, traveler information was thought to be largely in the public sector area of responsibility. It was the public sector, after all, that was deploying detection technologies on freeways, actively monitoring and managing systems from operations centers, and providing available data to travelers via roadside infrastructure such as dynamic message signs (DMS) and highway advisory radio (HAR). The media was an active partner, typically dominant in the area of radio information dissemination due to its well-established broadcast capabilities in metropolitan areas throughout the country. As more data became available, partnerships began to emerge between commercial media providers and public-sector transportation agencies, which broadened both the reach and quality of traveler information.

With the Metropolitan Model Deployment Initiatives in the late 1990s, new approaches and partnerships emerged as private-sector technology companies began to get more involved in providing innovative applications to support traveler information. Traveler information has evolved separately in each mode of transportation, with heavy focus on traffic information. Only in recent years has the emphasis moved toward regional and multimodal systems. Today, a unique balance between the public and private sectors provides real-time data to support traveler information across multiple modes. New advancements in communications and sensor technology have created additional opportunities to provide information for both the public and private sectors.

1.2 Purpose and Objectives for Assessing the Real-Time Traveler Information Marketplace

This report takes a multi-modal look at the "lay of the land" of the real-time traveler information market in the United States. This includes identification and characterization of the gaps in the domestic industry with respect to data coverage, data quality, data procurement methods, and data usage. Ultimately, the focus is to identify the gaps in real-time information across different modes (i.e. traffic, transit, parking, and intermodal/freight). The analysis also includes documenting the institutional, technical, and cost issues associated with collecting real-time data from these modes, opportunities for closing the gaps, and utility of real-time data for uses beyond traveler information. Although each mode offers a unique set of challenges, an important objective of this study is to identify opportunities to best leverage resources and innovative approaches that span multiple modes.

1.3 Modal Context

1.3.1 Traffic

From the traffic perspective, real-time traveler information has its roots in freeway and traffic management applications. Systems that have been deployed for urban freeway management, statewide maintenance, and weather detection, as well as operations of other agencies such as law enforcement, provide valuable inputs to a regional and statewide data set to support traveler information systems. Real-time data has traditionally been collected by sensor-based systems deployed and operated by departments of transportation (DOTs) as part of urban area freeway management systems. Combined with closed-circuit television (CCTV) cameras for visual monitoring, detection systems also provide a valuable data set to support traveler information functions that include speed maps, travel times, and access to corridor snapshots or streaming video. With the increased deployment of 511 and enhanced Web-based agency traveler information systems, there is a stronger focus on obtaining more precise data as well as real-time data that extends beyond urban area boundaries.

Partnerships among the public and private sectors have been a mainstay of traveler information. For example, the media has been, and remains, a key partner in traveler information dissemination through a variety of communications modes—radio, TV, and Web access are among the most prevalent. Other private-sector partners play important roles in data aggregation and dissemination, and there has also been an increase in the role of the private sector in data collection in recent years. This marks an important shift, in that these partners are developing systems with a broad national footprint, as opposed to localized or regional systems with a specific target audience. It has also spurred an increase in vertical partnerships within the private-sector supply chain to provide a full spectrum of services for traveler information, including collecting and aggregating data; providing a data output; combining with other data and information types; linking to map-based applications; and delivering to users through in-vehicle, Web-based, and mobile-accessible applications.

1.3.2 Transit

Various forms of static transit traveler information (e.g., printed schedules, systems maps, and fares) have existed for decades. While this static information is still needed for various route planning activities, new technologies have allowed additional information to be accurately provided to transit riders in real time. Patrons appreciate real-time information when it is available and use it for both routine day-to-day trips and unfamiliar trips, such as those taken in a new city or on a route that the traveler typically does not take. Information disseminated to customers can include service disruptions, vehicle locations and arrival time, or even vehicle capacity. Many transit agencies strive to provide real-time information that is widely available across multiple media paths and is presented in a seamless stream to customers across the entire network. This consolidated information source should support a variety of access methods that range from pre-trip information available on a Website or by phone to mid-trip information provided via mobile device while en route, at a stop, or on the transit vehicle while it is en route.

Many transit agencies focus their real-time information efforts on providing vehicle location and arrival time information, which is made possible by a variety of intelligent transportation system (ITS) technologies—most notably, global positioning system (GPS) based automatic vehicle location (AVL). Most agencies have deployed GPS-based AVL data for fleet management purposes, but the data also forms the backbone for providing real-time transit information to customers. Once location is determined, an algorithm can be used to predict estimated time of arrival at downstream transit stations and stops, which can be disseminated to customers. Transit agencies of all sizes are beginning to see the benefits of obtaining AVL data for transit routes. The need for this type of data originated with transit agencies striving to optimize operations and monitor system performance, but the ability to share that information with patrons provides yet another user benefit.

Some transit agencies have preferred to contract out to private companies data collection device installation, data aggregation, and information dissemination, so that the agencies can continue to focus on their core competency—transit operations. In addition to their partnerships with private companies, transit agencies are beginning to partner with each other to create more robust traveler information networks, especially across agencies located in the same metropolitan area or region. Data and information sharing between agencies is primarily related to the trip planning function and is based on scheduled, not real-time, information. Unfortunately, a lack of standards, systems with credible information, and understanding of the nature of real-time data often prevents collaboration and full utilization of real-time transit data.

1.3.3 Parking

With respect to parking, notable progress has been made in the past few years in providing real-time parking availability information. The public and private sectors are working together to make this information readily available to the public in real time, as well as to explore the possibility of actively managing parking availability by adjusting prices. Often, parking is available, but travelers are not properly matched to spaces. In other situations, public parking is in short supply, but private parking is readily available; or there truly is a parking shortage, but travelers are not aware of it until they arrive at their destination.

Increasingly, ITS is seen as a potential solution for many of today's parking shortage problems, including issues related to parking for passenger and commercial vehicles. Advanced parking information systems (APIS) have resulted in measurable traffic flow improvements for locations including airports and downtown central business districts. Public- and private-sector agencies also have technology options available to monitor parking utilization and the paid status of parked vehicles in real time to increase the percentage of parking violators that are cited. Thus, such information systems have benefits for the traveling public as well as the potential to increase revenue for regional and local governments. Potential business models are being developed for smart parking applications for both the private and public sectors including models based on payment from end users and municipalities; these models will continue to develop over the next few years.

1.3.4 Freight

Both government and the industry are concerned with the increasing congestion faced by freight and intermodal traffic on the nation's heavy-freight highway corridors and at freight bottlenecks. Commercial drivers are often already aware of recurring congestion, but need additional updates to inform them of unexpected delays stemming from incidents, road closures, and weather. Truckers use traveler information applications from both the public (e.g., 511 systems and DMS) and private (e.g., telematics) sectors to help them to increase their productivity, improve routing and route choices, optimize fuel consumption, and more effectively manage time. For example, dynamic routing around traffic incidents will allow truckers to decrease the amount of time lost due to non-recurring congestion, which is currently estimated to cause 40 percent to 60 percent of the lost productivity.

The public sector has focused some of its real-time freight information technology on providing additional freight-specific information to truckers as part of existing traveler information systems. These add-ons consider the size, probable route choices, and operational characteristics of commercial vehicles. For example, instead of the local weather updates that most passenger vehicles would be interested in, trucks on long-haul routes might be interested in predicted weather conditions several hundred miles down the road. Truckers might also require information regarding parking availability along their route in order to properly utilize their available hours of service. The public sector has also focused on deploying systems at intermodal facilities and border crossings, where freight traffic frequently bottlenecks.

The private sector has developed in-vehicle communications systems that can be installed in a vehicle's cab to provide additional real-time information regarding weather, routing, and congestion. These systems can also provide information related to tolling and truck lanes, size and weight restrictions and permitting, and security. Systems can also be leveraged as probes to track individual truck movements and operational performance metrics to more closely manage fleet operations.

1.4 Research Methodology

The process for the development of this report included performing a literature review, conducting a series of interviews with industry experts, synthesizing an overall industry assessment and gap analysis, and developing recommendations. Information was gleaned through review of literature and interviews with industry experts from the public sector, private sector, and academic organizations with perspectives across each of the modes. Additional input and reviews from multimodal experts at the US DOT were sought to gain valuable insights to the process. With the breadth of potential information that could be utilized in this study, the research team focused on the following core focus areas within each mode to guide the research and interview processes:

- Current systems and programs
- Technology applications and data collection strategies
- Coverage and extent of deployment
- Data quality, including quality measures
- Customer and internal usage of real-time data for traveler information
- Procurement methods and business models
- Agency perspectives on the current state of the industry and the current and future role of the public sector in the traveler information marketplace
- Private-sector perspectives on important trends and developments in the industry, as well as approaches to partnering and business models
- Gaps in the current real-time traveler information marketplace (technology, coverage, usage, etc.)
- Trends and vision for the traveler information marketplace in the next 5-year horizon
- Specific triggers or barriers to reaching that vision
- Potential roles for the US DOT to advance the marketplace over the next 5 years.

This section describes the research team's approach to consolidate the most recent research and industry perspectives on the real-time traveler information marketplace.

1.4.1 Literature Review

The literature review focused on identifying reports, studies, system documentation, user surveys, evaluations and procurement documentation, and regional and national statistics. The research team reviewed over 100 resources across all four modes, with approximately half covering the traffic mode. In most instances, available literature was able to provide quantifiable statistical data (such as coverage of 511 systems, number of transit agencies using AVL, regions deploying real-time parking, etc.) as well as program-specific documentation about current and past projects at the regional and national levels.

1.4.2 Interviews with Subject Matter Experts

The research team conducted interviews with more than 62 industry experts across modes, which included practitioners and system operators from the public sector, private-sector technology and service providers, academia, other industry experts (including association/coalition representatives), and the US DOT. The interviews captured current trends and issues not readily available in published literature and obtained input on the current and future states of the real-time traveler information marketplace.

1.4.3 Gap Analysis Synthesis

One of the key objectives of this study was to identify gaps in current approaches, systems, partnering strategies, and technologies relative to the real-time traveler information marketplace. This gap analysis assessed a range of different issues within each mode and identified gaps at the institutional level (e.g., partnerships and procurement strategies), coverage between systems operated by the public sector and those operated by the private sector, and variability in quality and different customers' quality expectations as well as usage (which included how or if data collected could serve purposes beyond traveler information). Gaps range from inability to deploy data collection technologies on highways (by the public sector) beyond urban areas where demand is greatest for real-time network data, to effectively integrating multiple data sources (such as from different transit operators) for a comprehensive regional real-time data set.

1.5 Organization of Report

This report covers the four modes (i.e., traffic, transit, parking, freight) under six key topic areas (i.e., technology, data coverage, data quality, uses of real-time data, procurement, and costs). However, these modes and topic areas are inter-related. One topic area in a mode could potentially impact another topic area within that mode, the same topic area in another mode, or even another topic area in another mode. For example, advancements in data collection technology in one mode could potentially reduce traveler information system implementation costs and help increase the data coverage and quality for that mode, thereby increasing its usage. At the same time, since many of the modes utilize similar technology, including sensors and probes for data collection, communications infrastructure for data transmission, computer applications for data aggregation, and various types of equipment for information dissemination, advancements in technology could potentially benefit more than one mode. Achievements in deploying 511 systems, developing data quality metrics, and creating data procurement models can also have similar multi-modal impacts.

In view of these interdependencies, this white paper presents an integrated modal perspective on the different aspects of the real-time traveler information marketplace. However, in some instances where applicable, this white paper describes specific modal issues in more detail to provide a comprehensive discussion on specific attributes or challenges. Each section includes an overview of the topic area, identifies important trends, discusses key gaps, and provides recommended strategies to close these gaps and roles for the US DOT in addressing the gaps. **Table 1.1** lists the key sections of the white paper.

Table 1.1: White Paper Key Sections

Section	Highlights and Topics Covered
1. Introduction and Overview	Presents the background and objective for the study, provides a context for the different modes being examined, and presents the research approach. This section also includes some important cross-cutting issues and trends among the mode areas.
2. Background	Discusses different technologies to support real-time data collection and information dissemination, as well as identifies emerging technologies and applications. Also identifies different procurement approaches for real-time data, and some of the challenges with public-private procurement processes.
3. Real-Time Data Coverage	Discusses coverage from a modal perspective, with subsections on traffic, transit, parking, and freight. Also details coverage gaps for each of the respective modes.
4. Data Quality	Looks at the different quality measures and metrics in use today for traveler information, including tools to measure quality. Also discusses how quality is perceived from different perspectives and identifies gaps.
5. Uses of Real-Time Data	Discusses the different ways in which real-time data can support traveler information, system management, and operations, as well as uses of data for performance monitoring and improvement. Also presents different perspectives from the public and the private sectors.
6. Costs	Presents system costs by mode for information collection and dissemination, and discusses the different cost considerations for the various real-time systems. Also identifies summary-level costs to fill gaps at the national level.
7. Conclusions	Presents recommendations and roles for the US DOT and other entities to close the real-time data gap and achieve the vision of real-time information for all roads and modes, all of the time.

2 BACKGROUND

2.1 Real-Time Technologies

The provision of information to travelers in real time depends on a variety of different technologies for data collection, aggregation, communication, and dissemination to the user. Many of these technologies are common across modes, although others are mode-specific. **Table 2.1** lists some of the advantages and disadvantages of different sensor technologies.

Table 2.1. Comparison of Real-Time Technologies

Technology	Applications	Advantages	Disadvantages
Data Collection Technologies			
Infrastructure-Based Sensors	• Signal actuation • Arterial system detection • Ramp metering • Transportation Planning • Traveler Information • Operations • Parking management	• Capture high resolution data at a point • Capture vehicle occupancy • Capture traffic volumes • Capture vehicle classifications	• Expensive to deploy and maintain • In-pavement sensors
Probe Detection	• Fleet AVL • Traveler Information	• Captures high resolution data for individual vehicles • Captures traffic stream without requiring infrastructure-based sensors	• Sampling does not capture all traffic stream information (volume, occupancy) • Communications can be expensive
Communications Technologies			
Wireless	• Mobile vehicle communication s • Rough terrain (for fixed point to point) • Urban areas (for fixed point-to-point)	• Allows continuous communication with mobile vehicles • Allows communications over rough terrain or where conduit is not feasible	• Lower bandwidth • Higher latency • Less upgradeable (fixed point to point) • May require licensed band for high bandwidth, high availability line (fixed point to point) • Distance limitations
Wireline	• High bandwidth, low latency applications	• Bandwidth can be increased with updated	• Susceptible to line breaks

Technology	Applications	Advantages	Disadvantages
		electronics	
Dissemination Technologies			
511 Systems (phone)	• En route traveler information	• Accessible anywhere • Only requires a phone • Easy to remember number	• User must initiate • User must navigate menus • Information is audio only
511 Systems (Web)	• Pre trip traveler information	• Graphical interface • Interactive	• Requires PC access • Information is limited to what can be provided by the DOT host
VMS	• En route traveler information	• Information pushed to travelers	• Fixed locations • Limited message size
Wireless Applications (personal navigation devices [PNDs], Smartphones)	• En route traveler information • Parking reservation systems • Location based services	• Accessible anywhere • Graphical interface • Interactive • 2-way communications	• Limited to those who can afford them • Low bandwidth
HAR	• En route traveler information • Construction traveler information systems • Special event traveler information systems • Tourist information systems	• Location-specific information	• Requires user to tune in • Limited broadcast range • Low audio fidelity • Not interactive, i.e., no menu structure
Telematics	• (see wireless applications)	• (see wireless applications)	• (see wireless applications)
Parking Management System Technologies			
Space-by-space parking sensors	• Real-time parking information	• Highly granular data • Enables more efficient facility operations (e.g., space-maximized layouts, reduced	• High cost (installation and operations and maintenance)

Technology	Applications	Advantages	Disadvantages
		emissions, time to find space)	
Entry/exit parking sensors	• Real-time parking information	• Less difficult to install • Optimized sensor placement can decrease costs and improve data	• Accuracy may decrease in poor weather • Requires well-organized entry/exit points • Counters must be able to distinguish vehicle type for commercial vehicle application • Requires manual counts to reset • Requires buffer

2.1.1 Collection

To provide real-time traveler information, situational data concerning the travel conditions must be collected from the transportation network. Data collection requires sensors that can gather data, including infrastructure-based sensors or probe-based sensors. Infrastructure-based sensors are deployed as part of the modal infrastructure and monitor a specific point within the network. Probe-based sensors are deployed to vehicles operating within the infrastructure and track specific vehicle movements. Aggregated speed, location, volume, and weather information can be used to provide an indication of how vehicles are operating across a network. Although many of the collection methods can be used individually, gathering data from multiple methods often improves data collection efforts.

2.1.1.1 Infrastructure-Based Sensors

Infrastructure-based sensors are stationary data collection devices that monitor vehicles and weather conditions at a specific point of the transportation network. Often the most prevalent technology for many real-time data collection applications, they include in-pavement or non-intrusive detectors that measure vehicle presence, volume, and speed. In-pavement technologies are predominately inductive-loop detectors or magnetometers; non-intrusive detectors include passive/acoustic detectors, and, side-fire radar. Demonstrations were conducted in the Houston, Texas, area to determine the feasibility of using automated number plate recognition as an alternative to radio frequency identification (RFID)-based toll tag readers for determination of link travel times on urban arterials. Environmental Sensor Stations (ESS) are another type of sensor that collect road weather information for travelers.

Some transit agencies use signpost/odometer reading as a type of AVL technology that determines vehicle location by knowing the location of a fixed wayside signpost and the vehicle's current odometer reading and scheduled route. The wayside equipment identifies the passing vehicle by a tag/transponder placed on the vehicle. Alternatively, loop detectors can be used instead of a tag reader. The wayside point relays information regarding the specific identification of a vehicle to a central point, while the vehicle relays information regarding the vehicle's current odometer reading. This information is cross-referenced with the known location of the signpost, determining the vehicle's location. Modern transit rail systems use wayside signaling for command and control operations and traveler information because they operate on dedicated right-of-way where schedule adherence is likely and often underground—where satellites cannot communicate with GPS transponders. However, while wayside systems were common in past decades for fixed-route buses, recent technology refreshes have provided for the proliferation of GPS-based AVL. Since these vehicles can communicate via a more accurate GPS-based system, the accuracy of vehicle location improves for vehicles traveling in dynamic traffic conditions.

Real-time parking data collection is also commonly supported by infrastructure-based sensors. Similar to collecting traffic information, smart parking must first gather data on the availability of parking spaces at targeted facilities. Such systems can employ a variety of detection methods including beam inductive loops, magnetometers, infrared or ultrasonic sensors, or video cameras and counting software. Determining the number of available parking spaces usually occurs by deploying sensors that typically either count the number of vehicles entering/exiting a given area (including entry and exit points or between areas within the structure) or detect the presence of a vehicle in a particular space. In choosing a real-time parking solution, implementers must make decisions regarding required data granularity based on the needs of the operator and customers. Space-by-space systems are able to provide highly granular and accurate information, maximizing facility efficiency, but require high installation and maintenance costs. Entry/exit facilities are less costly to install but are not as accurate, require manual resets, and buffer estimates.

Real-time parking information for commercial vehicles also uses the above methods, but due to the varying lengths of commercial vehicles, sensors require additional considerations. The Federal Motor Carrier Safety Administration (FMCSA) is currently working with vendors to demonstrate the ability to measure commercial vehicle parking availability with enough accuracy to warrant a pilot deployment.

CCTV cameras are another type of infrastructure-based method used to support incident detection/monitoring, system outages, and visual-based traveler information (such as through Web dissemination and media). While they do not typically provide quantitative data—although they may with the use of image-processing tools—they are widely used by the media and the public. Television stations will typically use a high-quality stream for broadcast, while Web sites will reduce image quality to save bandwidth. Analog video is being phased out in many locations for digital video, which can be compressed and shared more easily.

2.1.1.2 Probe-Based Sensors

In contrast to infrastructure-based sensors, probe-based sensors are mobile devices deployed to vehicles operating within the infrastructure. These sensors can be used to track the movement, location, speed, and volume of a specific vehicle (e.g., transit vehicles) or any vehicle across the network (e.g., passenger vehicles on a roadway) where a vehicle is tracked via a cellular, WiFi, satellite, or other wireless signal. With the growth in mobile computing and wireless communications, probe-based sensors are becoming more common. They are particularly conducive to transit information as transit agencies can more readily deploy and maintain systems on their fleet of vehicles. AVL devices using GPS are the most common form of probe-based sensors for transit vehicles. Although GPS AVL data serves fleet management purposes as well, it also forms the backbone for providing real-time transit information to customers.

Detection systems use GPS-based AVL to determine where transit vehicles are located, particularly in relation to their next scheduled stop. They use a group of geosynchronous orbiting satellites to bounce signals to a terrestrial transponder on a vehicle. Three or more satellite signals are used to estimate the vehicle's location, speed, and heading, providing a highly accurate indication of the vehicle's present location. One of the largest agencies in the United States, the Los Angeles County Metropolitan Transportation Authority has successfully deployed GPS-based AVL to its entire fleet to collect vehicle location information.

Probe-based methods for traffic data collection have seen increased interest as a means of expanding geographic scope beyond roadside sensor deployments. The private sector is collecting data from other private-sector partners such as commercial fleets (with GPS AVL) and cellular phone location data. GPS provides speed, location, and heading with a high degree of accuracy and has proven to be more accurate than methods that triangulate phone signals from cell towers. Triangulation methods also rely on business partnerships with the cellular carriers, for which traffic information is not a core focus. To date, despite rapid growth, firms have not been able to capture a sufficient market penetration of GPS-enabled phones to support probe-based traffic data, but the marketplace is rapidly evolving:

- Research firm Forward Concepts projects the compound annual growth rate for GPS chips used in cell phones at almost 40 percent through 2011.
- ABI Research predicts that by 2013, one in three phones sold will be a Smartphone, most if not all of which have GPS capability, an unlimited data plan, and the ability to run a wide variety of applications such as travel information.

Additional existing mediums are also being utilized for use as probes including Bluetooth tracking devices and RFID. RFID is most common with tolling systems, which are also being tapped to provide segment point-to-point travel time calculations.

2.1.2 Communications

Real-time information systems require reliable communications as the backbone of their operation including the effective transmission of data from data collection devices and other ITS applications, such as data from individual loop detectors, GPS transponders, and CCTV images. After sensors collect data, information must be transmitted to a central collection system. To accomplish this task, systems require relay from sensors to a local process via radio transmission, fiber optic, or other communications medium. Data is aggregated to a central collection system. Wireless communications including cellular or radio transmission can be used, although they may incur substantial transmission costs. There are multiple systems using point-to-point and point-to-multipoint wireless backhaul that were installed extremely cost effectively. Dedicated systems provide high-quality real-time information, but are expensive and usually require communications infrastructure to be installed as part of the facility's construction or as an add-on. To this end, some regions and states have established direct connections between DOT transportation reporting systems and law enforcement/public safety computer-aided dispatching (CAD) systems. **Figure 2.1** shows a conceptual real-time communication diagram.

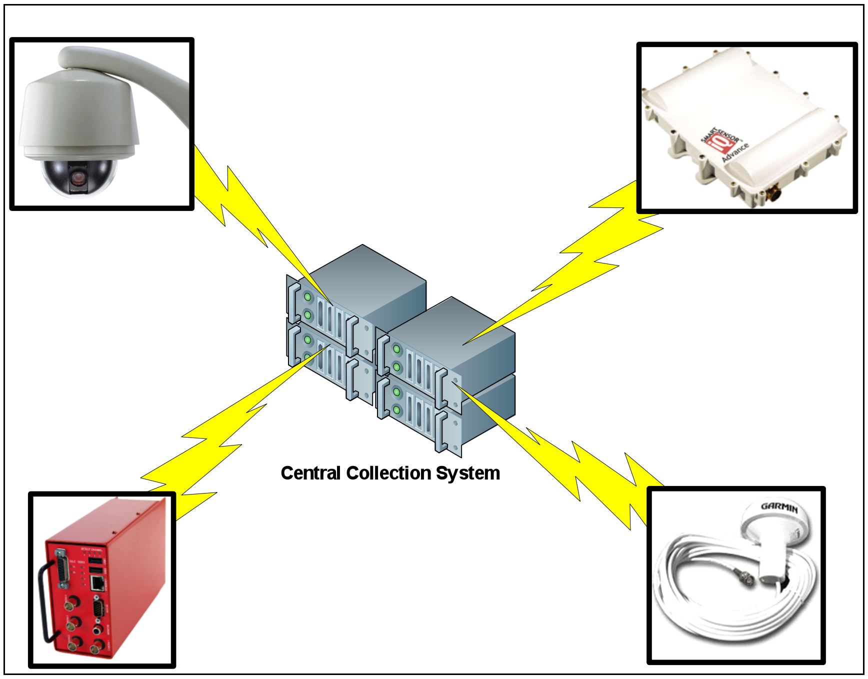


Figure 2.1: Conceptual Real-Time Communication Diagram

Many agencies are striving to develop more cost-effective methods for communications infrastructure. Communications technologies like T1 lines require sizeable monthly fees, while using Web and Extensible Markup Language (XML) technologies over wireless communication links promises to be less costly because these systems require minimal infrastructure. For example, providing real-time transit information for all of the Chicago Transit Authority's (CTA's) approximately 2,000 buses would require a wireless communications infrastructure capable of handling the entire network, especially since location updates need to be received frequently. CTA is exploring using cellular networks or WiMAX to provide continuous cost-effective communications updates. In addition to wireless communication in real time, AVL data can be stored onboard for nightly retrieval to evaluate schedule performance.

2.1.3 Aggregation

Once data pertaining to situational awareness is collected and communicated to a central server, it must be aggregated and analyzed to develop useable information. Algorithms are used to predict estimated travel time for in-traffic or next-vehicle arrival time at downstream transit stations and stops. To maximize the accuracy of information outputs, it is often best to collect and aggregate many types of data from various sources to ascertain real-time traffic conditions and performance measures.

2.1.4 Dissemination

2.1.4.1 Location for Information Dissemination

Methods of dissemination for real-time traveler information adhere to three specific intervals when and where customers seek real-time information, including pre-trip, in-terminal, and in-vehicle information. While pre-trip and in-vehicle information is relevant to all modes, in-terminal information is only related to transit and freight information. Travelers require different types of information at various periods of their journey, as described in **Table 2.2**.

Table 2.2: Real-Time Information Intervals

Locations for Dissemination	Relevant Modes	Time/Location of Information Received	Dissemination Applications
Pre-trip	All Modes	Before the traveler makes the journey (e.g., home, work, walking to transit station)	• Static network maps and schedules • Online trip planners • 511 • Smartphone applications • TV and radio alerts
In-station	Transit Freight	Waiting for transit vehicle at station/stop Waiting for loading and unloading cargo	• 511 • Digital displays • Smartphone applications • In-terminal announcements • Kiosks
In-vehicle	All Modes	While riding in a personal, transit, or commercial vehicle	• HAR • Dashboard systems • 511 • Smartphone applications • Automated service announcements • In-vehicle telematics and navigation devices

2.1.4.2 511 Systems

All of the transportation modes can use 511 to disseminate information to customers. 511 is a publicly available service that allows users to retrieve relevant transportation information over the phone. 511 systems use Interactive Voice Recognition (IVR) systems to allow callers to access both static and real-time information by dialing 511, voicing or keying in their specific mode and/or route choices, and listening to information. State DOTs, regional transportation agencies, and transit agencies continue to plan for and invest in both phone-based and Web-based 511 services (available to 70 percent of the population in 2009). 511 systems have the added benefit of being accessible to customers at any point in their journey including pre-trip, in-terminal, and in-vehicle.

Similarly to passenger vehicles, commercial vehicles can receive real-time traveler information, including truck-specific information, from the public sector in a variety of ways including 511 systems. 511 systems, while convenient and practical given the large number of drivers that own cell phones, have recently been discouraged for trucks by the National Transportation Safety Board (NTSB) because they create a safety issue by introducing a distraction for drivers. Restrictions on cell phone use for drivers of passenger vehicles is also restricted to hands-free use in some states including California, Connecticut, New Jersey, New York, Oregon, Washington State, and Washington, DC.

2.1.4.3 Dynamic Message Signs

DMS are light-emitting diode (LED) or liquid crystal display (LCD) in-terminal or roadside signs displaying traveler information that can be updated in real time. A DMS is usually effective anywhere in the vicinity of travelers. DMS can be particularly useful for providing location-specific parking information, next-vehicle arrival times at transit stops, and wide-area alerts during emergency situations. The public sector has seen an increased reliance on DMS for incident/closure information and real-time conditions (existing in 43 metropolitan areas and planned for 15 more).

2.1.4.4 Online Applications

Online applications provide a medium through which travelers can access a variety of static and real-time information regarding vehicle arrival and preferred routing. Online applications can also be used to disseminate alerts, congestion, weather, parking, and schedules via data feeds using email, Websites, Really Simple Syndication (RSS) feeds, and Twitter. Emails can be used to disseminate information to customers who sign up to receive automatic updates, allowing them to receive information specific to routes or geographic areas for which they are interested. RSS feeds are XML messages that allow users to access information such as news headlines and blogs, but are also able to display travel information. Twitter, a social networking application, is a text-based microblog that can display updates including service delays or outages. One Website, my511.org, allows users to set up a personalized 511 service for faster, easier access to information regarding recurring trips.

Many agencies and operators are focusing their efforts on developing add-ons for applications and devices already owned by travelers, allowing them to skirt additional infrastructure costs. Many external developers are also focused on providing applications including Google and Apple, through Google Maps and iPhone applications, respectively. However, the information that agencies are able to provide via social networking applications may be limited by state/local laws or the agency's charter.

Parking information Websites were cited as the primary method for pre-trip information dissemination. When providing pre-trip information, service providers should be cognizant of how they provide information to customers. In addition to providing reliable predicative information, it may be necessary to contextualize the number of spaces available via a color scheme (e.g., green means ample parking, red means no parking) so that customers can make informed decisions. Websites can collect information from a variety of public and private sources as well as allow social networking functions where users can discuss their experiences with specific parking locations.

Wireless applications, such as those in Smartphones and personal navigation devices (PNDs), also provide real-time traveler information at any point in a customer's journey. Smartphone applications allow users to wirelessly access information from their everyday handheld devices, including many of the online applications discussed in the previous section. Such applications are an increasing focus for many operators and agencies because of the ease of pushing information into the public domain and into the hands of users. In addition to providing drivers with parking information, Smartphone applications that provide two-way communication allow customers to reserve a parking space in anticipation of their journey. As opposed to Smartphones which access online content, PNDs receive device-specific content via satellite.

This can be used to provide turn-by-turn navigation as well as to disseminate real-time traffic information including congestion and incident alerts. PNDs could also be used to disseminate parking or transit information to travelers, but so far only a few examples have been deployed.

2.1.4.5 Highway Advisory Radio

An HAR disseminates traveler information by AM or FM radio. It is frequently used to disseminate information in specific locations via low-power radio stations. It has been used to provide parking information at some large airports, although few examples have been deployed. Similar to passenger vehicles, commercial vehicles can receive real-time traveler information via HAR. Additionally, truckers can utilize CB Wizard, a Citizen's Band (CB) radio system that broadcasts real-time direct message information to commercial vehicles. It has been met with mixed opinions in the industry. While many truckers appreciate the information provided to them, others would prefer to keep the channels open for peer-to-peer communication.

2.1.4.6 In-Vehicle Telematics

In-vehicle telematics is a fast-growing industry. As with most in-vehicle technologies, these were first seen in luxury cars, but they are quickly becoming more commonplace in all makes and models of personal vehicles. Both in-vehicle and aftermarket personal navigation systems are now very common and affordable. Examples of in-vehicle telematics systems are GM's On-Star and Ford's SYNC. On-Star has been providing two-way communications services for a few years now, including notification of when the airbag has deployed or human interactive directions. Ford SYNC connects with other portable devices and provides directions and traffic information.

Aftermarket PNDs, such as those from Garmin, TomTom, and Magellin, offer directions and real-time traffic services on some models. These additional services often come with a fee. They are also typically communicate one-way over FM radio frequency sub-bands.

To date, the commercial vehicle industry has the most successful deployment of in-vehicle telematics, including onboard communication systems linked to an information service provider. Systems are available factory-installed by the manufacturers on some newer vehicle models or as an aftermarket add-on. Devices provide two-way communication between drivers and dispatchers/service providers via satellite or cellular communications.

Systems are capable of tracking a vehicle for the entire length of its journey using GPS transponders on the vehicle, allowing a trucking company or third-party provider to monitor route, operational performance, and external conditions. This data can be communicated back to the driver and the vehicle to improve performance and provide information to other vehicles in the vicinity. The service provider also can forward routing, traffic, and weather information to the driver. Such systems are particularly useful for long-haul drivers, who often operate in areas they may not be familiar with and are isolated from their dispatchers and maintenance crews for longer periods of time. While many technologies are available to commercial vehicles, some difficulty exists in convincing computer-resistant truckers to adopt newer technologies. Several specific onboard communications systems include:

- **Volvo Link Sentry** is an onboard system provided by Volvo on all of its new vehicles, allowing for communication directly to the driver via instruments on the dashboard. The equipment monitors systems on the truck, returning the data to Volvo, who can monitor and adjust onboard systems in real time, diagnose problems, help maintain emissions regulations and fuel optimization, or even effect a vehicle shut down when necessary. Such systems are attractive to smaller trucking companies because they allow them to level the playing field by receiving information that, until recently, was only available to the large companies via dedicated company dispatchers.

- **Qualcomm** provides after-market in-cab systems, which can provide drivers with information related to load assignments, route suggestions, and fuel optimization. Many systems also track hours logged per day and per week. Qualcomm's system can track each vehicle by satellite to provide relevant information alerts to drivers via a text message display within the cab including routing, load assignment, and traffic information as well as other updates such as AMBER and terrorism alerts. For safety reasons, only the first 16 characters are displayed in motion, providing enough information for the driver to determine whether it is necessary to pull over to read the entire message. The system also features a "weather button," which provides the driver with real-time radio updates regarding current and forecasted weather, procured directly from the National Oceanic and Atmospheric Administration (NOAA).
- **Maptuit** provides in-cab information to commercial vehicles regarding traffic and routing, providing trucks with the safest, fastest route available. Routing information updates are collected from and redistributed to all participants in real time, with trucking companies sharing the benefits of knowing where each truck is located. However, because all individual origin/destination (OD) information is kept internally and only sanitized information is disseminated to trucks, companies are able to protect their proprietary location data.

2.2 Emerging Technologies and Applications

The technologies that support real-time information collection, communication, aggregation, and dissemination are evolving. For example, improved sensor technology is creating new opportunities and business models. More robust deployments are providing the opportunity to collect more accurate data. Increases in the proliferation of wireless communications and in-vehicle telematics are providing new opportunities for connectivity.

2.2.1 Increased Probe-Based Programs

To promote the deployment of real-time traffic information systems, the use of probe-based data collection programs is increasing to provide more robust coverage of geographic areas with limited sensor coverage. In May 2008, a series of awards were made to areas for field operational tests (FOTs) to develop and demonstrate applications that meet the SafeTrip-21 goals and objectives, including:

- **California Connected Traveler FOT in the San Francisco Bay Area** – The test uses GPS data from GPS-equipped personal mobile/wireless devices to develop applications to enhance the reliability of data. The "Mobile Millennium" ITS application was developed in California to use location data from up to 10,000 GPS-equipped mobile phones voluntarily collected to develop improved travel-time predictions for both highways and arterials. The "Network Traveler" application supports audible alerts on GPS-enabled cell phones regarding upcoming hazardous conditions, supports transit travelers with en-route transit trip information, and supports more customizable information to travelers.

- **I-95 Corridor FOT between North Carolina and New Jersey** – The test is developing an "Intercity Trip Planner" that uses vehicle probe data, trip planning software, and map display software to provide a graphical display of real-time roadway conditions/speed via a Website. The test may serve as a model for providing more complete multimodal trip planning.
- **Private-Sector Probe-Based Programs –** Firms such as INRIX, NAVTEQ, TrafficCast, and others are leveraging commercial fleet GPS and other sources of traffic data for information services. These vehicles are far more likely to have GPS and transmit their location in real-time for fleet management purposes. Private-sector probe-based systems leverage supply-chain partnerships to deliver probe-based traffic data. Furthermore, these private-sector traffic information providers are now integrating data with more traditional navigation systems to further extend their probe-based networks.

2.2.2 Improvements to Transit AVL

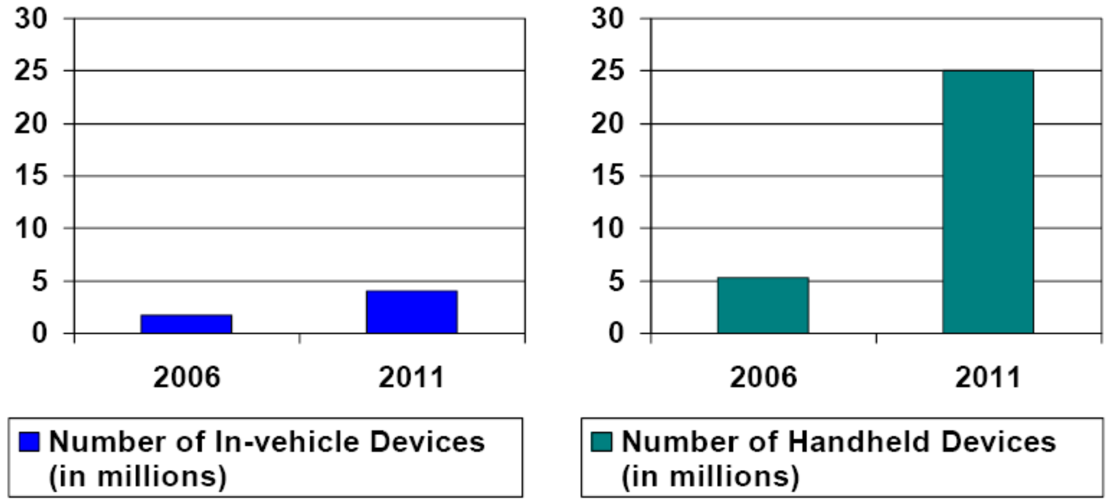
Transit vendors are creating more efficient AVL communications systems that provide for more frequent updates and are integrated with additional technologies for improved accuracy and/or reliability. For example, newer systems often supplement GPS-based AVL with a dead reckoning capability, which combines the vehicle's odometer output with GPS to increase accuracy. However, transit agencies with newer systems may have to reconcile GPS and AVL systems from different vendors and technology eras to achieve uniform functionality. For example, the systems may also provide data at different frequencies (e.g., anywhere from 1 to 5 minutes), different levels of accuracy (e.g., 0.5 to 250 feet), or from different algorithms that provide the estimated time of arrival differently (e.g., is the arrival time estimated for a bus stop, or is it calculated as a schedule deviation from last time point).

2.2.3 More Accurate Parking Sensors

Unlike many other market segments, real-time parking information is a relatively newer field. Vendors providing sensors are developing more accurate and affordable infrastructure-based sensor technologies to create more sustainable business models. Sensors are rapidly becoming cheaper, smaller, and more ubiquitous, allowing more systems to use the more granular vehicle presence detection method and increasing overall accuracy. In particular, vendors are close to developing sensors appropriate for usage in commercial vehicle parking facilities, allowing expansion into this additional market where the variable sizes of commercial vehicles have previously limited deployment.

2.2.4 Proliferation of Wireless Devices

The proliferation of new wireless technologies is allowing more customers to connect to real-time information on a regular basis. The penetration of cell phone usage has exploded in recent years to the extent that there are now a number of households without landlines and a number of young people who are only familiar with cell phones. 3G wireless networks have facilitated faster and large data transfers using cellular technology, allowing Smartphones to quickly access real-time information. With the recent rollout of 4G networks in several select cities, wireless communications will become even faster. Figure 2.2 shows the estimated increase in wireless devices, both in-vehicle and handheld devices.



Source: Presentation to the International Consumer Electronic

Figure 2.2: Estimated Increase in Wireless Devices

2.2.5 In-Vehicle Telematics

In-vehicle telematics that provide two-way connection devices will become increasingly common. This will enable drivers to receive more information and entertainment in their vehicles, including the integration of navigation systems that display real-time information. In-vehicle telematics could be the next frontier for bringing an on-screen interaction into the average American's life, just as they use televisions, computers, and cell phones. Such an extensive market penetration would require close coordination with each of the major automobile manufacturers, who currently maintain individual in-vehicle software applications that might be difficult to integrate into a common system. Ideally, such systems could one day provide a variety of real-time information, including more robust incident, congestion, weather, transit services, parking space location and reservation, and gas prices.

New devices like in-vehicle telematics and Smartphones can serve a dual purpose. In addition to providing the customer with real-time information, the GPS-equipped transponders and other sensors can also be used as probes to collect information. Limitations include the funding and development of applications to support the collection of data other than speed and flow. The technologies have been developed to allow for additional data collection, but a higher level of demand is required to implement this capability. This additional data includes information such as road condition, pavement condition, and other types of information, which will enable more active traffic traveler information (including safety warnings and alerts). Both the public and the private sectors see Smartphones as an opportunity to collect quality data based on their growing market penetration. Early deployments of data collection are working through certain privacy challenges and concerns and will establish some base standards for expansion of data collection through these devices.

While the commercial vehicle industry has already deployed the most complete in-vehicle telematics applications of any of the market segments, the proliferation of onboard communications devices will increase in the industry, particularly in private-sector applications provided by original equipment manufacturers (OEMs) or after-market vendors. Initially, only large operators were able to fund the substantial capital costs associated with obtaining telematics. While many small carriers still balk at procurement costs, the addition of new vendors to the market has forced costs down. Trucking companies will continue to install GPS transponders and in-vehicle telematics in their vehicles to the extent that most companies, even small carriers, can experience benefits. Even short-haul trucking companies (e.g., drayage, dump trucks, and garbage trucks) are retiring their radio-based communications systems for public carrier push-to-talk services and in-vehicle telematics that include integrated AVL and data applications.

2.2.6 IntelliDrive℠ and Commercial Vehicle Infrastructure Integration

IntelliDrive℠ represents an opportunity for real-time data to be collected and used by onboard vehicle systems. This capability could potentially serve as a means of gathering and distributing vehicle data in support of applications and products designed to diagnose and predict road weather conditions and share that information with agencies for disseminating traveler information. The automotive industry is making significant technological advancements in the areas of vehicle environmental sensing and vehicle responsiveness to road conditions. Because of these developments, direct measurements of environmental factors such as pavement temperature and barometric pressure could provide a robust real-time data set; vehicular activities such as wiper setting, activation of anti-lock brakes, and stability control could also support onboard safety applications as well as transmit this data to operations centers. It is also expected that continued innovation within the automotive sector will provide opportunities to measure additional atmospheric and road condition parameters. IntelliDrive℠ also seeks to enable multi-modal application, providing users with an in-vehicle application that combines traffic, weather, transit, and parking information in a single application.

The New York State DOT's Commercial Vehicle Infrastructure Integration (CVII) program is working to develop commercial-vehicle-specific applications including real-time truck travel information. However, unlike passenger vehicles, a large number of commercial vehicles already have in-cab systems, and there is less need for static fixed-roadside readers. CVII will be successful if it can develop methods to retool the commercial vehicle industry's existing IT infrastructure. The proliferation of commercial vehicle telematics systems and CVII could increase the ability of both the public and private sectors to use the 2.7 million trucks on the road as data probes to provide more detailed information regarding traffic conditions and freight movements.

2.2.7 Proliferation of Social Networking

Social networking is increasingly becoming an additional tool for state and local transportation agencies to disseminate real-time traveler information. Customers can access Websites via their computer or wireless to receive traffic updates, work zones information, and emergency notices. Information is often in the form of short text messages, although longer audio messages are also possible via some online media. Additional information regarding social networking and the issues surrounding its use can be found in the Usage Section of this document.

2.3 Procurement Approaches

Real-time traveler information is rarely the work of one entity to deliver. There are many potential roles for many partners, from both the public and private sectors, to provide the necessary technology applications, data collection strategies, information aggregation, and fusing of real-time (and potentially non-real-time) data to use for traveler information and other purposes, as well as ultimately disseminating that information in a format that is usable by travelers and other entities.

There are a number of gaps that could require both the public sector and the private sector to seek out partnerships to fulfill traveler information program needs. For example, traffic data collection has historically been a responsibility that resided with the public sector; DOTs deploy detection on urban area freeways to provide real-time traffic volume and speed data that could be used to support traffic management as well as traveler information needs. Similarly, transit vehicle location and performance data has largely been the responsibility of transit operating agencies, sometimes supported by a system vendor for the AVL data systems. Parking information, on the other hand, includes significant involvement from both the public and private sectors in that facilities can be either municipal-owned or privately owned. Real-time data for parking was often focused more on revenue-collection systems, but there is increased recognition that information about parking facility and space availability is a growing area of interest, particularly in congested urban areas.

With partnerships and formal contract arrangements come a range of questions and issues that must be addressed for the partnership to be successful, including data and system ownership; privacy; intellectual property rights (particularly for private sector systems); data quality standards; data sharing; and in recent years, the commercial value of data.

This section discusses different procurement and partnership approaches to support the continued expansion and enhancement of real-time traveler information systems, as well as presents some case study examples of successful partnering and contracting approaches.

Partnerships and procurement approaches between public- and private-sector entities can take several forms:

- **In-House Data Procurement** – The public sector can do it all, and has limited involvement with the private sector to support its traveler information activities.
- **Partnership with Private Entity –** The private sector provides a contracted service or commodity for a fee to the public sector; this could be to supplement what the public sector is already doing or to address a gap in public-sector coverage, capabilities, or technical resources. In addition, the private sector could be an "in kind" partner, who obtains access to data that is generated by the public sector (often at no charge to the private sector), and then uses that data to support the private business model and activities.
- **Buy Data –** The private sector provides a substantial operations or other role, for a fee, and is an essential partner in the development or delivery of a traveler information function or service.

2.3.1 In-House Data Procurement

This model represents a substantial investment by the public sector in the data collection and dissemination arenas, but one that provides the agency with the most control over its data and its dissemination. Traditional models for traffic-focused traveler information have seen a substantial role for the public sector (typically, the state DOT) to deploy equipment, collect real-time data, consolidate or aggregate that data, and provide it to users through their publicly owned infrastructure (including DMS, HAR, agency-operated Web sites, 511 phone systems, and other dissemination means). This does not necessarily mean that the private sector is not involved; in fact, equipment and systems are typically procured from the private sector (particularly for detection). However, the agency would retain primary responsibility for data management and data usage to support traveler information and other operational functions.

Transit also has historically seen a large role for the public sector transit operations agency for data collection and dissemination, although vendors may play a role through contracting arrangements. For example, the CTA operates its own prediction software based on AVL, and is enhancing its prediction software using historical information derived from stop adherence and remotely installed devices. This could be a function of the AVL vendors, but the CTA's decision to keep this activity in-house provides them with increased freedom over information outputs including how it is provided to transit riders. Denver Regional Transportation District (RTD) is also in the process of developing in-house algorithms after too many difficulties trying to rectify internal data sources with external software packages. While large transit agencies such as the CTA and Denver RTD have the technical ability and resources to develop in-house applications, many smaller transit agencies lack the scale and technical expertise to make the development of these systems cost effective.

For parking, it is advantageous for municipal governments to maintain control over data about their facility operations. Municipal governments are the primary customer of parking information and take primary responsibility in funding for parking information to the public. They need to be aware of how parking affects long-range planning, pricing, performance measurement, and workforce management. Parking information can be used for policy planning, systems optimization, and how pricing or temporal effect will affect the use of the new parking systems. Information can be shared with operators, municipalities, transit authorities, and urban planners. This data might not be as readily accessible to public-sector entities if they did not have a significant share of control in the data.

2.3.2 Partnership with Private Entity

Private vendors are often focused on developing innovative technologies that can be turned into cost-effective marketable products, particularly when there is a niche that is not already being met by other vendors. Vendors strive to increase implementation of their products and technologies, investing in market development when necessary.

AVL is a key example of an area where transit agencies can choose to deploy and manage such systems, but most opt to contract with private vendors with the expertise to install AVL systems and supply data outputs for agency use. The private sector is enthusiastic to provide AVL data for transit agencies and develop innovative products when evidence suggests a market niche, providing a trend of continuous deployment and implementation. However, the public sector, not end users, is the private sector's primary customer. This differs from some of the traffic models where the private sector often has market potential with the public sector; other private partners; and in some instances, the end user directly.

The Intelligent Transportation Infrastructure Program (ITIP) was the first large-scale effort to outsource the collection of traffic flow information to the private sector. ITIP was originally designed to provide traffic data to public agencies for operations and planning, while enabling the private entity to earn a sustaining profit through commercial use of the data collected. There was no charge to the agency for the data, and in exchange, the agency would provide right-of-way for the data collection sensors. Of those 40 metropolitan areas, 25 have deployed or are deploying sensors under this program. The program did not receive full support by many of the states invited to become partners, due largely to the restrictions placed on what the agency could do with the data, even though the agency was receiving the data at no charge. Most significantly, many agencies were not allowed to use the data for traveler information, either on Web sites or on DMS, in order to protect the commercial value of the data and allow Traffic.com to be able to generate revenue through its other partners. (http://ops.fhwa.dot.gov/travelinfo/ttidprogram/ttidprogram.htm)

Parking is another area where public and private partnerships are necessary to lead to the most effective regionally integrated parking systems. Public agencies and private garage operators look to private sector experts to provide the most advanced technology, requirements, and specifications for implementing parking information solutions. Once systems are deployed, information sharing among public and private entities is a necessary component of smart parking to aggregate information regarding availability and pricing across multiple facilities within a geographic area to maximize the benefit to customers. It is important to note that the public and private sectors may have conflicting interests in the deployment of parking information systems; for example, the public sector is concerned with maximizing utility, while the private sector aims to maximize utilization and revenue. However, both sectors have a common interest in improving parking facility efficiency.

2.3.3 Buy Data

In recent years, the private sector has emerged as a viable source of real-time traffic data, a role traditionally kept within the public sector realm. The emergence of probe-based approaches and applications allows for more ubiquitous coverage on the roadway network for speeds and travel times (important for traveler information), but does not provide the granularity of data that is typical of a sensor-based deployment. Although this is an emerging model for traffic information, probes are not yet considered a viable data source for transit or parking.

Public agencies are now viewed as an important customer base for private companies focused on real-time traffic data collection. First, through cell phone tracking technologies and, more recently, through contracting with fleets for GPS data, private firms are selling their traffic data to both public agencies and private companies. Notable procurements include the following:

- The Wisconsin Department of Transportation (WisDOT) contracted with INRIX to provide real-time traffic flow data for nearly 250 miles of US 41 and I-43 between Milwaukee and Green Bay.
- Cellint has been delivering cellular-based traffic information to the Georgia Department of Transportation (GDOT) since 2006 on Georgia 400 and nearby arterials.

- INRIX is providing data on 1,500 miles of freeway to the I-95 Corridor Coalition, the public sector's largest-ever traffic data procurement.
- NAVTEQ has been selected to provide statewide traffic data to the state of Michigan. While not yet under contract, this will be the second-largest public-sector probe data procurement to date.

This procurement option provides agencies with data on urban and non-urban area corridors that are not instrumented through typical public-sector detection approaches, due to the lack of resources to deploy, operate, and maintain detection equipment on the part of the agency, or as a supplement to existing systems. Although this is an emerging model, the procurements identified above will provide valuable lessons learned in the public-private partnering for real-time probe data to support traveler information as well as other agency operations functions that rely on real-time network data.

Privately supported data collection, aggregation, and information dissemination strategies can have a significant impact for freight. Vendors like Qualcomm and Maptuit are already providing real-time traveler information to the commercial vehicle industry and have developed sustainable business models providing a suite of location, traffic, routing, weather, and vehicle performance information. Truckers value such information because it can increase efficiency, including saving time and decreasing fuel consumption. Trucking companies, especially small carriers, value having a third-party provider aggregate and manage such information. Although some states have begun to implement freight-related data as part of their traveler information systems, it is often not comprehensive enough to meet the information needs of commercial drivers.

2.4 Procurement Trends

As travelers and the providers of data grow accustomed to having real-time traveler information based on probe data, business models will emerge to be able to incorporate IntelliDrive℠ and safety applications across all modes—traffic, transit, parking, and freight. Vertical integration is envisioned to be a sustainable business market to continue to position the private sector for maximizing their potential and for public agencies to leverage the innovations of the private sector.

Three very recent public-sector procurements for private-sector data for traffic information mentioned in the previous subsection (WisDOT, I-95 Corridor Coalition, and Michigan DOT statewide data) point to the trend of agencies seeking alternate sources of network conditions data on corridor and statewide levels. Recognizing that there are cost and resource limitations to public-sector funded infrastructure-based solutions for detection, these procurements (and the resulting evaluations) indicate that although agencies see value in having real-time corridor information beyond urban area freeways, there is an opportunity to explore alternative means of obtaining this information on a larger scale, and procuring from a private entity could potentially address this need.

It is important to include the private sector in the process of providing real-time traveler information. The private sector has had difficulty in developing sustainable business models involving a direct real-time information transaction with the end user. The industry has discovered that travelers are only willing to purchase real-time traveler information when it is part of bundled services, such as an add-on to a navigation system; stand-alone information has not been marketable. To continue to ensure private-sector participation, the public sector needs to be willing to support open and standard data formats that begin to converge on de-facto transit standards. While open source data can provide opportunities for independent developers, it can threaten the existing business models of traditional private-sector vendors who rely on the data as their proprietary information.

Although it is still a developing industry, several potential business models have been developed for smart parking applications for both the private and public sectors including models based on payment from end users and municipalities. Most parking vendors have developed both purchasing and leasing models for their products, charging parking facility operators a flat fee for implementation and operations and maintenance (O&M) of their products. However, a profit-sharing model is also possible, where a vendor would provide free installation in exchange for a percentage of the facility's revenue. Another potential model exists for a private company to collect and license information to users for other applications including municipalities, aggregation Websites, handheld GPS navigators, or wireless applications.

2.4.1 Subscription and End-User Charging Models

There remain some unknowns in travelers' willingness to pay for real-time information. The subscription model has been a common approach in the traffic arena for several years, although those models that were based solely on end-user subscription fees have not proved to be sustaining. The most successful approaches have leveraged different potential sources of revenue, and have not been dependent on one specific revenue source. From a private-sector perspective, there is continued growth in supply-chain partnerships among multiple private providers to deliver traffic data, and an increased trend toward integrating data with more traditional navigation systems. As firms with a national footprint for data collection (including NAVTEQ, INRIX, and TrafficCast) partner with application developers and distributors, there is a continued trend toward enhanced offerings (bundled services) through subscription-based services.

Automobile OEMs have strategically partnered with providers of traveler information, navigation, and telematics services as technology and innovation have been greatly enhanced in the last decade. INRIX has collaborated extensively with Ford to enable personalized driving content and technology for Ford SYNC with traffic, directions, and information. XM and Toyota have extended their partnership through 2017 to provide XM NavTraffic in their vehicles. Lexus also partners with XM to provide the navigation package in its vehicles. ATX is a provider of customized telematics services to automobile manufacturers including Toyota, BMW, Lexus, Mercedes, and Rolls-Royce. Some OEMs such as GM have offered OnStar, an in-vehicle warning/safety system, at no additional cost in the sale of the vehicle. These services include location-specific emergency and roadside assistance, automatic collision notification, remote diagnostics, and real-time traffic and navigation assistance. The cost of the electronics equipment is dropping as technologies and competition develop and production volume increases.

Transit agencies have not been able to develop a way to make money on real-time information, instead viewing it as an add-on to transit services. Even when providing travelers with real-time information, agencies have been reluctant to charge the customer for more than the normal fare. However, sustainable business models have been developed by the private sector with the public sector as its main customer, including private sponsorship of transit data as part of a public-private arrangement for providing real-time transit information.

End users can be charged directly for smart parking by either public or private operators, via either a surcharge at a facility or as part of an online reservation. Parking reservations have proven a powerful value-added service for which many customers are willing to pay a surcharge, especially when it is bundled as part of a transaction (e.g., adding reserved parking at the stadium when purchasing baseball tickets). The Rockridge deployment showed that the majority of users were still willing to use the reservation service even with an associated charge, signaling that many users preferred to make a reservation (pay with money) instead of arrive at the station at an earlier time (pay with time). Some users may also be willing to pay a premium to receive attribute-level data regarding security (e.g., Is it in a safe neighborhood? Is there adequate lighting? Is it gated? Are there security guards?) and convenience (e.g., Does it accept credit cards? Is it close to my destination?). Following its pilot implementation, XM Radio was unable to convince customers or car companies that parking information was a realistic value-added service as part of a navigation system, but future integration with automobile manufacturers, similar to the real-time traffic information, could prove it as a usable business model.

2.5 Procurement Challenges

2.5.1 Agency Contracting Processes

With the growth in private-sector provision of traffic data from non-traditional sources, DOTs wishing to purchase this data must enter into contracts that differ from what their contracts personnel are typically familiar with. A subscription for an XML stream over HTTP does not have tangible deliverables that can be verified for milestone payment. DOT contracts personnel need to be educated on these types of procurements so they have an understanding of and comfort level with the terms and conditions. When a DOT enters into a contract for traffic data, the contract must include standards of performance for that data. At a minimum, it must specify minimum acceptable levels of accuracy and availability.

The I-95 Corridor Coalition, which purchased data for over 1,300 miles of freeway, is using Bluetooth tracking and floating car runs to validate its data every month. Each month, the validation focuses on a different state, so that each state is validated every few months. Michigan DOT, which has just entered into a contract with a different private-sector provider for a similar data stream, will use similar techniques. For each of these procurements, the contracts have mechanisms to penalize the data provider for data that does not meet standards. Whether the penalties are set appropriately remains to be seen. With data on hundreds or thousands of segments every 5 minutes every day, it is likely that standards will not be met for some locations and times. Further, it is only practical to validate a sample of the data each month, and those sampling techniques can make a difference. Penalties need to be set on a graduated scale that takes into account systematic versus episodic errors and the severity of those errors.

2.5.2 Data Compatibility

Both public- and private-sector entities providing real-time freight information may lack the ability to standardize information to share with other entities. The federal government has the opportunity to encourage, although not mandate, the creation of standardized information exchanges, including working with vendors and the trucking industry to develop more accepted data standards. In the creation of data-sharing standards, it is imperative that there be a strong focus on creating incentives to encourage the commercial vehicle industry to participate.

A clearer definition of what information should or must be collected and disseminated by the public sector versus what should be the responsibility of the private sector is still yet to be determined. Leveraging information from both public and private sources, the private sector has clearly established and developed its own need and use for in-cab telematics, but improving freight travel and goods movement is in the best interest of the public. Intermodal facility and border-crossing freight information systems, such as the Cross Town Improvement Project (C-TIP), have required the public sector to encourage development by establishing partnerships and providing funding and leadership. While the public sector does not expect these systems to continue as a government service, additional research must be conducted to develop effective business models for providing information to commercial vehicles for a cost-effective service fee.

As the successful collaborations have already been developed with telematics vendors, the public sector can develop further partnerships with the commercial motor vehicle industry and device vendors to steer requirements and standards and share information.

2.5.3 Privacy and Data Protectionism

Information related to the locations and operating characteristics of commercial vehicles provides for improved real-time information. However, many carriers have concerns about making such information available for several reasons, including:

- **Enforcement** – Carriers are concerned that federal, state, or local agencies could use collected information for enforcement purposes.
- **Plaintiff lawsuits** – Carriers are concerned that plaintiff lawyers could use information to build cases, particularly in jurisdictions that stipulate that if a driver is 1-percent responsible for a crash, he can be held 100-percent liable.
- **Competition** – Carriers are concerned that competitors could gain proprietary information related to operating characteristics, common routes, or lists of customers.

This is also true in the traffic realm. Many of the probe-based deployments that are able to provide speed estimations have established partnerships with fleet operations (which could include a wide range of fleets, such as commercial freight, rental cars, and others). These arrangements are proprietary, with no disclosure as to density or specific vehicles that might be providing data.

While the commercial vehicle industry may be reluctant to share proprietary information directly with the public sector, third parties may serve as a useful liaison. The public sector currently partners with the American Transportation Research Institute (ATRI) and the trucking industry through the Freight Performance Measures Initiative to aggregate and scrub freight probe data to establish a baseline for freight mobility and the transportation network. Many trucking companies also use Qualcomm and Maptuit, private companies that provide in-cab routing services based on current vehicle location, leveraging traffic and weather information from other in-network vehicles (these may be some of the same partnerships that contribute to traffic probe data). Since it is unlikely that the public sector will have access to unrestricted, uncleansed data, it must work with carriers to develop additional mechanisms for data sharing, while ensuring that proprietary information remains secure by establishing additional partnerships and non-disclosure agreements to provide a means for public and private partners to access relevant freight information that has been scrubbed of proprietary information. As part of any partnerships that are developed, a clear understanding must be communicated regarding what proprietary information will or will not be shared and with whom.

2.5.4 Sharing Data Among Partners Across Geographic Regions

The inability to share data is a barrier in developing real-time traveler information systems, although there continues to be strong interest in exploring partnerships for data collection, aggregation, and dissemination, including public-public, public-private, and private-private partnerships. Merging multiple data sources can be resource-intensive from an institutional as well as technology standpoint.

From a public-sector perspective, agency integration efforts to harness incident data from law enforcement/public safety through automated information exchanges are resulting in significantly expanded capabilities for providing incident information. For non-urban corridors, this might be the only available real-time data about corridor travel conditions. Two benchmark deployments for CAD and traffic management center (TMC) integration were conducted by Washington State Department of Transportation (WSDOT) and Utah DOT. Key lessons from these deployments indicated that it is largely up to the public sector traffic/DOT to initiate and spearhead this kind of collaboration and data-sharing arrangement, including bearing any cost requirements for integrating systems or modifications to the public-safety CAD system. Establishing these partnerships to share automated incident data feeds requires collaboration among state DOTs and state and local police and law enforcement, as well as CAD system vendors.

Many metropolitan areas, especially large metropolitan areas, have several transit agencies located in close vicinity to each other, with overlapping and concurrent transit services. This requires a substantial amount of coordination among the agencies to develop a seamless information network across the multiple transit agencies. Data and information sharing between transit agencies is primarily related to the trip-planning function and is based on scheduled, not real-time, information.

While transit agencies are the primary actors with respect to implementing real-time transit information partnerships, outside companies with particular technical expertise are beginning to show interest (including Google Transit and some cell phone companies). Some transit agencies prefer to allow third-party access to open-source data, providing them with the opportunity to develop additional traveler information applications. Open-source data allows companies such as Google Transit more freedom to create user-friendly transit applications and may also provide for additional and more sustainable business models. Issues such as data security and knowledge of data usage are two key challenges that must be overcome. Transit agencies must develop an improved understanding of their responsibility toward their data and when the benefits of sharing data outweigh the risks.

Parking is another area where there has been increased emphasis on establishing more regional networks that include information from a variety of information sources, both public and private. Presently, many deployments use proprietary data and patented systems and business models. To develop the industry, parking operators must be educated on the benefits of information sharing and how information can be safeguarded to ensure that it does not directly benefit their competitors. Additional communication between the private and public sectors will ensure that collaborative solutions can be developed and issues can be resolved quickly, including ensuring that data is available and information is provided when necessary.

A common theme among all real-time freight information systems, both public and private, is that each requires substantial buy-in from a variety of stakeholders, often public agencies and always private companies. Providing freight information to commercial vehicles can only be effective when trucking companies are willing to participate in the process, including sharing information regarding their real-time information needs. For example, WSDOT has actively engaged the trucking industry in developing its Freight Notification System including industry debriefs, online surveys, and complaint monitoring to assist the agency in understanding the types and frequency of information required by trucking companies.

2.5.5 Industry Fragmentation

While some commercial vehicle industry groups have had some success pooling resources to benefit the industry, trucking remains fragmented with the majority of trucking companies only owning a few vehicles. This fragmentation increases the difficulty to develop collaboration within the industry to build data models and provide real-time information. In the limited number of deployments involving collaboration between the public and private sectors, trucking companies have been very cooperative in helping to develop real-time systems. However, additional interaction is needed, particularly among competitors.

Fragmentation is also apparent in the public sector, with little inter-agency collaboration between state DOTs, metropolitan planning organizations (MPOs), port authorities, and border agents working to build real-time freight information systems. In fact, only a handful of systems that provide freight-specific information in real time exist across the country. One of the newest systems, C-TIP, may serve as a useful model for deployment to other high-freight areas. The public sector must establish improved partnerships among its agencies and with the private sector to identify freight bottlenecks that would benefit from real-time information. Some 511 systems are also beginning to add information that is more beneficial to freight, although the nature of 511 being operated by individual states does not lend itself well to multi-state corridor conditions via the phone (through public-agency-operated systems). The Web provides an easier platform for this kind of information, but may not be as accessible to freight drivers en route.

2.6 Potential Roles for the US DOT

Regarding procurement and partnerships, the US DOT could take a leadership role in the following key areas to provide valuable guidance to states and operating entities.

Agencies are interested in support from the US DOT to better ensure traffic data quality. Processes to validate purchased data have been enacted by a few DOTs with private-sector data contracts, but there is no consensus on the appropriate validation methods or how the data provider should be penalized for failing to meet data quality standards. Roles for the US DOT could include white papers, proof of concepts, research, or analysis of existing systems, and continuing to sponsor outreach and forums to allow for peer exchanges of lessons learned (similar to the Probe Data Quality Workshops currently underway).

Quality standards can be developed on the national level to ensure that the amount of data collection devices or probe vehicles would satisfy a basic level of quality for the dissemination of that data to the public. The 1201 Rulemaking begins to define this for traffic, but does not provide the detailed quality parameters that would be necessary for contracting purposes. This will give local and state agencies clear and consistent guidance and direction as to what they could or should do to get better data for their systems. Linking the quality of data with the revenue provided to collect that data would help to increase the standard for quality.

There was particular interest mentioned for the US DOT/FHWA to explore negotiation with the private sector on a national level that would provide data on a local or state level. This could provide not only a standardized method for distributing the data to public agencies, but it would also support the reliability of that data due to the larger scale application.

The US DOT needs to encourage states to increase situational awareness of traffic and weather conditions and develop multi-state networks of information, including providing incentives for state DOTs. Funding could also be dedicated to collaborative groups like the I-95 Corridor Coalition, which could continue to foster innovative demonstration projects for both traffic and freight, particularly in a multi-state context.

3 REAL-TIME DATA COVERAGE

3.1 Traffic Data Coverage

3.1.1 Types of Data

This discussion of traffic data coverage includes several different types of real-time data that are available, as described in **Table 3.1**.

Table 3.1: Types of Real-Time Traffic Data

Data Type	Description
Traffic flow	Sources include roadside or in-pavement sensors and vehicles as probes. This type of data includes road segment speeds, travel times, volumes and occupancies.
Incidents	Sources include linkages to public safety CAD systems, video surveillance, "tipsters," aerial surveillance (e.g., airplane, helicopter). This type of data includes incident location, severity and estimated impacts (e.g., length of backup and rubbernecking effects)
Construction	Primary source is DOT field offices that plan and manage construction projects. This type of data includes where and when lanes are closed for construction, including schedules for recurring closures and project duration.
Weather	Primary sources are National Weather Service (NWS) and private forecasting services, and roadside road-weather information systems (RWIS). This type of data includes general temperature and precipitation forecasts and to a lesser extent, road surface conditions.

The coverage extent of each different type of data is reported differently. The public sector continues to invest in detection infrastructure. The private sector continues to expand its capabilities to provide data on corridors beyond what is currently instrumented by public-sector-operated detection systems. This is done using a combination of fleet-probe GPS data; cell phone probes; privately owned detection infrastructure; aggregated public sector detection data; incident data (from public and private entities); and in some cases, historical corridor travel patterns. Arterial coverage remains a challenge, whether through traditional sensor-based deployment or through probe-based applications. However, many arterial management agencies recognize the value in CCTV/video coverage. Coverage areas for incident data tend to be larger than for flow data because no infrastructure is needed on public right-of-way. Also, incident coverage may be claimed for a metropolitan area even if only the major incidents on primary freeways are reported. However, incident data coverage is increasing due to the prevalence of cell phones and the ability to use police scanners or links to police CAD systems to obtain real-time incident information. Weather data is obtained from the National Weather

Service (NWS) primarily and includes general forecasts and temperatures. Road condition is a data type that is not always communicated; however, it is available in some regions.

3.1.2 Coverage by Public Sector Systems

3.1.2.1 Freeways (Urban Areas)

Freeways continue to be the primary focus for real-time data collection throughout the country. The public sector, private sector, and industry are in agreement that there is generally good coverage of urban area freeways through public-sector-operated sensor deployment systems. The system reliability of those sensors can challenge the effectiveness of the data that is disseminated to the public. Some agencies actively assess the downtime of sensors (public-agency-owned or private-sector-owned) to ensure that the data they are receiving is reliable. Agencies also use the downtime information to determine private-sector contractor fees. With 38 percent of urban area freeways covered by detection systems, there has been progress made in the detection coverage of the freeway system, although there is recognition that more can be done. Most states are doing well with limited access freeways and incident data. Planned event data/construction data still has room for improvement.

The data collected from a public agency through mainline detection technologies can be lane specific; however, the information provided to the traveler is typically segment speed and flow data, rather than lane-by-lane data. Incident information in some areas collected by the local public safety CAD is shared with the local TMCs. In some cases, this is an automatic feed from the CAD system to the DOT's operating systems; in other cases, there is an incident feed provided, but it still requires manual intervention to enter data at the transportation agency. This information supplements their traffic speeds and flow maps with the real-time conditions on the roadway and effects of the incident on traffic.

States indicated that there are gaps in coverage from what their systems currently provide. There are limitations as to how much detection infrastructure can feasibly be deployed and maintained with current resource constraints. Arterials were identified as another key gap/limitation of current DOT coverage capabilities.

The largest cities tend to have a higher percentage of incident freeway mile coverage, although even the largest cities fall significantly short of full freeway coverage. **Figure 3.1** shows the coverage by public sector systems. The size of the circles corresponds to the relative number of freeway miles within each urban area, and the shading indicates how many of those have real-time flow coverage by agency-owned systems. In several areas, the coverage miles do not equal the urban area freeway miles.

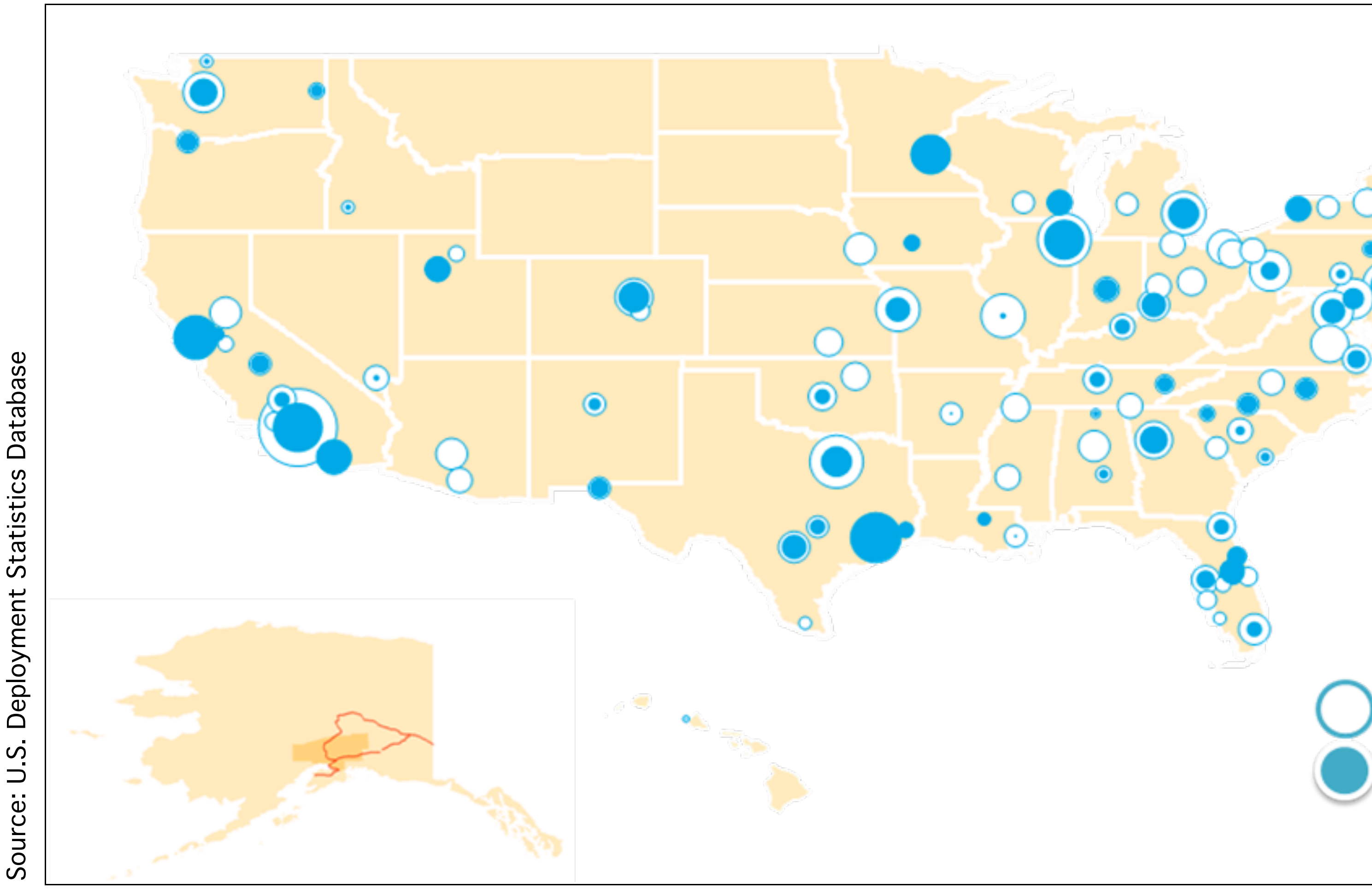


Figure 3.1: Map of Public Sector Deployments

It should be noted that these data are self-reported and may not accurately represent all metropolitan areas. There are several cities that did not have any coverage reported, although they are known to have ITS deployments. It should also be noted that these coverage data only include sensor coverage and not incidents, construction, weather, or other types of data. That being said, public agencies will typically only report incidents in areas where they have the ability to visually confirm reports through camera imagery, which tends to cover roughly the same roads as their traffic sensors.

Incident coverage by public sector systems can be broad due to the public's access to CAD systems and, when available, CCTV systems. Arterial real-time information is typically limited to incidents, as it has proven difficult to accurately capture other types of data for arterials. Also, with regard to the availability of incident data, a 2006 survey of states that use a statewide incident reporting system found that 33 states (of the 34 that responded) reported having either a municipal, regional, or statewide incident reporting system (*Statewide Incident Reporting Systems – Business and Technology Plan*, page 11). Statewide real-time incident coverage (to include rural area Interstates, state routes, and US routes) does not presently occur.

Many states have implemented systems to capture construction and planned events information, although this is not real time. The accuracy of these systems is directly linked to regional/district as well as statewide resources keeping the information up to date. Construction data comes in the form of real-time data collection for actual lane closures, delays, and other impacts to traffic from the construction activities, which can be shared with the traffic management agencies to disseminate more accurate information to the traveler.

The most exhaustive source of data on public-sector ITS deployments in the United States is the US DOT ITS Deployment Statistics Database. The most recent statistics (survey year 2007) reveal the following facts (trends are shown in **Table 3.2**):

- 39 percent of urban freeway centerline miles within 64 metropolitan areas are equipped with real-time data collection technologies. This is an increase from 33 percent in 2004. (94 metropolitan areas returned surveys.)
- 12 metropolitan areas (13 percent of respondents) responded that they had specifically deployed probe data collection technologies. These are typically toll tag readers, and the largest deployments are in Chicago, Houston, New York City, and West Palm Beach. (This does not include private-sector probe data sources, which is addressed in the next section.)
- 34 metropolitan areas (36 percent of respondents) report freeway travel times to the public, either via DMS or Web sites.
- 30 metropolitan areas (32 percent of respondents) report freeway speeds to the public.
- 82 metropolitan areas (87 percent of respondents) report incident information to the public.

Table 3.2: Coverage Trends

Data Type	2004	2005	2006	2007
Urban centerline miles with real-time data collection technologies (%)	33%	38%	38%	39%
Metro areas with probe data technologies (%)	8%	10%	11%	9%

Data Type	2004	2005	2006	2007
Metro areas reporting freeway travel times (%)	23%	41%	35%	36%
Metro areas reporting freeway speeds (%)	19%	35%	38%	32%
Metro areas reporting incident information (%)	60%	82%	83%	87%

Source: ITS Deployment Statistics Database 2007

511 systems provide a tool to allow users to access available information via an interactive voice response or touch-tone request. Data needed to support minimum content requirements includes incident information, planned construction/planned event information that impacts travel, weather information, and general traffic conditions. Some 511 services also offer travel times on pre-defined routes. According to the 511 Coalition/Statistics reporting, 511 will be accessible to 70 percent of the population in 2009, compared to 32 percent of the population in late 2005. State DOTs and regional transportation agencies continue to plan for and invest in both phone-based and Web-based traveler information services.

511 statistics as of May 2009 (THE most recent information available through the 511 Deployment Coalition) include:

- Over 146 million calls placed nationwide since inception
- 511 service available to over 166 million Americans (54 percent)
- Forty-six 511 services available to the traveling public operating in 35 states, 2 Canadian provinces, and 1 Canadian territory.

Figure 3.2 shows the national coverage of 511 systems that disseminate traffic information.

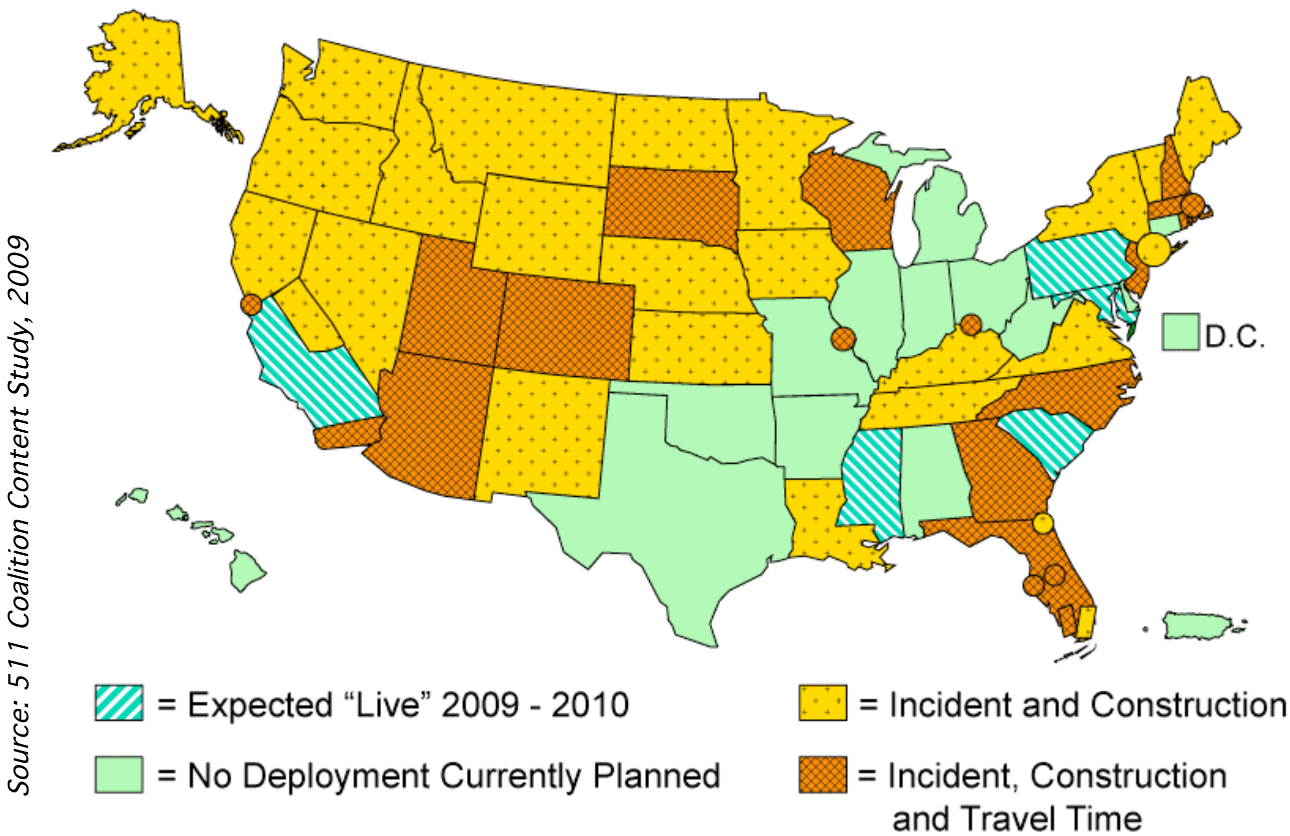


Figure 3.2: 511 System Traffic Coverage

3.1.2.2 Statewide/Rural Corridors

Statewide real-time coverage (to include rural area Interstates, state routes, US routes, or others) does not occur. However, many states have implemented incident and event reporting systems to capture construction, planned events, and incident information, although this is not always provided in real time. The accuracy of these systems is directly linked to regional/district as well as statewide resources keeping the information up to date. Some agencies indicated challenges internal to their organization that made it difficult to capture all of the events, as well as keep information current once it has been entered. There is recognition that there is available data (through law enforcement/police CAD systems and other agency systems), but there has been a challenge in harnessing that data into a workable database.

Because rural corridors have, to date, been a lower priority for real-time data, it has been difficult for some states to justify the investment. Some states indicated that the RTSMIP/1201 requirements would require concerted focus on getting information on these corridors, although some identified concerns about what the cost and resource implications would be to do so.

RWIS are a common ITS application, especially in cold weather states with snow and ice. While RWIS are commonly deployed for winter weather maintenance decision support, they can also be a valuable traveler information tool. However, most areas do not have sufficient RWIS density to provide route-specific road-weather information.

Figure 3.3 shows that, even for a state like Colorado with a significant RWIS deployment, there still may be significant gaps between ESS on Interstates and arterials alike. The NWS collects weather data across the country, but its sensors are typically located at airports and other locations more optimal for wide-area forecasts. RWIS sensors are typically located in known trouble spots that may be leading indicators for deteriorating road conditions. Nonetheless, even in states with mature RWIS programs, there are wide swaths of areas in adverse weather regions with no RWIS sensors.

Source: Clarus

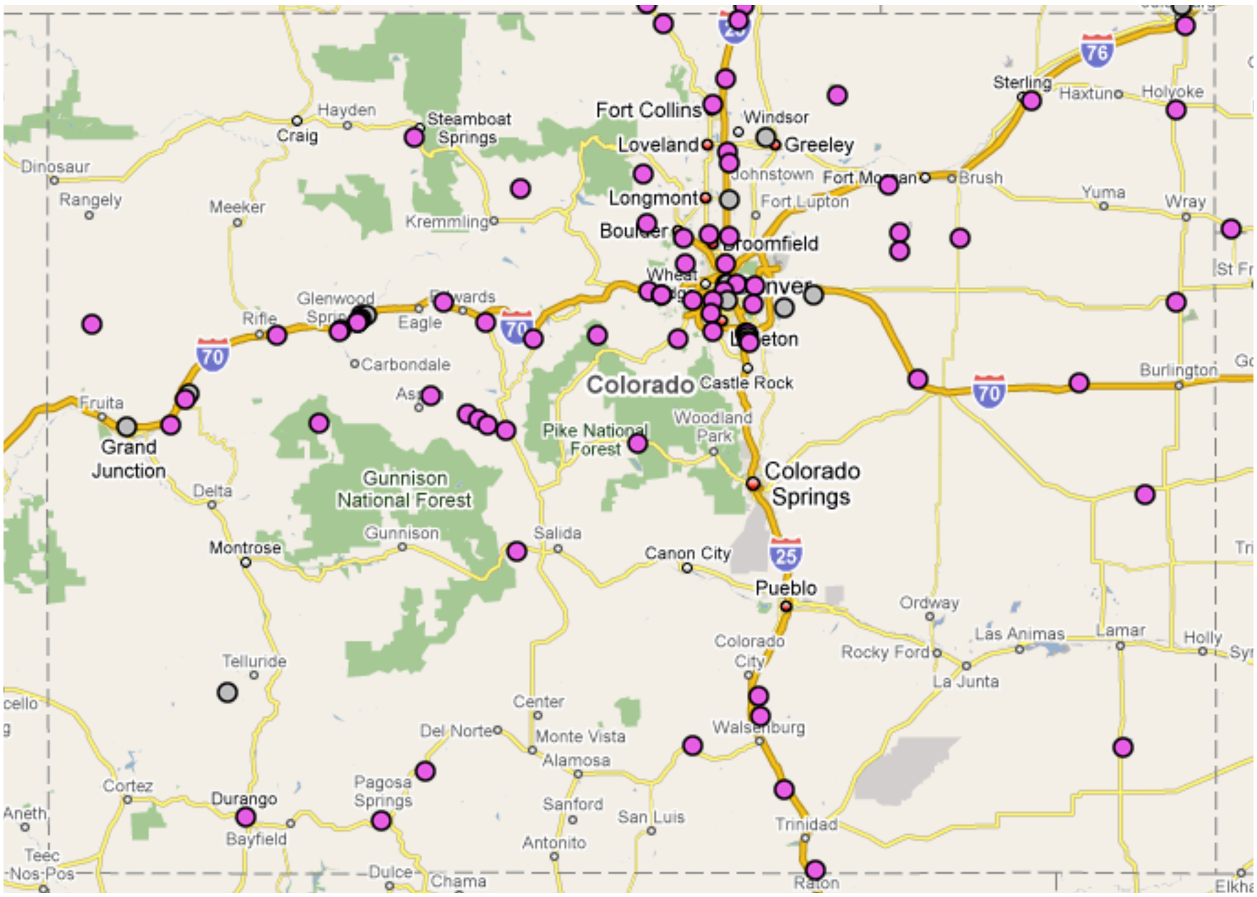
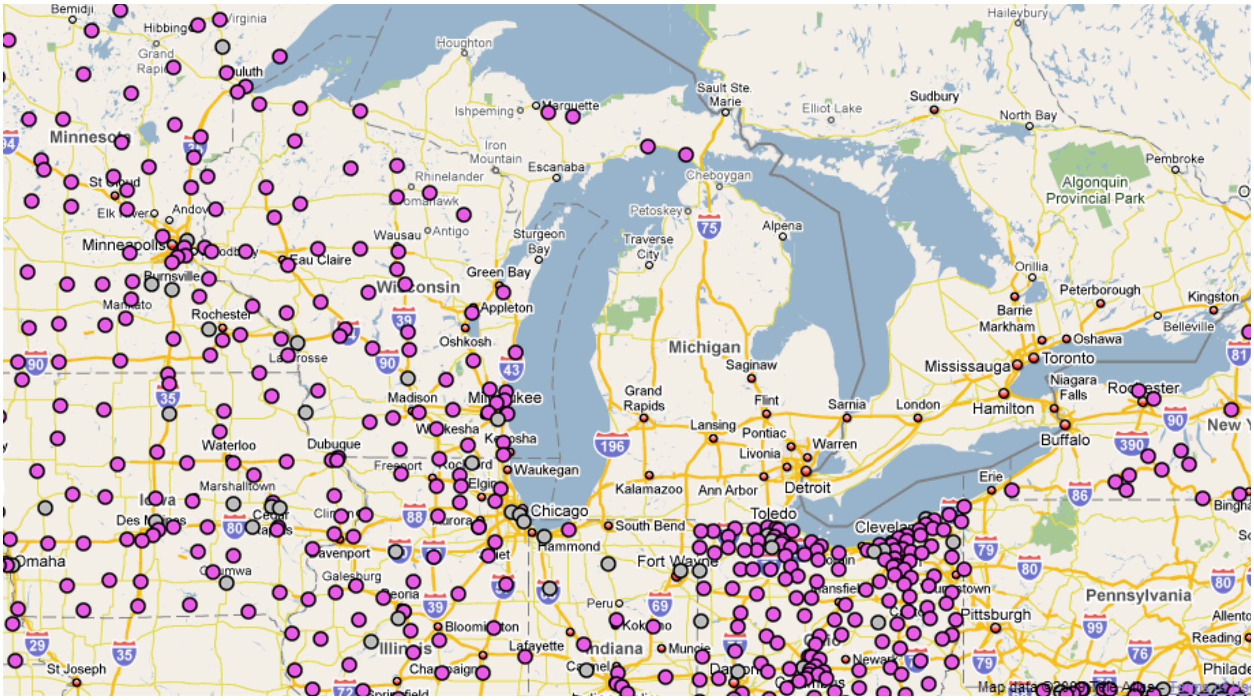


Figure 3.3: RWIS Coverage in Colorado

In addition, there is a significant disparity in RWIS coverage between states—even those with similar characteristics. Given limited resources, some DOTs have focused their deployments on applications other than weather, particularly where local agencies perform much of the winter weather maintenance. Weather data may also be an area where DOTs can obtain information from other sources, such as the NWS, universities, US Army Corps of Engineers, or others. **Figure 3.4** shows several Midwestern states, some of which have dense RWIS coverage and some of which have sparse coverage.



Source: Clarus

Figure 3.4: RWIS Coverage in Several Midwestern States

3.1.2.3 Arterial Coverage

Arterial real-time information is typically limited to incidents, as it has proven difficult to accurately capture flow conditions on interrupted flow facilities (those with traffic signals). For arterials, fixed sensors do not adequately capture true delays, which are driven by intersection queues. If an adequate market penetration of probe vehicles can be obtained, it might be feasible to obtain arterial flow information. Recent studies have shown the required market penetration to be high (Tarnoff and Bullock, TRB 2009).

Real-time data available from arterials is scarce, which requires the public agencies to rely on inadequate data or private sources to provide that information to the public. The cost of providing infrastructure on arterials cannot outweigh the benefits that are realized by the arterial users—this has typically resulted in only major arterials being instrumented with data collection devices, rather than the entire arterial network. The information currently available for arterials is primarily intersection detection data, but it is used exclusively for signal control; information does not leave the controller. With additional investment in communications, there could be a great deal more data transmitted to TMCs.

Because most statewide reporting/data systems that support traveler information have been designed for state corridors and facilities, there are few that have the capability to support arterial information. Some state DOTs have expanded their reporting systems to include arterials on a limited basis, to at least be able to capture incident or planned event information for those routes. The impetus for doing so has been to include this information on 511 phone and Web-based services. Barriers to addressing this include funding and resources.

3.1.3 Traffic Data Coverage of Private-Sector Systems

The private sector has been providing traffic information for many years. Historically, it has been in the form of radio traffic reports, which feature a radio personality reporting on traffic from various sources including tipsters, fixed-wing aircraft, helicopter, police scanners, and public agency surveillance cameras. The two largest companies in this business are Clear Channel's Total Traffic Network and Westwood One's Metro Networks, which each cover approximately 100 urban markets in the United States. However, coverage in this sense is not reported according to mileage. Ostensibly, any road in a metropolitan area is considered covered in that, if a significant enough incident were to occur, it may be included in a traffic report. However, the effective coverage is limited in the number of traffic reports that can be mentioned in a single 30-second radio spot.

More recently, public-private partnerships became popular as the private sector could employ profit-generating business models and the public sector owned right-of-way on which sensing infrastructure could be installed. One example of this is ITIP, which was enabled by SAFETEA-LU to advance the deployment of ITS traffic-monitoring technologies. This public-private partnership was originally designed to provide traffic data to public agencies for operations and planning, while enabling the private entity to earn a sustaining profit through traveler information services, that would then be shared with the local public agency. The program called for the construction of data collection infrastructure in more than 40 metropolitan areas with 300,000 or greater population. Of those 40 metropolitan areas, 25 have deployed or are deploying sensors under this program. **Table 3.3** identifies the metropolitan areas participating in the program.

Table 3.3: Sensor Deployment under the ITIP

ITIP City	Metropolitan Area Population
Los Angeles	12,875,587
Chicago	9,524,673
Washington, DC	5,306,565
Atlanta	5,278,904
Boston	4,482,857
Detroit	4,467,592
San Francisco	4,203,898
Phoenix	4,179,427
Seattle	3,309,347
San Diego	2,974,859
St. Louis	2,803,707
Tampa	2,723,949
Baltimore	2,668,056
Cincinnati	2,133,678
Sacramento	2,091,120
Las Vegas	1,836,333
San Jose	1,803,643
Columbus	1,754,337
Indianapolis	1,695,037

ITIP City	Metropolitan Area Population
Norfolk/Hampton Roads	1,658,754
Providence	1,600,856
Oklahoma City	1,192,989
Salt Lake City	1,099,973
Raleigh/Durham	1,047,629
New Orleans	1,030,363

Source: http://ops.fhwa.dot.gov/travelinfo/ttidprogram/ttidprogram.htm

Most recently, with the growth in mobile computing power and mobile communications, the private sector is now obtaining traffic information from in-vehicle sources, whether GPS devices or cellular phones. As a result, the private sector has become less reliant on the public sector for its business models. Further, private firms have the ability to collect flow/speed data on corridors beyond what is currently collected by public-agency sensor-based deployments. However, the focus continues to be on Interstate routes in and near major metropolitan areas. The private sector has indicated that although they can provide flow and speed information estimates on other corridors, the demand from private-sector customers for rural routes is not as high as the urban areas. Some within the private sector indicated expected growth in this market. Some within the private sector also indicated that past business models for traveler information were centered on FM broadcast areas, which do not typically extend into the rural areas. As a result, there was no basis for advertisement revenue associated with more densely populated urban areas. In addition, as the market continues to evolve with Satellite radio and in-vehicle systems, former broadcast mindsets may change, and the demand would likely increase for rural area corridors.

In the past several years, the private sector has greatly expanded its geographic coverage of both urban and rural areas through sources that do not rely on fixed infrastructure. While the accuracy of the traffic data from these probe-based sources is only beginning to be evaluated, these types of technologies can scale. As one of the pioneering firms in this area, INRIX reports the capability to provide real-time traffic in the form of travel time and speed information in 122 markets covering over 51,000 miles of interstates, freeways, and major arterials in the United States (http://www.inrix.com/coverageflow.asp). In fact, multiple private data providers offer traffic data on all urban freeways within the top 100+ markets. These data are not of the same resolution as sensor data, however. They measure only speeds—not volumes, occupancies, or lane-by-lane data. Often available to the public for free on Web sites such as Google, Yahoo!, NAVTEQ Traffic, and Airsage, private-sector traffic data extend public-sector sensor coverage for traveler information. However, it should be noted that the private-sector data made available on the Internet is not free and accessible to the public sector to add to their own system coverage.

Figure 3.5 through **Figure 3.7** show the coverage areas of various private traffic data providers.

Source: NAVTEQ

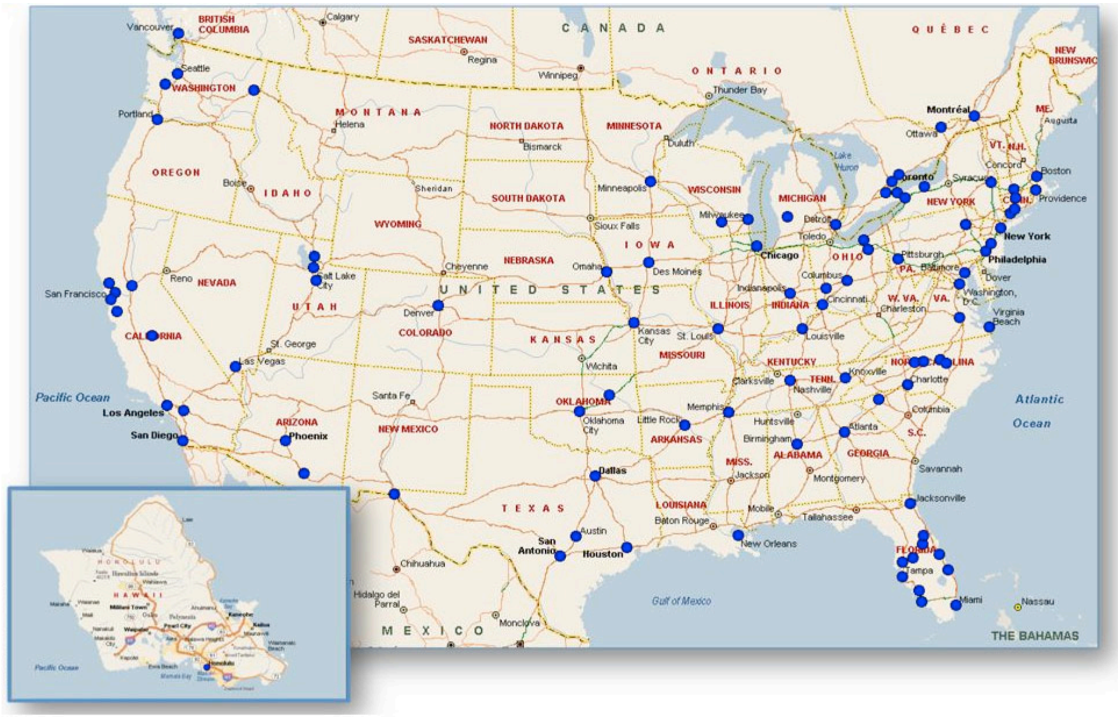


Figure 3.5: NAVTEQ Traffic CBSA Markets Map

Source: INRIX

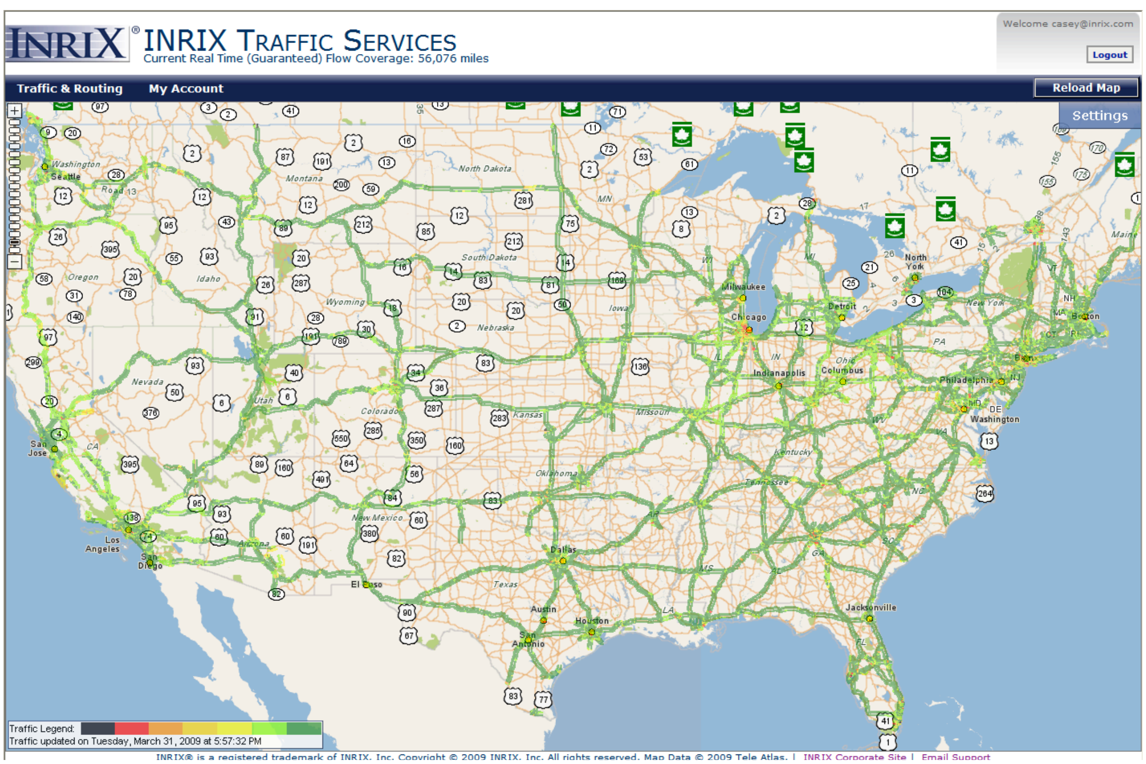
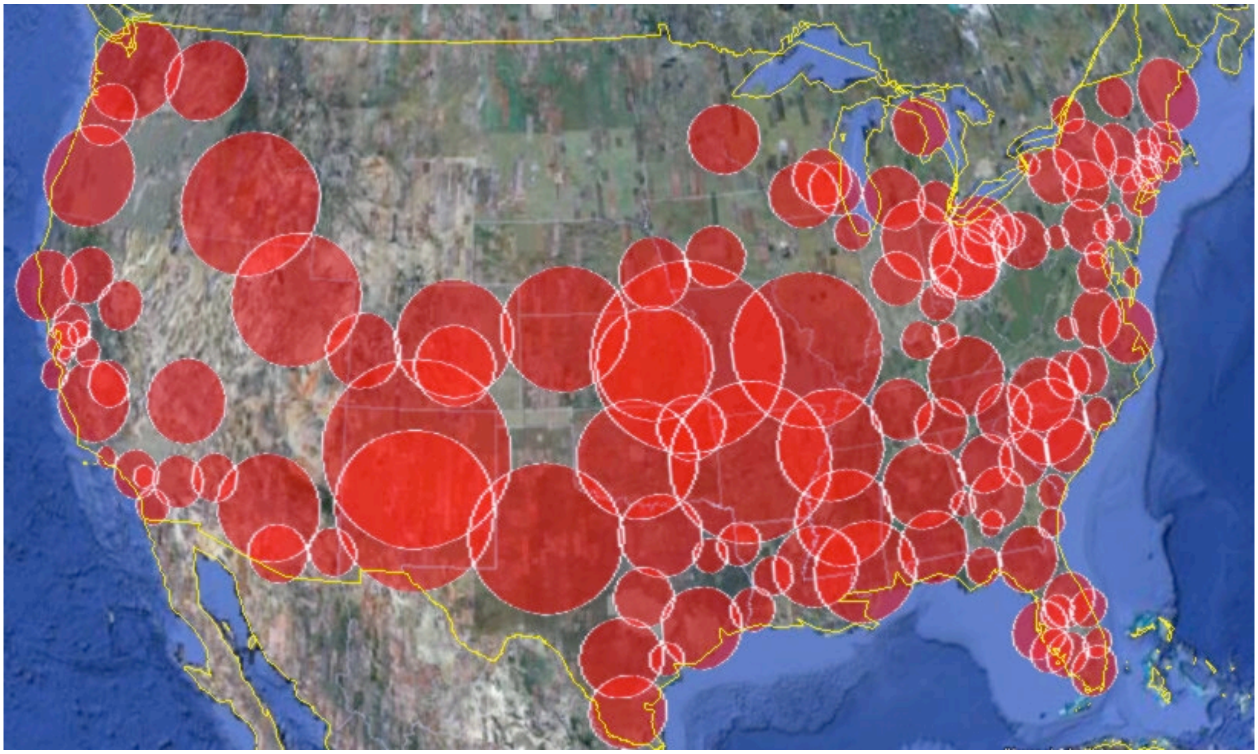


Figure 3.6: INRIX Nationwide Coverage Map



Source: Airsage

Figure 3.7: Airsage Coverage Map

Despite a few claims of nationwide coverage, most real-time traffic information providers—public and private sectors alike—focus on metropolitan areas, since this is where most of the users are and where most of the congestion occurs. For the public sector, covering primary urban freeways is enough of a challenge. For the private sector, the markets for real-time traffic information have centered on radio stations or other entities focused on metropolitan areas. That is changing with the growth of in-vehicle navigation systems, whose customers expect nationwide coverage. At the present time, however, real-time traffic data outside metropolitan areas is either limited or its quality is untested.

In the I-95 Corridor Coalition Probe Data Procurement, INRIX is providing real-time traffic data on approximately 1,500 miles of the "Core Network" as defined in the Request for Proposals (RFP), which includes Interstate and other limited access freeways in the Coalition States from New Jersey to North Carolina. In its proposal, INRIX claimed prior coverage of 1,244 miles of the 1,531 miles requested. Also requested were data on 1,000 miles of arterial roads, which INRIX offered to provide for free, but for which it would not provide assurance of its accuracy.

Other statistics of coverage reports by private-sector providers include:

- XM Satellite Radio provides traffic data from NAVTEQ in 80 metropolitan markets.
- Total Traffic Network, the traffic information arm of Clear Channel, provides navigation data to in-vehicle devices in 95 markets.
- INRIX provides incident data through a partnership with Clear Channel in 113 markets.
- TrafficCast provides flow data in 28 markets, incident data in 138 markets, and construction data in 146 markets.

- SpeedInfo, a private infrastructure-based provider, is a partner in 14 metropolitan areas. SpeedInfo provides data to both the public sector and other private-sector clients. In some cases, SpeedInfo supplements or extends current data collection strategies already in place by the public sector.

As with the public sector, private-sector providers recognize that arterial data is a key gap, and there are efforts underway to be able to bring that data to the real-time marketplace through GPS and other probe mechanisms. Although progress appears to be slow, these efforts are definitely underway. This is also one of the key components of the SafeTrip-21 Mobile Millennium program, and Caltrans is working with the private partners to be able to collect that arterial data through the private partner systems. The Mobile Millennium program uses an arterial traffic estimation algorithm that blends vehicle location data collected from mobile phones with NAVTEQ historical data collected from fleet vehicles. The real-time system can use any current vehicle location measurement and the correlation between road segments to produce an estimate of the current travel time along all segments. Arterial data will largely rely on the increase of users providing vehicle location information that travel the arterial corridors.

Firms like Waze seek to capitalize on the power of the community. With their products, each user provides information on its location and speed, which altogether comprise the traffic data that is aggregated and returned to users. More users equates to better information. Dash sells a navigation device with two-way communications, while Waze gives away free software that runs on various Smartphone platforms. To generate sufficient information for early adopters, Dash has partnered with a traffic data provider to provide a base level of information. It is not clear whether these ventures will ultimately be successful or yield sustainable business models.

3.2 Transit Data Coverage

Transit agencies of all sizes, even smaller agencies, are utilizing real-time traveler information to increase overall customer satisfaction. Each year, the US DOT/RITA surveys transit agencies across the United States to ascertain their use of transit systems management and operations tools and their deployment of ITS.

In 2007, 94 transit agencies across 6 types of transit vehicles (fixed-route buses, heavy or rapid rail, light rail, demand-responsive vehicles, commuter rail, and ferry boats) responded to the survey. For each vehicle type, agencies indicated the number of vehicles they possessed, whether these vehicles were equipped with AVL technology, and whether they electronically display automated or dynamic traveler information to the public. **Table 3.4** presents the results of the survey. The table also describes information from a similar survey in 2004, to which 80 transit agencies responded regarding the number of transit vehicles that have APCs, which track the number of passengers aboard a vehicle at any given moment, even if the information is not shared with the public.

Table 3.4: Transit Coverage Deployment

Transit Types	Measurement	Equipped with AVL	Display Real-Time Traveler Information	Equipped with APC
Fixed-Route Buses	Number of Metro Areas Reporting Use of Technology	60	28	41
	Vehicles with Technology	26,381	11,569	6,323
	Total Vehicles	43,233	43,233	43,233
	Percent	61%	27%	13%
Heavy or Rapid Rail	Number of Metro Areas Reporting Use of Technology	5	3	0
	Vehicles with Technology	2,013	454	0
	Total Vehicles	10,812	10,812	10,812
	Percent	19%	4%	0%
Light Rail	Number of Metro Areas Reporting Use of Technology	7	5	6
	Vehicles with Technology	452	264	134
	Total Vehicles	1,317	1,317	1,317
	Percent	34%	20%	8%
Demand-Responsive Vehicles	Number of Metro Areas Reporting Use of Technology	49	7	2
	Vehicles with Technology	5,260	198	9
	Total Vehicles	10,938	10,938	10,938
	Percent	48%	2%	0%
Commuter Rail	Number of Metro Areas Reporting Use of Technology	3	3	1
	Vehicles with Technology	1,348	397	100
	Total Vehicles	4,710	4,710	4,710
	Percent	29%	8%	2%
Ferry Boats	Number of Metro Areas Reporting Use of Technology	3	0	0
	Vehicles with Technology	30	0	0
	Total Vehicles	48	48	48
	Percent	63%	0%	0%

Source: RITA, ITS Joint Program Office

While it is not possible within the scope of this report to develop a complete list of every agency that provides real-time transit information, **Figure 3.8** exemplifies the diverse range of transit agencies across the United States that provide some form of real-time traveler information to their customers. However, the map also shows the large disparity between agencies that have deployed AVL systems to their transit vehicles but are not fully utilizing their data by providing real-time transit information to the public. The map also shows that only two metropolitan areas have the capability to provide real-time information across multiple agencies and transit modes. Even these two agencies have yet to fully deploy these pioneering systems.

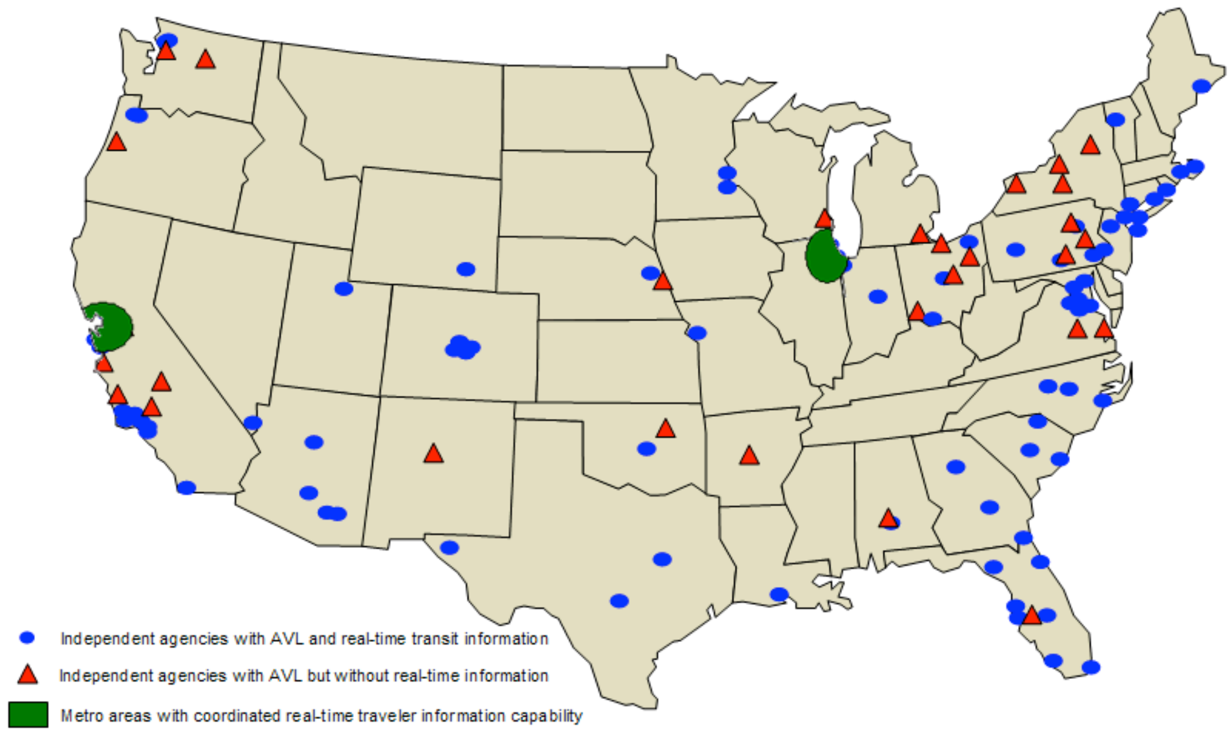


Figure 3.8: Transit Coverage Map

RITA's annual ITS Deployment survey on transit management also documents the number of transit agencies that use several common dissemination methods to provide traveler information to the public. In 2006, surveys from 95 transit agencies were returned. In 2007, 94 surveys were returned. **Table 3.5** documents the finding from these surveys.

Table 3.5: Common Transit Dissemination Methods

Method	Number of Agencies	Percentage of Agencies
From 2007 Survey		
Using automated telephone system to disseminate real-time transit schedule adherence or arrival and departure times to the public	27	29%
Using internet Web sites to disseminate real-time transit schedule adherence or arrival and departure times to the public	68	72%
Using pagers or personal data assistants to disseminate real-time transit schedule adherence or arrival and departure times to the public	13	14%
Using kiosks to disseminate real-time transit schedule adherence or arrival and departure times to the public	22	23%
Using e-mail or other direct PC communication to disseminate real-time transit schedule adherence or arrival and departure times to the public	23	24%

Method	Number of Agencies	Percentage of Agencies
Using 511 telephone system to disseminate real-time transit schedule adherence or arrival and departure times to the public	10	11%
From 2006 Survey		
Using dedicated cable TV to disseminate real-time transit schedule adherence or arrival and departure times to the public	2	2%
Using interactive TV to disseminate real-time transit schedule adherence or arrival and departure times to the public	1	1%
Using in-vehicle navigation systems to disseminate real-time transit schedule adherence or arrival and departure times to the public	5	5%
Using variable message signs (in vehicle) to disseminate real-time transit schedule adherence or arrival and departure times to the public	19	20%
Using monitors/VMS (not in vehicles) to disseminate real-time transit schedule adherence or arrival and departure times to the public	29	31%
Using audible enunciators to disseminate real-time transit schedule adherence or arrival and departure times to the public	22	23%
Using facsimile to disseminate real-time transit schedule adherence or arrival and departure times to the public	10	11%

Source: RITA

While the above coverage statistics show that a substantial number of transit agencies are disseminating real-time transit information to the public, many agencies have yet to provide sufficient real-time information for their entire transit network. Many agencies expressed the desire to increase system coverage across the entire network and/or increase the types of information available to the network. Many transit systems lack real-time information across the entire system or were unable to effectively provide static and/or real-time information to a substantial enough proportion of the traveling public due to insufficient data collection and information dissemination device deployments. In addition to overall data coverage, transit agencies are focused on increasing the level of multimodal information coverage being utilized, with many agencies unable to provide real-time information between opposing transit vehicles and even less between transit agencies. **Figure 3.9** shows the national coverage of 511 systems that disseminate transit information.

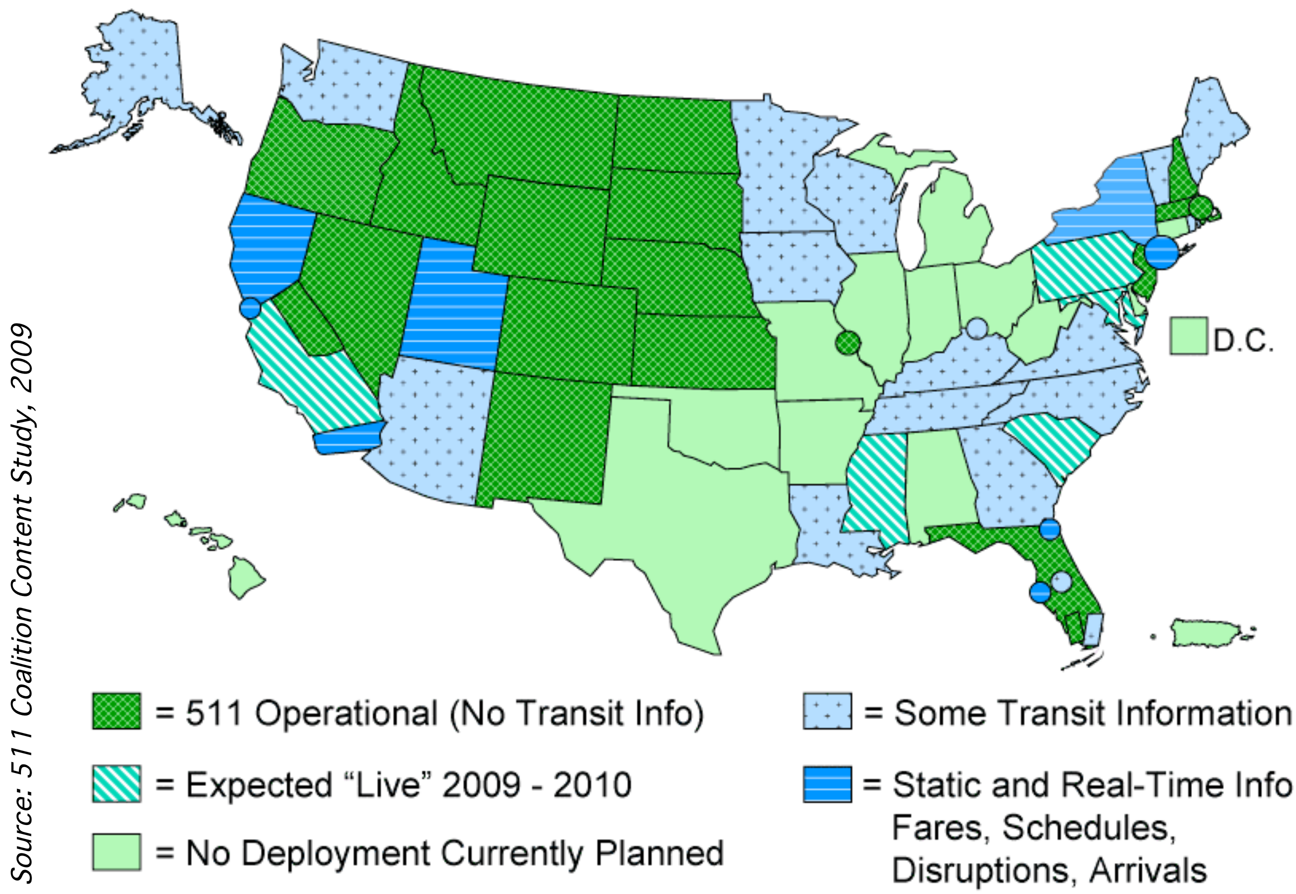


Figure 3.9: 511 System Transit Coverage

AVL vendors are working with transit agencies to deploy additional real-time systems. One vendor, Affiliated Computer Services, Inc. (ACS), has deployed 60 AVL systems in the United States, but estimates that only about 10 (17 percent) have opted to leverage AVL to provide real-time information. Another vendor, NextBus Inc. (a subsidiary of Grey Island Systems International Inc.), focuses more heavily on deploying real-time information as part of its AVL systems, and has deployed real-time information for all of its 53 systems, although many are pilot implementations that have not expanded to the entire bus network. Since buses operate on arterial roads with general traffic, while rail operates on dedicated track, bus arrival times are inherently more variable. Due to this variability, AVL vendors and transit agencies generally focus on providing real-time information to buses. Vendors expect that real-time information will become more common over the next 5 years, as agencies choose to add real-time systems as part of their periodic technology refreshes every 5 to 8 years, because the incremental cost of adding real-time information to an existing AVL system is low compared to building the AVL system from scratch.

Figure 3.10 demonstrates Nextbus' US and Canadian deployments of real-time systems. In comparison to **Figure 3.8**, the following map also includes several systems that have been implemented on a smaller level including several universities, which are operated by the universities themselves instead of transit agencies.

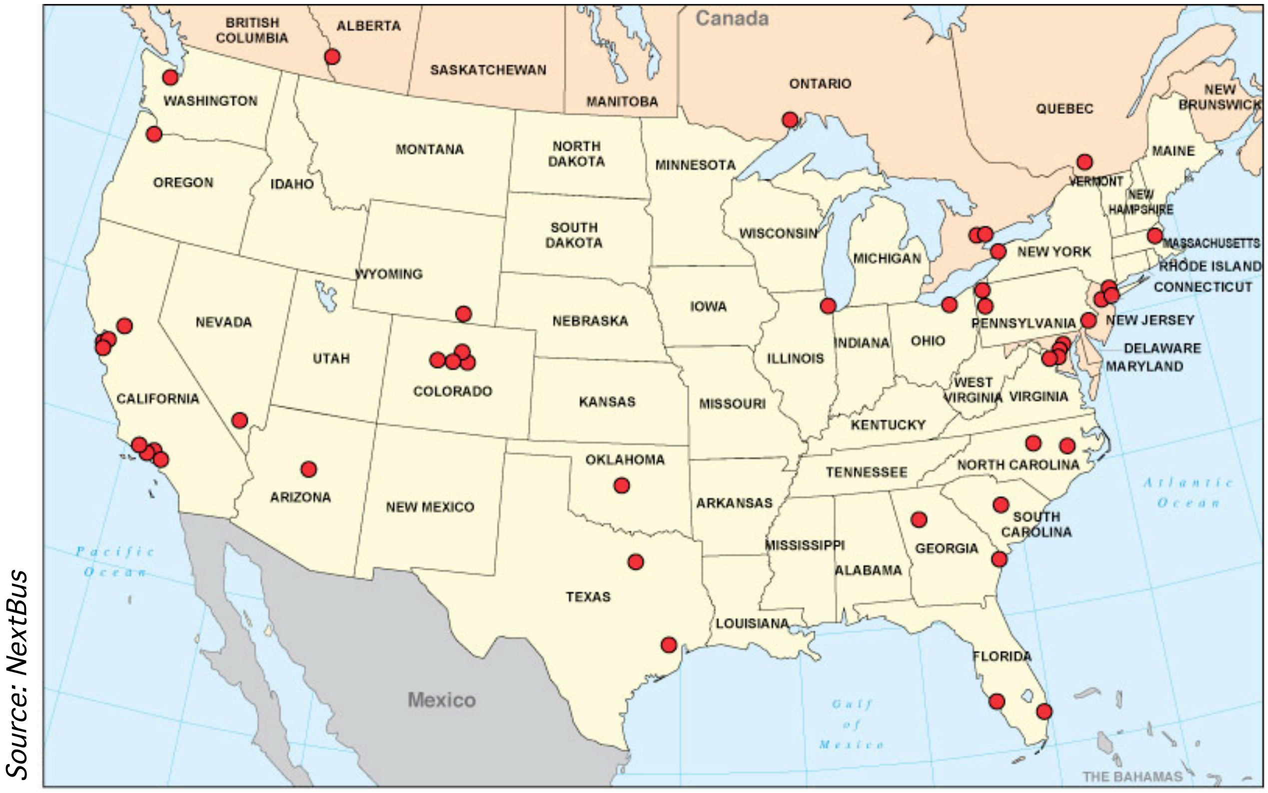


Figure 3.10: NextBus Coverage Map

When undertaking a real-time traveler information deployment, a phased approach is often used, leaving some transit routes underserved by traveler information for substantial periods of time. In general, only fixed-route real-time information is available for transit including buses, rail, and ferries. Due to the nature of its unscheduled trips, paratransit has little ability to effectively provide real-time information, although some agencies do provide static information and reverse calling when vehicle arrival is imminent. In addition to increasing the overall coverage area, agencies focus on increasing polling rates for reporting transit vehicle location updates. Los Angeles Metro currently polls every 5 minutes, but hopes to increase frequency to every 3 minutes with the integration of additional data channels. The agency has run into some difficulties due to the fact that radio channels spanning Los Angeles County are extremely difficult and costly to obtain, so the opportunity to further reduce from 3 minutes to 1 minute or 30 seconds would be difficult to achieve. The more likely option would be to move toward a public network (e.g., Sprint or Verizon), which carries hefty ongoing operational costs. A goal of sub-one-minute location polling rates is typical for many transit agencies.

Beyond the data collected by the RITA Deployment Statistics Survey, **Table 3.6** contains additional data coverage metrics for several prominent transit agencies. This information demonstrates that while transit agencies have deployed real-time traveler information systems to their networks, their systems are far from complete.

Table 3.6: Single Network Data Coverage for Sample Transit Agencies

	Bay Area Rapid Transit, San Francisco, California	Regional Transportation District, Denver, Colorado	King County Metro, Seattle, Washington	TriMet, Portland, Oregon
Percentage of fixed routes served by vehicles outfitted with GPS/AVL	100%	100%	100% AVL, no GPS	100%
Percentage of routes with real-time signs/displays at stops, shelters, or stations	100%	0%	<5%	20%
Percentage of stop locations equipped with real-time signs/displays	100%	0%	<1%	<1%
Percentage of transit stations that provide real-time arrival info by route via signs/displays	100%	0%	<5%	47%
Percentage of vehicles with APCs	0%	20%	15%	77%
Is load information from APC shared with travelers in real time?	No	No	No	No

Although some agencies collect APC information, they only use it for internal systems management purposes, and no instances of sharing this information with the public are known. However, some agencies, including Portland TriMet, are interested in exploring the possibility of combining AVL and APC information to provide to customers. This would allow riders to determine whether the next bus is at capacity. Combining this information with information about the arrival time of the following bus would allow passengers to determine whether they should attempt to squeeze onto the bus or wait for the next one.

3.3 Data Coverage for Parking

There are a limited number of real-time parking information deployments in the United States. Of the existing systems, most are concentrated at transit station park-and-rides, airports, and central business districts where parking is often scarce. Most parking facilities are run by individual operators, resulting in a fragmented industry with limited inter-operator coordination. Real-time parking information lacks a standardized platform to consolidate information and create region-wide information. Concerning more robust systems as part of a navigation device, many parking facilities are unwilling to implement and participate in smart parking systems until there is a more substantial customer base, and many customers and car companies are unwilling to procure parking information-enabled navigation devices until information is available from facilities, indicating cyclical inaction.

There are 12,321 parking establishments, or single physical parking locations, in the United States. Approximately half are owned by public agencies; the other half are owned by the private sector. Of the over 100 million parking spaces across the country, approximately two-thirds are off-street spaces, while the remaining third is on-street parking. Of all the facilities across the nation, only a handful have implemented real-time parking information systems that provide customers with information related to current parking facility availability. However, coverage is expanding for both access-controlled facilities and on-street parking.

Table 3.7 through Table 3.9 list the known locations and agencies across the United States that have deployed smart parking in central business districts, airports, and transit stations. The tables also indicate the level of granularity that each of the deployments displays to customers. Space-by-space systems lead customers directly to an available parking space via signage. Entry/exit systems only indicate whether there are available spaces in the lot and possibly the estimated number of spaces available, but do not indicate exactly where in the facility the available spaces are. Mixed systems have space-by-space systems in some areas of the facility and entry/exit systems in other areas. For example, some airports may have space-by-space systems in the hourly or daily lots, but entry/exit systems in the long-term lots.

Only six cities have deployed real-time parking information as shown in **Table 3.7**. **Table 3.8** shows that of the 50 busiest airports in the United States, only 7 (14 percent) were identified to have real-time parking information. The four transit stations identified in **Table 3.9** have deployed real-time parking information systems as part of pilot programs.

Table 3.7: Deployments in Central Business District

Location	Deploying Agency	Granularity
Los Angeles, California	City of Los Angeles	Mixed
San Francisco, California	City of San Francisco	Mixed
Century City, California	Westfield Century City Mall	Space-by-space
Portland, Oregon	Downtown Portland Garages	Entry/Exit
Ann Arbor, Michigan	Downtown Ann Arbor Garages	Entry/Exit
Seattle, Washington	Seattle Center	Entry/Exit

Table 3.8: Deployments at Airports

Location	Deploying Agency	Granularity
Atlanta, Georgia	Hartsfield-Jackson Atlanta International Airport	Entry/Exit
Chicago, Illinois	O'Hare International Airport	Entry/Exit
Dallas/Fort Worth, Texas	Dallas/Fort Worth International Airport	Entry/Exit
Denver, Colorado	Denver International Airport	Entry/Exit
New York, New York	John F. Kennedy International Airport	Entry/Exit
New York, New York	Newark Liberty International Airport	Entry/Exit

Location	Deploying Agency	Granularity
Charlotte, North Carolina	Charlotte/Douglas International Airport	Entry/Exit
Minneapolis/St Paul, Minnesota	Minneapolis-St. Paul International Airport/Wold-Chamberlain Airport	Entry/Exit
Boston, Massachusetts	Logan International Airport	Entry/Exit
Washington, DC	Washington Dulles International Airport	Entry/Exit
Baltimore/Washington, DC	Baltimore-Washington International Thurgood Marshall Airport	Space-by-Space
Washington, DC	Ronald Reagan Washington National Airport	Entry/Exit
Chicago, Illinois	Midway International Airport	Entry/Exit
Portland, Oregon	Portland International Airport	Mixed
Oakland, California	Metropolitan Oakland International Airport	Entry/Exit
San Jose, California	San Jose International Airport	Entry/Exit

Table 3.9: Deployments at Transit Stations

Location	Deploying Agency	Granularity
Oakland, California	BART Rockridge Station	Entry/Exit
Vienna, Virginia	WMATA Vienna Metro Station	Entry/Exit
Rockville, Maryland	WMATA Glenmont Metro Station	Entry/Exit
Chicago, Illinois	Chicago Metra Rock Island Station	Entry/Exit

Figure 3.11 shows the limited number of real-time parking information systems deployed across the United States. The figure also shows two metropolitan areas in California that are developing regional real-time parking information systems, including on-street systems, that will allow customers to locate a facility closest to them within the broad regional network. While real-time information is available for a limited number of deployments, advanced static facility information is more readily available across many facilities in major cities across the country. Such information is also useful to customers, including entry and exit locations, hours of operation, height restrictions, security features, and lighting conditions. Since this advanced static information has established some data collection, aggregation, and dissemination channels, these locations may serve as good candidates for future implementations. Parking information aggregators like MobileParking and ParkingCarma are collecting, consolidating, and disseminating both real-time and static information.

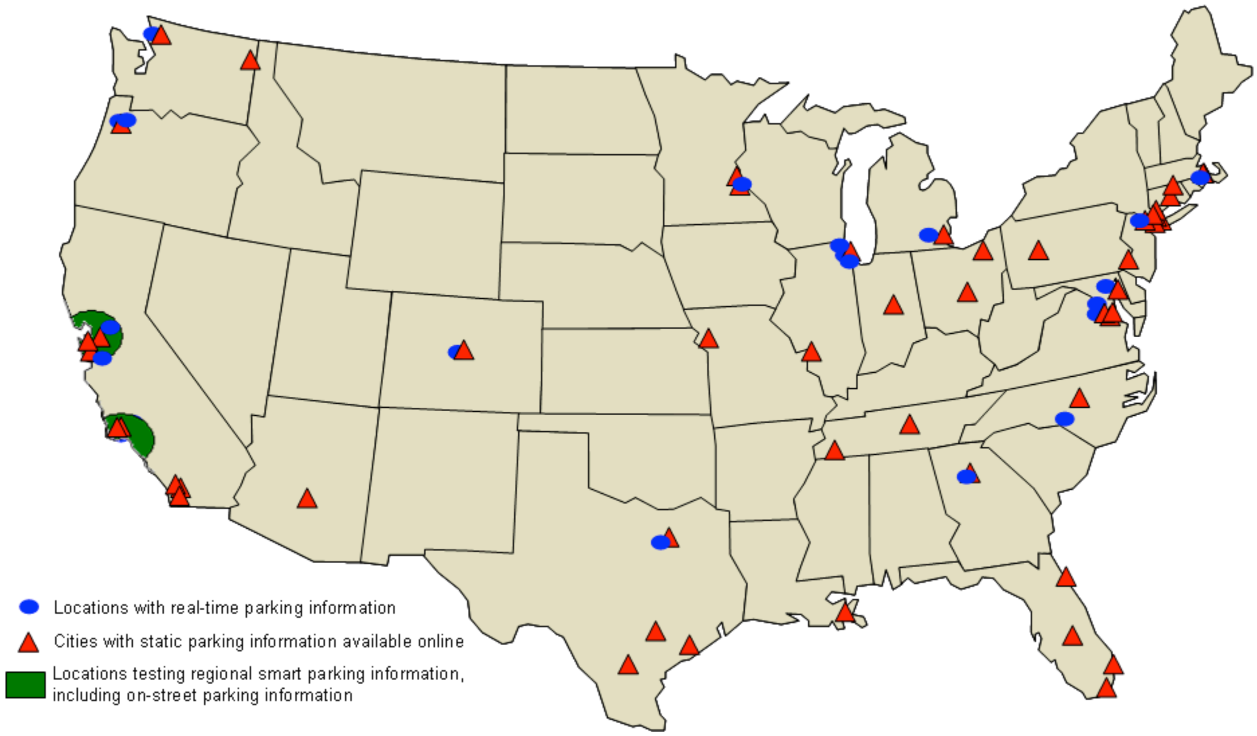


Figure 3.11: Parking Coverage Map

3.4 Data Coverage for Freight

Regarding the real-time trucker traveler information technologies utilized and applications deployed, public- and private-sector traveler information applications vary in scope and delivery. Privately run systems use onboard communications systems to track and provide information to a vehicle along its entire route. These systems provide information, to at least some detail, for the majority of roads in the United States. Conversely, public systems are deployed by individual agencies and are more limited in scope. Some public-sector systems seek to add freight-specific information onto existing passenger traveler systems. Others' systems focus on specific regions or locations where freight traffic is particularly high, such as border crossings and intermodal facilities.

Much of the focus for publicly sponsored real-time freight information systems has centered on major freight hubs and border crossings, which are choke points for the freight industry. Focusing on improving commercial vehicle throughput in these areas helps to increase overall goods movement. Currently, many of these areas lack a centralized switchboard for truckers to receive information, and trucks often lack adequate communication links with ports because there is such a vast quantity of data points. Information, particularly intermodal information, often does not flow well at such hubs due to the size of the systems and the fact that companies are hesitant to share their proprietary freight information. These facilities are frequently under the jurisdiction of public-sector entities including port and airport authorities.

Although some private-sector entities are working to provide commercial vehicles with real-time information, implementation at many of these facilities requires at least some government involvement. In some instances, the federal government has taken the lead on implementation by providing the funding, expertise, and leadership necessary to develop real-time systems such as C-TIP in Kansas City, Missouri, where trucks must frequently transport cargo from rail yards in one part of the city to another. Although the C-TIP deployment will not be completed until 2011, it will be the first fully functional cross-town real-time freight information system. The US DOT is already examining other locations for similar deployments if C-TIP is successful, including ports, airports, and rail transfer locations such as the Dallas metropolitan area or the area surrounding John F. Kennedy International Airport.

Many northern and southern border crossings are working to provide additional border crossing information, including wait times, which will be of particular interest to commercial vehicles. For example, the I-5/BC 99 crossings at the Peace Arch and Pacific Highway crossings in Blaine, Washington, display border wait times in anticipation of arrival at either of the crossings. Having wait-time information on a Website or on a sign allows vehicles to judge which crossing to enter. However, currently, only one of the crossings allows commercial vehicles, limiting the usefulness of the information for commercial operators because little choice can be made. North-to-south drivers may use the information to decide to delay their trip, but south-to-north drivers are often coming from farther away and will have little choice.

In addition to using real-time information systems to alleviate freight bottlenecks, some public-sector freight information systems have focused on providing freight-specific information via pre-existing 511 systems. **Figure 3.12** shows the border crossings and intermodal facilities that have deployed real-time freight information systems. It also shows the states that are making freight-specific information available via 511 or online.

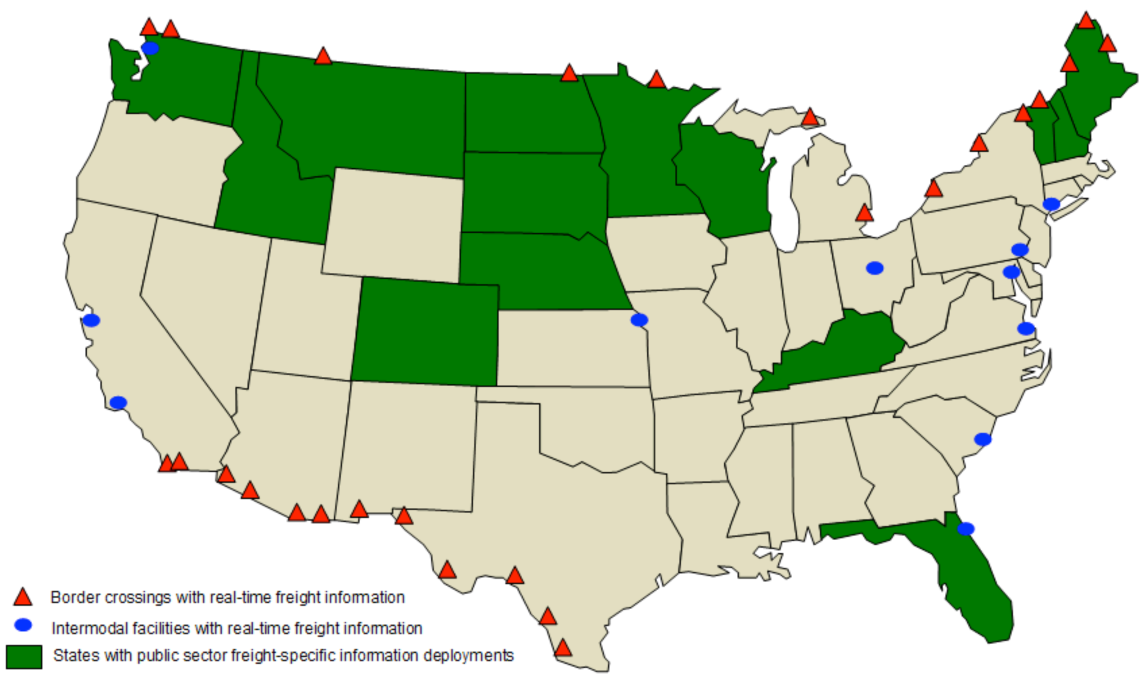


Figure 3.12: Freight Coverage Map

3.5 Trends

3.5.1 Traffic

The public sector continues to invest in detection infrastructure, and over the last several years, there has been an increase in the number of urban area freeways with real-time detection coverage. From 2004 to 2006, coverage has increased from 33 percent to 39 percent; however, there was minimal increase between 2005 and 2007 (38 percent to 39 percent, respectively). **Table 3.10** shows these trends in tabular format.

Table 3.10: Urban Freeways with Real-time Detection

	2004	2005	2006	2007
Number of urban area freeways with real-time detection coverage	33%	38%	39%	39%

The FHWA RTSMIP (notice of proposed rule issued in January 2009) in response to the SAFETEA-LU 1201 requirement could mean that this coverage will drastically increase over the next several years. The parameters of this rule include traffic and travel condition information for all Interstate highways, which includes incidents as well as construction and weather advisories. Urban areas (metropolitan statistical areas with over 1 million in population) will have stricter requirements (for latency), as well as a requirement for provision of travel times on interstate and non-interstate highways, which will require real-time speed data in order for agencies to meet these requirements. For those urban area freeways not already instrumented with public-agency-operated detection systems, agencies will need to seek alternatives to obtain this data.

The private sector continues to expand its capabilities to provide data on corridors beyond what is currently instrumented by public center-operated detection systems. Through a combination of fleet-probe GPS data; cell phone probes; privately owned detection infrastructure; aggregated public-sector detection data; incident data (from public and private entities); and in some cases, historical corridor travel patterns, there is an increased trend toward aggregating multiple data sources to be able to provide a baseline level of information on corridors that are part of the National Highway System. I-95 marks the largest corridor to date for which private-sector data has been made available. Future demand by other agencies will result in broader private-sector data coverage.

Arterial coverage remains a challenge, whether through traditional sensor-based deployment or through probe-based applications. Many arterial management agencies recognize the value in surveillance through CCTV camera or video coverage, and the quantity of deployments for arterial-based systems is increasing. Unfortunately, this deployment information is not tracked at the national level.

3.5.2 Transit

Real-time transit information is focused on improving overall data coverage by increasing information integration and information sharing. Agencies are moving toward closer integration between modes and regions, especially in larger metropolitan areas. One goal is to have a single access point for information so that users are provided with a single resource for information regarding all modes with a standardized user interface. Next-generation multi-modal trip planners have been developed in San Francisco and Chicago with real-time information included in the architecture. These programs involve multiple partnering agencies and are expensive to implement and operate, but demonstrate a need for real-time trip-planning capabilities independent of mode. The ability to integrate real-time data from multiple agencies is often more effective when using open-source solutions. Travelers' increased use of multi-modal solutions for longer trips will drive an increased focus on collaboration and information sharing across regions. Some regions are beginning to focus on expanding into statewide systems, such as New York State's Trips123.

Because of transit's dynamic operational environment, providing perfect information is not possible, and providing the public with an ability to make informed decisions supersedes any operational anomalies. Some agencies, like the Washington Metropolitan Area Transit Authority (Metro), have established a goal to develop portals that make schedule data available to third parties. Google Transit has proven to be a successful partner with many transit agencies and likely will continue to be a low-cost approach to aggregate and compile data. Social networking applications can also utilize transit data to provide information to customers, providing an additional dissemination medium for transit agencies. Making real-time data publicly available is a strategy that helps agencies to reach a broader audience through a multitude of personal devices and applications. Open-source information will allow these independently developed applications to improve over time.

3.5.3 Parking

Both public- and private-sector players are interested in expanding the coverage of real-time parking information. Municipalities and private operators benefit from improving the availability and accessibility of data. The stakeholders have an interest in expanding real-time parking information on all types of parking facilities including individual facilities, on-street systems, and city-wide and regional networks.

As part of its proposal for the US DOT's Urban Partnership Agreement (UPA), the City of San Francisco has undertaken SFPark, a smart parking initiative to create real-time dynamic pricing at the city's parking meters and in municipal garages. The goal is to relieve congestion on the roadway network by providing dynamic pricing for parking that adjusts based on availability. The pricing structure will be designed to maintain 15-percent vacancy at any given time out of the available parking spaces. The city plans to install multi-space meters in approximately 25 percent of the city's 24,000 spaces. In-street wireless sensors will communicate with meters to measure occupancy rates and set prices. Remote monitoring and pricing availability will allow users to confirm availability and current rates. Drivers will have the ability to receive specific parking information via cell phone or other handheld device. Information will include a warning if the meter is running out and notification of space availability. The SFPark implementation should result in a better understanding of sustainable business models and how smart parking can be used on a regional basis to relieve congestion, and could serve as a useful model for similar deployments in other regions.

After a successful pilot at the Rockridge Bay Area Rapid Transit (BART) transit station, Caltrans is currently working with the US DOT on the SafeTrip-21 initiative to deploy additional advanced parking information facilities on the Route 101 corridor in California. One such deployment under discussion by Caltrans is San Diego's Coaster line. To bring the project to the next level, Coaster plans to implement a corridor-wide system. The Rockridge study showed that many users were driving from farther away to use the new smart parking reservation system, actually increasing their vehicle miles traveled (VMT). Implementing smart parking along an entire corridor would allow users to utilize the system at their closest transit facility, helping them decrease VMT.

Due to their additional complexity and limitations within the market, commercial vehicle real-time traveler information systems have fallen behind their passenger vehicle counterparts. FMCSA is working towards a pilot demonstration in the near future, with additional implementations to follow. Within 5 years, the agency hopes to have multiple smart parking deployments along a 50- to 70-mile stretch of a major freight corridor. One possible corridor is along I-95 between Baltimore, Maryland, and Washington, DC.

3.5.4 Freight

The trucking industry has been a cooperative partner with the government and is expected to continue this relationship. However, many experts hope that future deployments will involve an increased interaction between government and industry. Additional focus also should be dedicated to information sharing among trucking companies. Breaking down such institutional barriers will help increase overall freight movement and security. Unfortunately, trucking is such a low margin industry, often at only 3 percent to 4 percent, so most companies do not have the necessary capital to make large investments, even with a promised high return on investment. Therefore, government support will be necessary to incentivize new deployments.

Public-sector deployments likely will focus on border crossings and other choke points where there is substantial delay and real-time information is a priority. At border crossings, bi-national research and partnerships often are necessary. While its initial implementation in Kansas City will take until 2011, FHWA hopes to expand a successful C-TIP model to additional intermodal cities, such as Dallas or St. Louis. The model also may be expanded to ports and freight airports. Another federal implementation, CVII, could be used as an add-on to obtain real-world data by ensuring that new applications are compatible with the industry's existing IT infrastructure.

Currently, the San Diego Association of Governments (SANDAG) is considering tolling area border crossings by 2013, but realizes it will need improved information to support the viability of this plan. Such a plan would require an improved IT strategy and infrastructure, innovative border-crossing strategies such as pre-clearance lanes, and more flexible Customs and Border Patrol (CBP) staff. To be effective, pre-clearance lanes would need to process vehicles at a 3-minute average per truck. The plan also will require bi-national coordination concerning how to effectively levy and collect tolls electronically across a national border. Such a system also would require industry buy-in. A toll border crossing was implemented for trucks on the Columbia Bridge near Laredo, Texas, but was unsuccessful because it rerouted trucks 14 miles and charged a fee.

Next-generation in-vehicle telematics have demonstrated several benefits over older models, but penetration among freight operators continues to lag. The newer systems use more advanced algorithms to provide drivers with improved accuracy for routing around traffic, weather, and unsafe routes, which allows for improved decision making. Also, while many of the earlier systems relied solely on satellite communications, newer systems are beginning to use a hybrid of communications that include cheaper WiFi and cellular technology. Allowing additional communications mediums also decreases the "urban canyon" effect, whereby satellites are unable to reach devices due to blockages by surrounding objects such as tall buildings. Many freight carriers do not have units in their vehicles or use outdated systems. This is particularly common with smaller carriers who do not have the capital necessary to invest in the technology and are not fully aware of the potential benefits of the more advanced systems.

3.6 Gaps in Real-Time Data Coverage

3.6.1 Traffic Coverage Gaps

Section 1201 requirements may not be easily attained by public agency systems. When considering gaps in the availability of real-time traffic information, geographic coverage (or the roads for which that information is available) is one of the most important aspects. Gaps in coverage are presented here for different types of roads and data types, including weather. Key gaps detailed in this section are summarized as follows:

- **Urban Freeway Coverage Gap** – Only about 39 percent of urban freeway miles have sensor coverage to supply real-time traffic flow data; and even the largest cities fall significantly short of full freeway coverage.
- **Rural Highways Flow Data Gap** – There is a lack of coverage on rural freeways, with minimal traffic sensor coverage. Additionally, the private-sector data providers have a difficult time with rural freeways because of the low traffic volumes and sparseness of probe data points on these roads.
- **Rural Highways Incident Data Gap** – Statewide real-time incident reporting coverage does not occur. Although many states have implemented incident and event reporting, most do not exist on rural highways.
- **Arterials Flow Data Gap** – Real-time traffic information on arterials is scarce, and most arterial detection is tied to localized intersection-based signal operations, rather than traveler information.
- **Local Roads Incident Data Gap** – Most statewide systems that support traveler information have been designed for state corridors and facilities, so there are few that have the capability to support arterial information.
- **Quantifying Coverage of Public-Sector Systems** – There is a gap in reporting on public-sector data coverage, and the Deployment Statistics Database has gaps in its reporting due to a lack of survey response from different agencies.
- **Route-Specific Weather Data Gap** – There is a significant disparity in RWIS coverage between states, even in states with mature RWIS programs. There are wide swatches of area in adverse weather areas with no RWIS sensors.

3.6.1.1 Urban Freeway Coverage Gap

Agencies, the private sector, and industry experts generally agree that there is good coverage of urban area freeways through public-sector sensor deployments. However, gaps still exist.

According to 2007 data from the US DOT Deployment Tracking Database, for a sample of 64 metropolitan areas surveyed, only about 39 percent of urban freeway miles have sensor coverage to supply real-time traffic flow data to traveler information and other traffic operations activities. This is up from 33 percent in 2004, but there remains a significant gap in data coverage considering urban freeways experience the majority of the nation's traffic, congestion, and travel-time variability. In most major metropolitan areas, there is at least one major freeway facility without any sensor coverage at all. This equates to many miles of roadway experiencing significant congestion and travel-time variability where the public sector is not able to accurately capture real-time corridor conditions.

Even within the context of urban areas, however, different sized urban areas have different amounts of congestion, incident activity, and priority given to real-time traffic information. Figure 3.13 shows the total freeway mileage and the freeway centerline miles with real-time data collection technologies for the largest 50 metropolitan areas. The source of the freeway mileage is the National Highway Planning Network (NHPN). These data include roads designated by the NHPN as "Interstate" and "Urban Freeway." They do not include any arterial miles. The source of the freeway centerline miles with real-time data collection technologies is the US Deployment Statistics Database.

Sources: NHPN, U.S. Census Bureau,

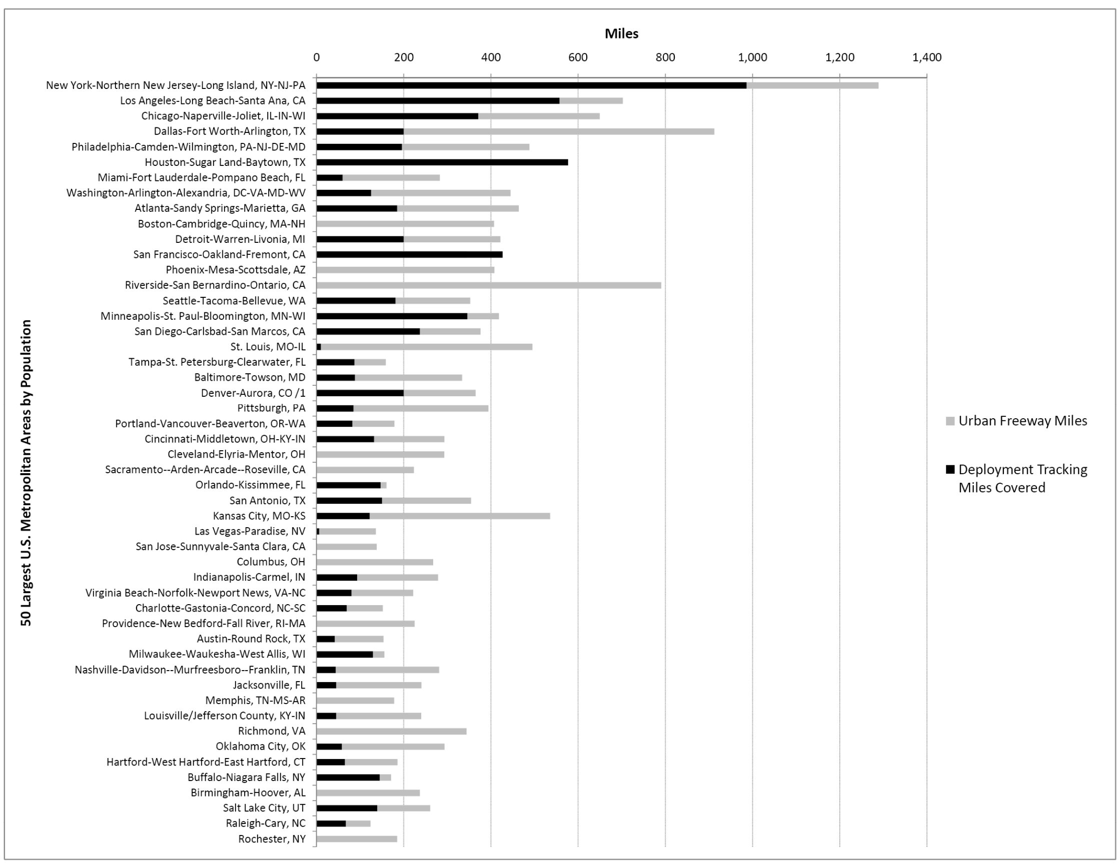


Figure 3.13: Urban Freeway Miles and Miles with Real-Time Data Collection Technologies in the 50 Largest US Metropolitan Areas, Ranked by Population

The largest cities tend to have a higher percentage of freeway miles covered, although even the largest cities fall significantly short of full freeway coverage. It should be noted that these data are self-reported and may not accurately represent all metropolitan areas. There are several cities that did not have any coverage reported, although they are known to have ITS deployments. States indicated that gaps exist in the coverage that their systems currently provide. However, there are limitations as to how much detection infrastructure can feasibly be deployed and maintained with current resource constraints. And in many cases, funding ongoing maintenance is an even bigger challenge than funding new sensor deployments.

It also should be noted that these coverage data only include sensor coverage and not incidents, construction, weather, or other types of data. That being said, public agencies will typically only report incidents in areas where they have the ability to visually confirm reports through camera imagery, which tends to cover roughly the same roads as their traffic sensors.

The private sector is beginning to fill real-time traffic information coverage gaps through non-infrastructure-based methods. In fact, multiple private data providers offer traffic data on all urban freeways within the top 100+ markets. These data are not of the same resolution as sensor data. They measure only speeds and not volumes, occupancies, or lane-by-lane data. The private-sector data is not always integrated with DOT or metropolitan organizations' central databases, but often it is available to the public for free on Web sites such as Google, Yahoo!, NAVTEQ Traffic, and Airsage.

3.6.1.2 Rural Highways Flow Data Gap

While urban freeways still have significant gaps, a lack of coverage on rural freeways is an even larger gap. Rural highways may have some environmental sensor stations and sporadic camera coverage, but there is typically minimal traffic sensor coverage. In addition, the private-sector data providers have a difficult time with rural freeways because of the low traffic volumes and corresponding sparseness of probe data points on these roads. Rural highways are typically a low priority for the public sector apart from traffic counts and weather applications in specific locations, especially considering the gaps in coverage in urban freeways. Public-sector representatives indicated a desire to provide more data on rural highways and noted increased requests from the public, but it is not financially feasible to do so. Despite the lower priority of local roads, there are certain rural areas that experience heavy seasonal congestion such as ski areas, which warrant traveler information. In fact, traveler information may be more valuable in these areas due to the direct economic impact of this travel and because vacation travelers are less able to anticipate traffic delays or know of alternate routes than urban commuters.

Nonetheless, the private-sector focus continues to be on Interstate routes in and near major metropolitan areas. Private-sector representatives indicated that although they do have capabilities to provide flow and speed information estimates on rural corridors, the demand is not as high as for urban areas. Some within the private sector also indicated expected growth in this market. In addition, past business models for traveler information were centered on FM broadcast areas, which do not typically extend into the rural areas. As a result, there was no basis for ad revenue associated with more densely populated urban areas. Moreover, as the market continues to evolve with satellite and Internet radio and in-vehicle systems, private-sector representatives expect former broadcast mindsets to change and demand will likely increase for rural area corridors.

Some providers are now claiming coverage of inter-city rural highways. However, at this early stage, it is difficult to discern the quality of the data available on low-volume roads. For the private sector, extent of coverage is closely tied to data quality. Since there is no public sector infrastructure (like what is available from freeway management system sensors in the urban areas), data comes from vehicle fleets, which may travel on any road in the country. With a sufficient pool and variety of vehicles within the data set, coverage can be obtained for any road on which these vehicles typically travel. However, the quality of the data depends on the number of data points that can be obtained through moving vehicles. The greater the density of data points, the better the accuracy of the data. Therefore, coverage must be defined not in terms of whether data points are available on a particular segment of roadway, but on whether there are sufficient data points to provide information of sufficient accuracy for the applications for which it is intended. If the application is a color-coded congestion map, the accuracy threshold is lower and the extent of coverage higher. If the application is to post travel times on a DMS, that requires a higher level of accuracy and fewer miles of the available coverage can meet that requirement. For these data sources, the accuracy is location-specific because it depends on the underlying vehicle fleet mix used to derive the data as well as the methods used to combine disparate sources of data, including historical data. These data sources are only beginning to be evaluated as more public-sector agencies purchase this data and perform accuracy studies. Public agencies purchasing this data are also becoming more interested in its underlying sources, whether it is predominately historical or real-time, and how much confidence the provider has in it.

3.6.1.3 Rural Highways Incident Data Gap

Currently, statewide real-time incident reporting coverage (to include rural area Interstates, state routes, and US routes) does not occur. Many states, however, have implemented incident and event reporting systems to capture construction, planned events, and incident information, although most of this is not real time. The accuracy of these systems is directly linked to regional/district as well as statewide resources keeping the information up to date. Agencies indicated the existence of challenges internal to their organizations that made it difficult to capture all of the events, as well as keep information current once it has been entered. Internal resource constraints, particularly regional and district staff needing to be responsible for a broad geographic area, may mean that staff are focused on responding to incidents or hazardous conditions, and are not able to access agency databases to continually update the situational information.

There is recognition that there is available data (through law enforcement/police CAD systems and other agency systems), but there has been a challenge in harnessing that data into a workable database. CAD systems tend to reside with local jurisdictions, and there are many different CAD vendors with no widely adopted standards for sharing information between them in real time. In one metropolitan area, there can be numerous different CAD systems in place, including state police/law enforcement; multiple fire/rescue organizations; multiple local law enforcement agencies; and in some areas, a separate 911 public safety answering point. There are excellent examples of state DOT and state police/law enforcement CAD data sharing, which supports more effective DOT response, as well as provides more comprehensive and timely data to support traveler information systems. In some states, however, there are multiple responder agencies that could take responsibility for incidents on state routes. Furthermore, while some agencies have adopted standards for exchanging data between public safety CAD systems and ATMS software used by DOTs, most CAD systems—and there are many different vendors—do not follow ITS standards voluntarily. While it is becoming more common to integrate platforms, these are site- and vendor-specific integrations. As a result, for a DOT to integrate with CAD systems over a regional area, it must be repeated for each CAD system, and rural areas tend to be the last with which to be integrated.

3.6.1.4 Arterials Flow Data Gap

Partly due to technology limitations and partly due to other factors, real-time traffic information on arterials is scarce. Most arterial detection is tied to localized intersection-based signal operations (or in some cases, corridor signal operations) rather than traveler information. As a consequence, stop-bar or system detectors do not provide information that is directly meaningful to the public. This is partially a technology challenge and partially an institutional challenge. Industry experts indicated that the information available currently for arterials is primarily intersection detection data, but it is used exclusively for signal control; information does not leave the controller. With additional investment in communications, there could be a great deal more data transmitted to TMCs.

The institutional challenge is in how that data is reported. Signal systems are local in nature, and a region may have several different signal systems owned by several different local agencies. There are no widely adopted real-time information exchange standards for signal systems, and there is little demand for such standards by the agencies that deploy signal systems. Some regions, in support of regional initiatives, have requested Synchro files from local signal systems as these file formats have become a de facto standard for signal timing information. Nonetheless, this information is not real-time, and is better suited to support internal operations rather than dissemination of external traveler information to the public. There is potential for probe data to fill these gaps, but market penetrations are not yet sufficient given the variability of travel times between individual vehicles. Infrastructure-based methods that track individual vehicles at high market penetrations hold the most promise for arterial travel times. This addresses the technology challenge, but the institutional challenges remain.

3.6.1.5 Local Roads Incident Data Gap

Because most statewide reporting/data systems that support traveler information have been designed for state corridors and facilities, there are few that have the capability to support arterial information. Some state DOTs have expanded their reporting systems to include arterials on a limited basis, to at least be able to capture incident or planned event information for those routes. The impetus for doing so has been to include this information on 511 phone and Web-based services. Barriers to addressing this include funding and resources.

One key challenge to providing incident data on arterial streets is the same as for rural incident data—decentralized CAD systems. While a DOT may integrate its traffic management software with a state police CAD system, which covers major freeway routes in an urban area, most 911 calls are routed to local dispatch centers with their own CAD systems. As there may be several disparate CAD systems in a region, to cover arterial streets, several different CAD systems need to be integrated.

3.6.1.6 Quantifying Coverage of Public-Sector Systems

In the development of this report, it has become clear that there is a gap in reporting on public-sector data coverage. The Deployment Statistics Database has gaps in its reporting due to a lack of survey response from different agencies. Previous sections of this document show some of the holes in this data for real-time data collection technologies (i.e., sensor and toll tag reader coverage). In addition to flow data, actual incident management coverage is difficult to assess, as is construction. That being said, 511 systems tend to provide broad geographic coverage of construction information, including most state roads in addition to Interstates and freeways. To assess coverage against requirements under the RTSMIP, current methods of assessing data coverage may need to be made more rigorous.

With regard to usage, there is no single measure of system usage for 511 systems, although 511 phone and Web services provide one of the most quantifiable usage source data for public-sector traveler information systems. With a 511 phone system, operating agencies can track the numbers of calls, when calls come in and from where, and the types of information that are being requested. At the national level, the 511 Deployment Coalition is tracking 511 phone usage from each system in operation, and uses this data to develop statistics and monitor usage trends over time. Traveler information Web sites pose different challenges for tracking usage; some systems track Web hits, others track user sessions. Depending on how a Web page is configured, multiple hits can register even though a user has not navigated from a home page. This will over-represent usage when compared to a metric based on user sessions. For systems where contractual payments are tied to usage, it may not be straightforward to achieve standardized definitions of usage.

3.6.1.7 Route-Specific Weather Data Gap

There is a gap in weather data as the information is generic when it is communicated to the public. The collection efforts may be route specific, but 511 and other traveler information services do not typically provide route-specific information to the public. The private sector is trying to use more route-specific weather data in their content.

3.6.2 Transit Coverage Gaps

While many transit agencies are deploying real-time information systems, many transit vehicles are still not equipped with the necessary technologies. Of those agencies that have deployed systems, most have not yet offered fully integrated coverage across their network and within their regional metropolitan area. Key gaps detailed in this section are summarized as follows:

- **AVL Gap** – While the number of transit vehicle is increasing, 62 percent of vehicles are not equipped with the AVL systems necessary to provide real-time vehicle location information.
- **Communications Gap** – Communications infrastructure is often not sufficient to provide real-time information, including networks that are unable to support the amount of data sent by large fleets.
- **Regional Information Gap** – There is a lack of system coverage at the regional level, including providing consolidated real-time information from transit agencies operating within a single region.
- **Real-Time Information Deployment Gap** – Some agencies have deployed AVL to a substantial portion of their transit vehicle, but have yet to leverage AVL information to provide real-time information; other agencies have developed the means to disseminate meaningful static information, but have not implemented real-time applications.

- **Vehicle Capacity Information Gap** – Although some agencies collect passenger count information, no transit agencies are currently sharing the information with their constituents.
- **Modal Information Gap** – Few agencies have developed integrated traveler information between modes, including traffic, transit, and parking. Integrating modal information is necessary to obtain real-time information for an entire end-to-end journey.
- **Integrating Real-Time Information from Multiple Vehicle-Types Gap** – Within transit agencies that operate a variety of types of transit vehicles (light rail, bus, ferry, etc.), there is a lack of integration of real-time information across various vehicle types, preventing customers from receiving end-to-end trip information.

3.6.2.1 AVL Gap

While AVL is becoming more common for transit agencies to own and operate, many agencies are still without AVL, often due to funding limitations or a perceived lack of need by agency managers. Despite this reluctance, many agencies are striving to increase AVL deployments to all transit routes. As a result, the number of transit vehicles with AVL has increased approximately 5 percent per year over the past decade as transit agencies discover the benefits of AVL and conduct periodic technology refreshes that include AVL, and as the public places a higher priority on receiving real-time information. Currently, 62 percent of transit buses across the country are equipped with AVL. However, 58 percent of those AVL-equipped transit buses do not provide real-time information to the public. As additional agencies bring AVL online, peer-to-peer networking could help these agencies learn to use their new data.

3.6.2.2 Communications Gap

While able to deploy AVL across a substantial part of their network, some transit agencies are unable to provide the communications infrastructure to support the collection of AVL data and dissemination of real-time information. The sheer size of some larger agencies' service area and vehicle fleets can prevent them from being able to implement robust real-time information systems. For example, CTA operates approximately 2,000 buses. If the agency were to provide real-time information for the entire fleet, a communications backbone would have to be developed that could handle the vast number of data packets to be sent with enough frequency to enable real-time information. With the limited number of radio frequencies available to transit agencies for their private communications network using land mobile radio systems, real-time information needs are difficult to support. The agency may be able to work around this existing issue using wireless networks including cellular or WiMAX, which each present various implementation challenges. The agency is attempting to develop inexpensive methods to exchange data using the Internet and XML technologies as well.

3.6.2.3 Regional Information Gap

While a desire exists to provide real-time information across regional transit networks, none have currently developed the ability. The New York State Department of Transportation (NYSDOT) developed Trips123, which consolidates static transit information from agencies throughout the state. However, the system is currently unable to provide real-time information via the aggregated sources. Similarly, Los Angeles Metro has contracted to receive information from a large number of transit agency and bus service provider partners in Los Angeles County, although most of the information is primarily related to trip-planning functions and is based on scheduled, not real-time, information. Los Angeles Metro hopes to adopt a phased approach to include additional transit agencies with real-time information via 511 and Websites, but realizes that each agency requires its own integration timeframe. The Chicago Regional Transportation Authority (RTA) has been able to develop a real-time information network with other major transit agencies able to provide real-time information, including CTA, Chicago Metra, and Pace Suburban Bus Service. However, the system has yet to be deployed to the public.

The Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area has developed a similar application in partnership with BART and the San Francisco Municipal Transportation Agency (Muni). Portland TriMet has also developed a robust real-time, next-arrival information network. It has set an aggressive goal to incorporate all transit users into a single system. As compared to US transit agencies, European agencies, including Turin Metro, Italy, and Transport for London, England, have developed more integrated data collaboration and information-sharing tactics between agencies and may serve as a model for US agencies.

There exists a need to increase system coverage within both single transit networks and within the regions. Several agencies indicated that due to rolling deployments or funding restrictions, they have deployed real-time information on only part of their agency's transit network, and have not yet been able to deploy across the entire system. Some transit agencies worry that they will not be able to deploy and support real-time traveler information in favor of continuing to support core transit functions based upon existing funding realities.

Some transit agencies have already begun to deploy regional traveler information systems using static information. One of the most robust is NYSDOT's Trips123, which aggregates static transit information from over 130 operators across the state. While Trips123 customers find the system highly effective, adding real-time information to the system is thus far out of reach for the agency. Chicago RTA has deployed an interagency transit information system with some real-time functionality, but only some routes are available as real-time information. In addition to increasing the amount of real-time information available, Chicago RTA sees a statewide system as a potential next step for the agency. As advanced as the systems offered by NYSDOT and Chicago RTA are, they are still well behind some European systems, including an extensive country-wide system in England that uses a national trip planner.

3.6.2.4 Real-Time Information Deployment Gap

The number of transit vehicles equipped with AVL systems has increased substantially over the past decade, such that agencies responding to the RITA survey report that approximately 62 percent of their transit vehicles were equipped with AVL as of 2007. Many agencies have deployed AVL with a primary focus on operations and fleet management, but they lack the capacity to disseminate real-time transit information to the public. A far greater number of agencies are able to disseminate static information, but not real-time information. Google Transit currently provides static transit information for over 100 metropolitan areas, but is not capable of receiving real-time information from its transit partners, although it has expressed interest in moving in that direction. **Figure 3.14** shows the extensive static coverage that Google Transit has achieved by collecting information from transit agencies. Future technological advancements and data sharing could potentially allow this information to be displayed in real time.

Source: Google Transit

Figure 3.14: Google Transit Coverage Map

3.6.2.5 Vehicle Capacity Information Gap

APCs could be included as part of a real-time information offering. Providing this information for passengers waiting for a transit vehicle, in conjunction with vehicle location, could offer them the ability to improve the comfort of their journey. For example, if a wayside sign was able to indicate to a customer that the next bus is nearly at capacity, but a nearly empty bus would be arriving shortly thereafter, the customer would be more likely to wait for the less crowded bus, improving the riding experience. However, some issues exist in providing APC information to customers. For example, providing customers with APC information may cause situations whereby too many customers decide to wait for emptier buses, which then reach capacity quicker than usual impacting load conditions downstream.

3.6.2.6 Modal Integration Gap

Agencies are also aware of the need to better integrate traveler information between modes, including traffic, transit, and parking information, as information involving each of the modes is often necessary for an end-to-end journey. The integration of such modes should focus on combining alternatives and supplying a singular source for information where each mode has a similar look and feel. Websites are seen as having the most to offer in terms of providing multimodal information to customers. Institutionally, there is often a disconnect between who should tackle this responsibility as real-time traffic information is often the responsibility of state DOTs, while transit information is the responsibility of transit agencies, and parking information may be the responsibility of any number of municipal or private entities. Technical barriers are also common, including conflicts with matching routing algorithms.

3.6.2.7 Integrating Real-Time Information from Multiple Vehicle-Types Gap

The other type of multimodal real-time information is transit information within a single agency, but within multiple vehicle types. Many agencies expressed the desire to incorporate this type of real-time trip planning. Although no systems are currently operational, both Chicago and San Francisco have developed such systems (however, they have not yet gone live). Many agencies do not believe they will be able to afford such expensive, robust systems at this time or in the near future. Since each mode is still generally a public medium, open-source solutions may present methods to make such systems more ubiquitous.

3.6.3 Parking Coverage Gaps

3.6.3.1 Mapping Data Gap

Currently, the parking industry is fragmented in both its operation and sharing of information, especially between public and private operators. Although a handful of private companies have begun the process, there is a substantial gap in the mapping of parking spaces and parking information across metropolitan areas and regions. It is important to map not only the location of parking spaces but also attribute-level information such as whether a space is in a safe neighborhood, its proximity to notable destinations, its security features, and its lighting conditions. This information can be developed by private companies as well as commented on by social networking applications. The public sector can also play a substantial role in developing region-wide and interregional parking information.

3.6.3.2 Standardization Gap

As part of aggregating parking information, processes must be developed to standardize information, including a platform to compile and share data. This includes a standardized set of measures for defining parking facility attributes. This will allow for the integration of data sources that can be consolidated not only to map parking spaces but also for planning, efficiency, and congestion research purposes.

3.6.3.3 Deployment Gap

The deployment of real-time parking information systems has been relatively sparse. While it is only practical to deploy in parking facilities frequently at or near capacity, such as transit station park-and-rides, airports, and central business and entertainment districts, many congested areas lack any parking information. Improvements in communications and sensor technology should make implementation more practical and affordable, allowing for more sector deployments. Even fewer on-street smart parking systems have been deployed, although San Francisco's full-scale implementation of real-time parking information dynamic parking rates via the SFPark program could provide a workable model for other cities to emulate. Additional deployments should focus on expansion toward corridor-wide deployments on transit lines, such as a Caltrans' deployment of smart parking information facilities on the Route 101 corridor in California as part of SafeTrip-21.

Finally, no commercial vehicle smart parking systems have been deployed, although the FMCSA is currently planning several pilot implementations. Successful pilot demonstrations should be followed by a corridor-wide deployment.

3.6.4 Freight Coverage Gaps

3.6.4.1 In-Vehicle Communications Systems Usage Gap

The commoditization of in-vehicle communications systems will allow for more operators to procure real-time information, although the still substantial price may make such devices still out of the reach of carriers and industry sectors operating on thin margins, including drayage operators in ports and intermodal facilities. Many operators, especially older, less technologically advanced truckers, still may not fully understand the benefits of such systems. Additional outreach is required to show them the clear purpose of collecting and disseminating such information and prove to them that the information will not be used against them for enforcement purposes or to help their competitors.

3.6.4.2 Public-Sector Deployment Gap

To improve the real-time information available to commercial vehicles, the public sector needs to deploy additional real-time information applications. This includes both state/region-wide add-ons to existing passenger vehicle 511 systems, as well as increased coverage to traditional freight bottlenecks, including intermodal facilities and border crossings. Few agencies implemented freight-specific add-ons to their 511 systems, although programs at Washington DOT and Florida DOT may serve as a useful model. While several information systems have been deployed to areas with freight bottlenecks, additional freight-congested areas should be identified. While some borders crossings are providing real-time information, there are currently no crossings that have successfully deployed a system that provides truckers with multiple realistic crossing alternatives.

3.6.4.3 Inter-jurisdictional Systems Gap

A substantial gap exists in the ability to establish information-sharing agreements across jurisdictional boundaries. The current funding model places limitations on inter-jurisdictional systems, creating a situation where states do not place a high value on developing partnerships. Some states are naturally more inclined to promote inter-jurisdictional information sharing, such as Maryland, Virginia, and the District of Columbia, because they share a major metropolitan area. An important place to start is encouraging counties that border another state to reach across state lines to neighboring counties. Other regional partnerships are also developing. The I-95 Corridor Coalition, a consortium of east coast transportation agencies, is currently collaborating to build an interstate real-time traveler information network, including freight information. The coalition has successfully designed programs to improve commercial vehicle operations throughout the member states.

3.7 Closing the Gap and Roles for the US DOT

For organizations to provide comprehensive data collection on their networks, alternative solutions to infrastructure-based deployments are required. These solutions may be enabled by advancements in probe-data technology and other private-sector innovations. Additional data sharing needs to occur between organizations that are successfully procuring and integrating probe data from third-party entities.

In the development of this report, it has become evident that there is a gap in reporting on public-sector data coverage and concise reporting on private-sector coverage as well. The ITS Deployment Statistics Database has gaps in its reporting due to a lack of survey response from different agencies, and it does not include any reports from private-sector data entities. The ITS Database could also improve upon its tracking of arterial coverage as well as soliciting responses from smaller metropolitan areas.

For transit applications, it is important to encourage infrastructure deployments to improve fleet tracking data, improve communications alternatives, promote interagency partnerships, and promote clearly planned timeframes for system expansions and improvements. For infrastructure-based improvements, organizations should encourage the deployment of AVL on transit vehicles. This includes working with transit agencies to fund the deployments and to educate agencies on the benefits of deployments including real-time traveler information, systems operations and management, and performance measurement. To support comprehensive data collection on larger fleets and larger geographic areas, agencies must work to deploy WiMAX, cellular, and other communication networks that can be used by transit agencies.

Partnerships that promote interagency deployments and coordination should be promoted. The relationships should focus on multi-modal regional real-time information and involve coordination between transit agencies and the private sector. Additionally, transit agencies should be encouraged to develop comprehensive timetables for real-time deployments including an analysis of limitations or restrictions within existing policies. Lastly, agencies should move toward modal integration of real-time information for interagency coordination to consolidate data between state DOTs (traffic) and transit agencies (transit).

In addition to supporting transit solutions, funding for public WiFi and other open-air communication networks also can support smart parking and other ITS technologies. Expanded data collection for parking spaces should include location attributes such as whether a space is in a safe neighborhood, proximity to notable destinations, security features, and lighting conditions. To provide consistent data, it is important to develop a standardized set of measures for all parking space attributes. The consistency of data will provide for easy integration of data for mapping of parking spaces, but also for planning, efficiency, and congestion research relative to parking. Similar to emerging technologies in traffic data collection, it is important to continue funding pilot deployments, especially for smart parking for commercial vehicles and developing sustainable business models.

With regard to commercial vehicle operations, outreach programs that focus driver education on the benefits of technology are important. Outreach programs should focus on the fact that data collection and the dissemination of real-time information will not be used against drivers for enforcement purposes, nor to benefit competitors—they will be used for the greater good of the industry.. This outreach can use existing organizations and channels through FMCSA and state partners. To improve national freight movement, deployments of real-time information should be expanded at border crossings and intermodal facilities. Lastly, inter-jurisdictional systems for freight should be encouraged.

4 DATA QUALITY

Data quality is the suitability of the data for its intended purpose. It is most commonly assessed by how accurate the data is (i.e., how close the reported data is to the "ground truth"), but it includes other metrics such as timeliness and availability. Clearly, traveler information must be of sufficient quality that users trust the information presented to them enough for it to influence their travel decisions. This section discusses how quality is measured; tools used to measure data quality; and industry perspectives on real-time traveler information data quality across the traffic, transit, parking and freight modes.

4.1 Data Quality Metrics and Parameters

4.1.1 Data Quality Metrics

A white paper entitled, "Defining and Measuring Traffic Data Quality," which was a product of an FHWA Traffic Data Quality Workshop in 2002, proposed a battery of data quality metrics including accuracy, completeness, validity, timeliness, coverage, and accessibility. In addition to identifying metrics, this paper suggests that data quality is only meaningful relative to the intended purpose of the data. While the white paper is specific to the traffic mode, these same metrics apply to other modes as well. In this treatment of the subject for real-time applications, we discuss quality in terms of accuracy, timeliness, and reliability. Other metrics such as validity, completeness, and accessibility relate more to archived data. Each of these measures can be used in a specification, and real-time data should be evaluated against them, with the possible exception of timeliness, which is difficult to measure. We will discuss data validation more in a subsequent section.

4.1.1.1 Accuracy

Accuracy is how close the reported data is to "ground truth," or actual conditions. Accuracy can be measured in many different ways depending on the type of data being considered. The simplest case is regarding a discrete event. One measure of accuracy is the percentage of time events are reported when they actually occur. An inaccurate message may be a missed event (false negative) or a message that persists beyond the life of the actual event (false positive). For non-discrete events, such as traffic congestion data, accuracy may be calculated in different ways including mean error[1], mean absolute error[2], root mean squared error, mean absolute percent error, mean squared error, etc. Ideally, mean error—or bias—can be adjusted for, as it represents a consistent over or underreporting in the data. However, the source of the bias must be considered. For some data sources, errors tend to arise when congestion occurs and it is not captured in the data due to an over-reliance on historical data or a scarcity of real-time data points.

There is no universal consensus on which accuracy measure should be used for different applications. It also matters whether speed or travel time is considered. Speed is typically preferred because it controls for varying segment lengths. Percent error is consistent across

[1] Mean error is actually bias, i.e., the tendency to systematically over or underestimate.
[2] Mean absolute error is a more accurate representation of accuracy since high and low measurements do not cancel each other out.

possible ranges of speed. When using mean speed error or mean absolute speed error, it is important to qualify what range of speed is being considered, and for this reason, it is typically reported in "bins," such as below 30 mph, 30 mph to 50 mph, or greater than 50 mph. An error of 10 mph is much greater if the ground truth speed is 10 mph than if it is 60 mph.

For the I-95 Corridor Coalition INRIX evaluation, data quality was measured on two criteria—average absolute speed error and the speed error bias. The mean absolute speed error was required to be within 10 mph within each of the following ranges of observed speed—below 30 mph, 30 mph to 45 mph, 45 mph to 60 mph, and greater than 60 mph. Data quality requirements were in place whenever the volume was greater than 500 vehicles per hour.

AVL data for bus tracking is evaluated on the basis of its positional accuracy. From a technical standpoint, it is usually very precise, often accurate to within 30 feet of actual vehicle location when properly maintained. In terms of providing accurate information to the public, while the public realizes that information cannot be perfect, information should be 95-percent to 98-percent accurate for riders to trust the information, meaning that information is within an acceptable error the vast majority of the time.

4.1.1.2 Timeliness

Timeliness, also referred to as latency or lag, is the time between when actual conditions occur and when those conditions are reflected in the real-time information source. It may have several components depending on the type of data:

- Aggregation intervals (the time periods over which multiple data points are averaged—i.e., average speeds over 20 seconds or 5 minutes)
- Polling rates, meaning how often data is pulled from an AVL system to estimate transit vehicle location and next arrival
- The time to perform calculations on the data, particularly if multiple data sources—including historical data—are combined to form a single estimate
- Other transmission time and push/pull polling intervals.

Timeliness can be difficult to measure. Acceptable values for real-time information are typically 10 minutes or less. Therefore, measuring timeliness requires a good estimate of when the actual event occurred (e.g., an incident or a traffic slowdown) and what is the comparable point in the real-time information stream.

4.1.1.3 Reliability

Reliability is sometimes also considered "availability," the amount of data available compared to the amount intended to be available. For instance, if some or all of a real-time data stream is down for some period of time, it is less than perfectly reliable. It is typically represented in percentage terms.

Poor reliability can have many causes, especially considering there is a sequence of events that must occur between data collection and dissemination. For example, the Los Angeles County Metropolitan Transit Authority's communications network provides 99-percent radio frequency availability, but that does not mean that every piece of information needed for accurate real-time information is available to the system. Vehicle maintenance issues, operator log-on issues, scheduling errors, and system-related issues can all contribute to the overall reliability of the system. Severe weather can also be detrimental to system performance. Poor reliability can undermine the public's confidence in a real-time information system. However, there is no national standard to determine when data should no longer be displayed due to system unreliability, with each agency determining its own threshold and refresh rates.

4.1.2 Measuring Data Quality

Historically, the quality of traveler information data is not often formally measured and published, especially for the public sector. Rather, most internal assessments have focused on customer satisfaction and feedback. Past research has attempted to define reasonable standards for data quality for different applications, but actual reports on whether these standards are met are rare. The next section will provide more detail on actual levels of data quality observed in recent evaluations.

With the growth in private firms providing traffic data to the public sector, measuring data quality is becoming more important. New innovative data collection techniques rely on combining traffic data from multiple sources to arrive at real-time estimates. Because many of these methods are new and unproven in all conditions, public agencies cannot rely on their familiarity with known technologies (e.g., point sensors) to understand the quality of this data. Therefore, public sector agencies must validate the data they are buying against the levels specified in the contract documents.

Some agencies typically measure the quality of data that is used to communicate traveler information to the public by:

- Validating travel times generated by detection systems (spot-check travel-time runs using GPS to calculate point-to-point times)
- Verifying incident accuracy by field devices and during travel-time runs
- Linking contractor fees for data supplied to the objective measure of quality resulting from private-sector validation efforts
- Considering feedback received from phone and Web-based comments (particularly with 511 systems).

In measuring the accuracy of traffic data, it is important to note that the baseline of "ground truth" against which the data is to be measured must also be measured. This introduces an amount of error in the "ground truth," which must be considered when determining the accuracy of the data provided. The I-95 evaluation used Bluetooth tracking devices to measure segment travel times for ground truth. Because of the variability between individual vehicles and the potential for error in the Bluetooth tracking technology itself, it was decided that the error in the INRIX data be calculated as the distance from the 95-percent confidence band (Standard Error of the Mean or "SEM Band" in the table) of the Bluetooth data rather than the mean (Summary Report for I-95 Corridor Coalition Vehicle Probe Project: Validation of INRIX Data July-September 2008, January 2009).

Another issue revealed by the I-95 evaluation is a need to filter out outlier data points. Even though the data may meet quality standards in aggregate, there were some occurrences of random spikes in the data that could cause potential issues for real-time applications such as posting travel times on DMS (I-95 Corridor Coalition Vehicle Probe Project: Validation of INRIX Data July-September 2008, pg 9).

Recently, Chicago RTA has planned to conduct field testing to develop accuracy specifications. The agency is most concerned with developing an improved projection of the average customer's experience with RTA's real-time applications, including how they perceive information available to them while at a bus stop.

4.2 Current Quality Perspectives

4.2.1 How Accurate Does Real-Time Traveler Information Need to Be?

High-quality data may come at a substantial cost to a real-time information system. Information providers must choose a level of data quality that is in line with the needs of their users.

As per customer demands, transit agencies are working to improve real-time information systems to reflect real-time conditions. Real-time transit information quality is inherently variable, but data must be highly accurate in order to be useful. GPS AVL generally allows for extremely accurate data in real time, usually to within 30 feet of actual vehicle location and seldom more than 100 feet. Most agencies strive for data that is accurate at least 95 percent of the time, often striving for numbers as high as 98 percent.

Many parking vendors and operators assert that actual sensors perform at a very high level of accuracy, often upwards of 95 percent to 99 percent. However, given the large number of vehicles entering and exiting a parking facility, even a small number of errors can accumulate to a large total error. For example, if 1,000 vehicles pass a sensor with 99-percent accuracy and only 990 are scanned, the system would calculate that there are 10 more spaces in the facility than are actually available. Over a period of 10 days, similar readings could increase this error to 100 extra spaces, undermining the system's usefulness. Thus, many facilities recognize the need to do periodic manual resets, often on a daily or weekly basis. Counting spaces manually and testing observed accuracy will also assist operators in developing appropriate baselines and buffers. Portland Airport noted that except for situations involving severe weather, their sensors were accurate enough to provide useful information. However, the operator's systems still required daily recounts, usually discovering that their system is generally off by about 2 percent to 20 percent per day depending on volume and weather. For entry/exit systems, resetting counters will always be necessary in the foreseeable future, but the goal is to decrease the frequency with which resets must be performed. Many facilities are striving for a goal of every 2 weeks by installing more accurate sensors and using existing sensors more efficiently.

Due to the variable size of commercial vehicles, vendors have had much more difficulty developing sensors that were accurate enough to be used for commercial vehicle smart parking deployments. FMCSA is working with two vendors to develop and test more accurate sensors, but both vendors have yet to develop a model that is accurate enough for a pilot implementation.

For traffic data, various thresholds for data quality have been proposed in different contexts. The I-95 Corridor Coalition, for example, required that the data it procured be within 10 mph within various ranges of speed. At 30 mph, the top of the lowest speed range, that equates to a

33-percent error. At 60 mph, the bottom of the highest speed range, that equates to a 17-percent error. A 2004 FHWA Report entitled, *Traffic Data Quality Measurement*, proposed targets of 10-percent to 15-percent root mean squared error, 95-percent reliability (termed "completeness") and "close to real-time" for timeliness, for traveler information applications. The RTSMIP proposed rule includes the real-time information data quality targets listed in **Table 4.1**.

Table 4.1: RTSMIP Real-Time Information Data Quality Targets

Category of Information	Timeliness for Delivery			
	Metropolitan Areas (in minutes)	Non-Metropolitan Areas (in minutes)	Availability (in percent)	Accuracy (in percent)
Construction Activities:				
Implementing or removing lane closures	10	20	90	85
Roadway or lane blocking traffic incident information	10	20	90	85
Roadway weather observation updates	20	20	90	85
Travel time along highway segments	10	NA	90	85

Source: Real-Time System Management Information Program Notice of Proposed Rule Making

Agencies recognize the importance of providing travelers with high-quality data, including data that is perceived as accurate. For real-time traveler information to be effective, travelers must trust the information being provided to them. While the public does not expect information to be perfect, highly accurate data is necessary. It is also imperative to consider that the level of accuracy required will vary depending on who is requesting the information.

Public sector systems vary substantially in the timeliness of the information they are able to provide. 511 systems often require information from highway patrol CAD systems, for which there is often a delay in the timeliness of information, which can substantially impact the flow of information. While not in real time, automatic permitting applications rely on providing timely information. Any road updates including new construction or detours must be integrated into systems to ensure that dynamic routing algorithms are accurate.

All this being said, there is no one standard for accuracy upon which all can agree, even disregarding the different applications for the data collected for real-time traveler information. Furthermore, there is a difference between the accuracy that is desired and the accuracy that is tolerated. Ultimately, however, users are the key measure of quality, both for agency traveler information systems as well as for private-sector data collection and dissemination systems. And, different users will have different quality expectations and thresholds.

4.2.2 How Do Agencies View the Accuracy of Traveler Information?

While expressing a desire to improve accuracy, most transit agencies felt they were already able to provide a level of service such that customers were satisfied.

In terms of the traveling public's perception of data quality, some agencies indicated that the public generally understands that there is an inherent lag time between what their traveler information is based on (e.g., travelers who have just completed their trip) and the actual door-to-door time they experience. As a result, the public is generally forgiving of some inaccuracies in the information they're given. The level of accuracy that is required for the public to make educated decisions is different from region to region, but it may not change between an urban road and a rural road in the same region. Some areas validate data with travel time runs to view it from the user experience, but this gets difficult in a larger urban setting covering more roadways. If the level of accuracy required from the data is set at a high standard, if that standard is not met, the information provided to the traveler is typically still adequate to make an informed decision.

Some agencies noted that states are placing increased emphasis on data quality, although they recognize that more could be done to improve data quality. One important reason for this emphasis is the growth and use of data archives. Agencies are seeing value in archiving their real-time information and actively trying to make it part of their culture and business processes. However, archived data generally needs to be of a higher quality than real-time data to be useful for all of its possible applications, such as transportation planning and performance monitoring. Some agencies suggested that operations staff typically have a lower threshold for data quality for real-time decision making.

Just because the agency is receiving information does not mean that it should be disseminated to the public. Transit data accuracy levels in excess of 95 percent were reported as necessary to provide real-time data to the public. Many agencies implement controls within their system to ensure that the system stops displaying information when quality falls below acceptable accuracy levels. CTA uses a predictive algorithm to determine location that will stop displaying information if they do not receive AVL data from a vehicle for five polling cycles. In such cases, not showing any information is better than showing inaccurate information.

Some traffic incident reporting systems include automatic alarms or time-out functions to be able to alert staff of information that might be outdated, which helps them to monitor the quality of information being sent out through traveler information systems. Some agencies have established manual processes for reviewing and verifying information before it gets released to the public (such as an incident or closure). Although this adds to the resources and human intervention needed to operate these systems, agencies indicated it made for a better quality product.

4.2.3 What Is the Prevailing Quality of Traveler Information?

The prevailing quality of traveler information varies greatly by location, source, and type. This section presents some findings that provide insight into the prevailing quality of traveler information for the various modes in this study.

4.2.3.1 Observed Accuracy

Perhaps one of the most exhaustive evaluations of private sector traffic data quality has been the I-95 Corridor Coalition INRIX data program. This evaluation of the probe data provided by INRIX to the I-95 Corridor Coalition presented the industry with a number of lessons learned for probe data procurements. In addition, it revealed a great deal of information regarding the data quality that can be expected from private-sector providers using nationwide probe data, although this evaluation was specific to one firm (January 2009).

Generally, the INRIX data was within 5 to 12 mph of the mean of the "ground truth" data, which was collected using Bluetooth readers. While this was the best possible method of collecting ground truth for the number of segments in the study, it was an estimate itself and introduced its own uncertainty. As a result, the INRIX data was validated against the SEM band, which was equivalent to the 95-percent confidence interval of the Bluetooth data. Using this as a comparison, the INRIX data fell within 2 to 10 mph of the SEM band. Lower levels of accuracy were measured at low speeds, while traffic traveling closer to free-flow speeds was more accurate. It must be noted that this was one evaluation, albeit over many miles in four states, of one provider of real-time traffic information. It is not possible to make broad generalizations of the data quality of other providers of similar data in other locations. I-95 in the study area carries a great deal of traffic, including truck traffic. Other locations with lower volumes—especially truck volumes, which are more likely to be data probes—may not see the same results, even for the same data provider.

While probe data has been shown to be viable for freeways, arterial travel times from private-sector probe-based systems are not considered accurate enough for traveler information. Many factors are at play including not enough data points and high variability introduced by signals and driveway turning movements.

In addition to the I-95 Corridor evaluation, several cell-phone probe evaluations have been completed in the last several years. Cell-phone triangulation-based models, which were common before GPS was prevalent, have faced challenges. Companies typically enter into partnerships with one cell phone provider and are then dependent on data points that are anonymously tracked to derive segment speeds from data points. This creates a dependence on "hand-off data," rather than making a direct determination on vehicle location. Performance (and data quality) appears to degrade for complex networks, which could be attributed to the hand-off strategy versus a more precise location strategy.

Additional evaluations of private-sector data in recent years have revealed the following (note that the market continues to change rapidly, and new products and technologies will warrant continued evaluation of vendor offerings):

- Cell phone data is viable in free-flow conditions, but is not accurate in congested conditions.
- Probe-based data is generally sufficient for congestion maps (red, yellow, green) but less suitable for travel times or operations purposes.

Another evaluation of two private-sector providers found the overall mean error of the two firms' data to be 19.4 percent and 22.9 percent, respectively. However, errors for both were significantly higher during congested conditions than uncongested conditions, suggesting that historical data was relied upon heavily to fill in gaps in real-time data. The result is several congested periods were inaccurately reported as free flow.

Of the few real-time freight information systems today, a small number have developed robust measures of data quality, including tracking observed accuracy. Public-sector staff often have a more general understanding of the accuracy of their systems, but are unaware of more in-depth measures of data quality. Often data quality is judged simply as feedback from users, such as comparing estimated border wait times to observed ground truth. Many of these border wait-time estimates are considered relatively accurate the majority of the time, even though specific metrics do not exist. Certain areas are particularly lacking in high-quality data, including areas where situational awareness is limited, such as more rural areas where there is no TMC.

The accuracy of in-cab communications systems varies based on the type of information being provided. The trucking industry considers its systems highly accurate in their ability to track vehicle location—often within 5 minutes of real time. GPS as part of a communication system is usually accurate to within 30 feet of a vehicle's actual location. However, weather and routing information is often not as accurate as required. For example, weather information often cannot be disseminated to drivers to forecast conditions for their expected locations in several hours or how the conditions will specifically affect commercial vehicles. The accuracy of routing is often limited in areas with current construction or in metropolitan areas with complicated or changing roads. The dynamic routing provided by the system is accurate enough to be useful, although it still requires improvement. Data quality is expected to improve as more companies deploy these systems and share information, particularly larger carriers.

Table 4.2 and **Table 4.3** show observed data quality metrics in the transit and freight sectors.

Table 4.2: Observed Data Quality Metrics from Sample Transit Agencies

Data Quality	Denver RTD, Colorado		King County Metro, Washington		TriMet, Portland, Oregon	
	Desired	Observed	Desired	Observed	Desired	Observed
Accuracy	98%	~70 - 75%	95%	95%	99%	Unknown
Vehicle Location Update Rate (polling rate)	30 seconds	2 minutes	60 seconds	2 - 3 minutes	30 seconds	1.5 - 2 minutes
Timeliness (refresh of information for traveler displays)	15 seconds	15 seconds	15 seconds	15 seconds	20 seconds	20 seconds
Reliability	99% of time	90% of time	99% of time	95% of time	99% of time	99% of time

Table 4.3: Typical GPS Telematics Data Quality

Accuracy	Within ~30 feet
Timeliness	Polling ~every 5 minutes
Reliability	~98 percent

4.2.3.2 Observed Timeliness

Evaluations of private-sector data in recent years have revealed that latencies of 5 to 10 minutes are typical of probe-based systems (note that the market continues to change rapidly, and new products and technologies will warrant continued evaluation of vendor offerings).

For transit agencies, observed polling rates ranged from as infrequent as every 5 minutes to as frequent as every 30 seconds. More frequent polling allows for improved accuracy. TriMet currently polls vehicles every 90 seconds but is working to increase the polling rate to every 30 seconds to improve customer information and dispatch accuracy. CTA buses report every 2 minutes, with count-downs on their electronic displays updated every 90 seconds to minimize errors. CTA has also implemented a system to cease the display of information when necessary if bad information is being provided. The CTA predictive algorithm will stop displaying information if an AVL unit fails to provide information for 5 polling cycles. Travelers usually prefer frequent updates so that they can match transit schedules to their own in real time.

Real-time parking information systems vary in the timeliness of the information being provided to parking operators and customers. Deployed sensors relay information to a centralized server nearly instantly, including space-by-space counters, which poll for vehicle presence every few seconds. However, there is a larger disparity in terms of how often information is relayed to the public. More advanced systems update Websites and DMS every 1 to 5 minutes. However, simpler systems may not update automatically, requiring an operator to update manually, which is only done every half-hour or less. Although these less frequent updates often are adequate for most patrons, information must be updated more frequently for a system to truly be in real time and fully optimize the use of its sensors. Ideally, real-time parking information updates should be provided at least every 15 minutes to stay relevant for users.

Border agents on the northern border strive to update information for the public every 5 minutes, although this is not always possible. However, border crossing information does not always need to be updated so frequently. For example, border agents on the southern border only collect border wait time information for their own purposes and only require updates every 30 minutes. Receiving information any more frequently would not be helpful to agents as they are unable to update their staffing any faster. In this way, it is important to consider the needs of individual user groups when assessing the required timeliness of real-time information.

Another example is the Otay Mesa Border Crossing in Texas, where CBP only wants refresh rates in 30-minute intervals. Faster refreshes would not be useful because CBP cannot change its staffing any faster. However, truckers might want new information in more frequent intervals, requiring a different communications medium with different refresh rates. Real-time systems must establish data quality through contractual arrangements tied to incentives. Technologies must be verifiable and match system needs.

4.2.3.3 Observed Reliability

Reliability measures the robustness of the system and the performance of its real-time information components over time. Most transit agencies reported that reliability was extremely high, often in excess of 99 percent. AVL systems have high reliability, especially when only simple location information is being detected. Requiring a robust suite of information technology equipment on vehicles can create complex systems that can require a substantial amount of onboard, data, communications, and network maintenance to remain reliable. Under optimal conditions, smart parking systems are highly reliable, with many systems capable of exceeding 99-percent data completeness and reliability. However, extreme conditions can reduce sensor reliability substantially, including adverse weather conditions such as snow or heavy rain or customer overflows at facility gates where cars cannot be distinguished from each other.

4.3 Trends

While data quality has improved in recent years, additional improvements are necessary. Data quality can be determined in a variety of ways. For example, a transit agency that uses WiFi or cellular for its communications network can provide coverage for 99-percent of a geographic area, but that does not equate to all information being 99-percent accurate, available, and reliable due to vehicle maintenance issues, operator log-on issues, scheduling errors, and system-related issues that all contribute to the overall quality of the data being reported by the AVL system. Agencies must have pro-active onboard equipment maintenance programs, active dispatcher management of operator log-on and service restoration updates, and accurate route and schedule development processes in place to overcome these issues.

The growth in private sector data is a key component of trends in real-time traffic data quality. Public sector data, which is primarily based on inductive loops, radar, acoustic, or magnetometer, has been consistent in quality for some time. The key variable with infrastructure-based data is how well the sensors are maintained. However, where sensors are deployed and well maintained, traffic data is generally good according to public sector representatives who participated in this study. The data quality of the private sector is very different, however. Instead of having good quality in localized areas and no data elsewhere, probe data sources can boast wide area coverage, but there is a continuum of quality over that coverage that varies by factors related to from where the data points are coming. The few evaluations cited above provide a glimpse into that data quality, but as new sources of data become available, it may change quickly. It is likely that the probe data quality will only improve over time and because it can scale to a very broad coverage area, it may one day take over as the predominant source of real-time traveler information. Note that there will always be applications that rely on volumes and other data that only point sensors can provide.

4.4 Gaps in Data Quality

4.4.1 Traffic Data Quality Gaps

Another significant area where gaps exist is data quality. This includes areas where data quality must improve as well as gaps in understanding of the levels of data quality that are required for different applications and how to measure it.

4.4.1.1 Factors that Limit Accuracy

It is only possible to have complete situational awareness at the moment the information arrives. Situations change, diminishing accuracy. Additional factors such as construction on local roads may also affect accuracy. Lack of communications may also limit situational awareness, including law enforcement agencies that do not coordinate information to provide robust situational awareness for the entire region. When providing information related to road closures and forecasting, information accuracy often depends on a human-made decision. For example, if flooding is expected to shut down a major interstate, an individual in a TMC or emergency operations center (EOC) must determine the proper information to provide to travelers, including whether the road is expected to be shut down and if so when it is expected to close and when it is expected to reopen. While traffic operations managers may desire completely accurate information, providing actionable forecasts often requires information that is less than perfectly accurate.

4.4.1.2 Data Quality Standards Gap

The quality of traveler information data is not often formally measured and published. Rather, most internal assessments focus on customer satisfaction and feedback. And, one person's assessment of data quality is often different from another's. Past research has attempted to define reasonable standards for data quality for different applications, but actual reports on whether these standards are met are rare. Implementation of the RTIP established under SAFETEA-LU Section 1201 may help to set national benchmarks for data quality for real-time information as it defines targets for timeliness, percent availability, and percent accuracy. In addition, the RTIP proposes to establish a standard data format to exchange traffic and travel conditions on major highways among state and local government systems and the traveling public. This being said, adoption of the standards referenced by the RTSMIP (IEEE 1512, TMDD, SAE J2354) are not yet widespread.

For public sector deployments, there is rarely an impetus to measure data quality unless it is part of a federal showcase where a formal evaluation is required. Even then, many of these evaluations focus on lessons learned rather than quantitative numbers.

4.4.1.3 Probe-based Data Validation Methods Gap

With the growth in private firms providing data to the public sector, measuring data quality is becoming more important. New innovative data collection techniques rely on combining traffic data from multiple sources in order to arrive at real-time estimates. Because many of these methods are new and unproven in all conditions, public agencies cannot rely on their familiarity with known technologies (e.g., point sensors) to understand the quality of probe-based data they procure from the private sector. Therefore, there is an inherent requirement that public sector agencies validate the data they are buying against the levels specified in the contract documents.

The most comprehensive evaluation of private sector data to date is underway by the I-95 Corridor Coalition. This has become a model to follow due to its rigor, although many other such evaluations preceded it. These prior evaluations of private sector data used a diversity of metrics including binary comparisons (e.g., speed ranges against a red-yellow-green map), absolute error, percent error, errors grouped by speed ranges, and data lag. Furthermore, the I-95 evaluation identified some unforeseen issues with validating data quality. First, in measuring the accuracy of traffic data, it is important to note that the baseline of "ground truth" against which the data is to be measured must also be measured. This introduces an amount of error in the ground truth estimate that must be considered when determining the accuracy of the data provided. The I-95 evaluation used Bluetooth tracking devices to measure segment travel times for ground truth. Second, there may be a need to filter out outlier data points. Even though the data may meet quality standards in aggregate, there may be periodic outlier data points that could present complications for certain real-time applications such as posting travel times on DMS. Finally, data latency or "lag" is an important measure of quality, but it is difficult to measure. Lag is defined as the difference in time between when a traffic event takes place (e.g., a slow-down caused by an incident or a bottleneck) and when that event is reflected in the data.

It was determined as part of the I-95 evaluation that this was too difficult to measure, and it was discarded—at least temporarily—as an evaluation metric.

4.4.1.4 Probe-based Data Accuracy Gap

Evaluations of private sector data in recent years have revealed the following observations (note that the market continues to change rapidly and new products and technologies will warrant continued evaluation of vendor offerings):

- Cell phone data is viable in free-flow conditions, but is not accurate in congested conditions.
- Latencies of 5 to 10 minutes are typical of probe-based systems.
- Arterial travel times from these systems are not reliable. Many factors are at play including not enough data points and high variability introduced by signals and driveway turning movements.
- Probe-based data is generally sufficient for congestion maps (red, yellow, green) but less suitable for travel times or operations purposes.

4.4.1.5 Sensor Maintenance Gap

Public agencies face challenges in maintaining their existing sensor deployments. With limited funds, it is often difficult to fund maintenance even if capital dollars are available for new deployments. In California, according to the Caltrans PeMS, between 60 percent and 80 percent of Caltrans sensors are functioning at any given time. This is typical, if not good, for the industry. Further, there is often little incentive to maintain sensors to a high level of accuracy unless they support a high-profile application such as ramp metering. In practice, however, real-time traffic information is typically not important enough an application to drive sensor maintenance, which negatively impacts traffic data, signifying a gap in quality.

4.4.1.6 Travel Times Forecasting Gap

While the traveler information industry is striving toward full coverage of accurate real-time data, what travelers ultimately desire is a forecast of the traffic conditions that they will face, rather than what was measured in the immediate past. Even for travelers en route, conditions may change over the course of a long trip and current measurements may not accurately reflect that. For travelers accessing pre-trip information, there is a lag between when that information is accessed and when the trip is made. Multiple private sector data providers reported that they are working toward providing travel time predictions, although they are not currently offering them. One study participant compared the state of traffic information now to the way weather reports were many years ago. When weather prediction models were less reliable than they are today, weather reports focused on what the day's weather *was*. As forecasting models have become more accurate, they now focus on the expected weather over the next several days. This evolution may take place similarly in the traveler information industry as the quality of the data improves and prediction models develop.

4.4.1.7 Real-Time Construction Information Gap

While construction information is valuable information for travelers such as recorded 511 construction messages, these systems often fall short of providing real-time information on the impacts of the construction. Construction information advisories will typically indicate the nature of the construction activity, the dates that it will be in effect, the times of day that lanes will be closed, and the types of delays one might expect, but they not typically inform drivers of current conditions. Furthermore, there are times when contractors will open or close a lane at times other that what was previously scheduled. While that may not be of consequence in rural areas, in urban areas, a contractor that is late getting out of the road in time for the morning rush, despite a contractual requirement to do so, may cause additional unplanned delays.

Within a DOT, there is likely someone who knows the status of a construction lane closure at any time, either as part of a permitting process or as part of project management. Ensuring real-time lane status information is available in a common database in real-time is feasible if the appropriate business processes are in place. While other types of events such as incidents or congestion must be discovered by a DOT, the DOT or other maintaining agency should be the originator of real-time construction information.

In addition, for 511 construction systems free-form text is entered as in the comments field, which is common for lane closure reporting systems. While it may be more readable for someone calling the 511 system or viewing the Web page, it is not usable by third parties who may wish to aggregate construction information into their travel time estimates, vehicle routing algorithms, or a common nationwide real-time incident data stream. As private-sector traffic information providers are trending toward nationwide coverage in line with their changing customer base, they require an ability to scale their data aggregation methods to the entire country. Common formats across jurisdictions facilitate higher-quality nationwide information from these providers, which benefits the industry.

4.4.1.8 Barriers or Challenges to Improved Data Quality

Industry practitioners and experts indicated the following barriers or challenges to improved quality of real-time traffic data:

- A significant implication of poor or inadequate data is trust.
- Available funding limits the geographic scope to which agencies can deploy and maintain sensor-based networks
- Equipment reliability is a significant barrier to higher quality data for agency sensor networks. Non-functioning equipment and equipment reliability are a concern in terms of how they impact quality (rarely 100 percent of field equipment is working all of the time). To date, there is little incentive to keep equipment functioning and operating, and there is a need for more financial implications for not maintaining sensor networks.
- Quality has been identified as something that could be managed.
- Outsourcing data is viewed by some as a potential risk. It may be difficult for agencies to trust that the data is of a certain quality that a DOT would be comfortable in accepting. There are also some unknowns in terms of how that data could be used. Previous partnerships had very strict limitations on what could be done with the data.
- While most DOTs/agencies share their sensor data with the private sector, there are some agencies that do not make this information available at no cost.
- It may be challenging to validate data coming in from the private sector, when there are a lot of unknowns about the sources of that data (particularly, the number of probes). There is strong interest in the probe data validation efforts underway through SafeTrip and the I-95 Corridor projects.

- There could potentially be a correlation between data quality and measuring performance, which could drive the need for agencies to verify and validate the data they receive. If there was more of a focus on using the data for other purposes beyond real-time operations, the data quality would improve. If operators were interested in using the data for performance measures, for instance, they would be more diligent about maintaining high data quality.

4.4.2 Transit Data Quality Gaps

4.4.2.1 Data Standards Gap

Presently, many inconsistencies exist across the real-time information provided by transit operators. While developing integrated systems for regional systems, there is presently no national data standard for determining the definition of "a route," as routes often converge and split with each other. There is also no national standard to quantify what is an acceptable accuracy for real-time information. To effectively share data and integrate real-time timetables, a common data structure must be developed so that each agency's data structure can be mapped to a common data file. There is also a lack of standardized information in determining and sharing incident reports. Developing systems that use the same structure would allow for increased interoperability and improved real-time incident reporting to travelers.

4.4.2.2 Polling Rates Gap

Most agencies deployed systems over the last 10 years with an emphasis on command and control and currently only poll vehicles every several minutes, commonly every 3 to 5 minutes. Increasing polling frequency would greatly improve data quality to support accurate real-time information, although difficulties exist in achieving more frequent rates. Increasing the polling rate requires an increase in the amount of data transferred over wireless communications networks, which is limited by the amount of bandwidth available on local networks. Large fleets with communications networks at or near capacity will have difficulty increasing their polling rate, as the large number of AVL devices interfacing on the network may cause the network to run over-capacity. Likewise, expanding network capacity can be very costly to transit operators. One potential alternative for agencies is to use variable rate polling, which polls vehicles' variable frequencies depending on proximity to the next stop, traffic conditions, and additional factors. System designs must consider the available location polling rate in order to avoid unintentionally misleading the public about the accuracy of information provided by the predictive algorithms.

4.4.2.3 Algorithms Gap

Many transit scheduling and real-time algorithms are unable to accommodate for the range of operational situations that occur in transit fixed-route operations. For example, "short-turning" a vehicle so that it does not complete its route as intended but instead turns around to focus on the highest traffic area of its route must be documented and shared with external systems in real-time if the predictive algorithm is to act upon this change in the schedule. Such operations can cause erroneous data, frustrating customers when the appropriate actions are not taken by the agency. This data accountability is a new concept for transit to address as they commit to publicly providing better real-time traveler information. However, data accuracy does limit the use of some real-time applications. For example, TriMet has developed a real-time bus mapper, but only uses it internally because accuracy limitations would likely result in the public misinterpreting the information.

4.4.3 Parking Data Quality Gaps

4.4.3.1 Dataset Size Gap

Although improved sensors are increasing data quality, improvements still need to be made to provide parking managers with the capability for better decision making. Current sensors and algorithms are unable to compensate for outliers and extreme circumstances in parking operations, such as special events, which cause erroneous information. One potential solution for this issue is to build larger datasets. This will allow parking managers to better understand driver and operator actions, create more robust algorithms, and improve forecasting and operations. Larger datasets will also allow parking managers a more holistic view of parking within a region, including how parking in one neighborhood affects another.

4.4.3.2 Standards Gap

Due to the fragmented nature of the parking industry, real-time parking information systems lack uniform standards. To aggregate parking information and pass it along to customers, there needs to be more standardized messages in terms of communicating parking availability and attributes. Many systems use similar green, yellow, and red indicators to display parking availability, but there is no standardization for what each of the colors mean from one facility to another.

Smart parking also requires more defined data standards. For example, facility attributes can have a substantial impact on customers' parking decisions, including entry/exit points, security features, lighting conditions, and distances to notable landmarks. Similarly, no standardized system for how to measure each of these attributes has been implemented. Those standards that do presently exist as part of the national ITS architecture are outdated or do not promote increased information sharing. In addition, a national standard created organically through collaboration of the public and private sectors is needed to allow more thorough evaluations for comparing procurement methodologies for potential implementers, improved understanding of parking effects for policymakers, and more direct comparison of facility amenities for customers.

4.4.4 Freight Data Quality Gaps

4.4.4.1 Public-Sector-Related Gaps

While many public sector agencies report reasonably accurate systems, very few keep robust data quality metrics for freight information systems. It is the responsibility of the public sector to develop and promote useful freight information data standards to facilitate information flow between entities, including sharing non-proprietary information among public and private sector entities, as well as setting data quality standards.

4.4.4.2 Private-Sector-Related Gaps

Many commercial vehicles are without in-vehicle telematics or have outdated systems. The newest systems have greater ability to dynamically reroute based on changing conditions as well as track actual drivers' hours expended and hours available. Since congestion is getting worse, it is of growing importance to provide high-quality information to improve decision making.

4.5 Closing the Gap and Roles for the US DOT

All modes of real-time information can benefit from the establishment of standards for collected data and performance measures to evaluate the accuracy and effectiveness of the use. Agencies should benefit from a national knowledge base concerning data quality, but maintain the ability to develop performance measures that address organizational goals. The US DOT should continue efforts to support research, support the development of white papers, promote partnerships like the 511 Coalition, and sponsor meetings and workshops for information dissemination and networking purposes. Detailed studies should be conducted to analyze and document the level of data quality that real-time information systems are able to provide and should provide. Polling rates for field devices should be evaluated to determine the optimal interval for information timeliness and accuracy.

The US DOT could improve real-time traveler information by increasing real-time data exchange and setting traveler information standards. To date, many standards are not as widely used as they should be and this hinders the ability to widely share and use information, which improves data quality. Making standards freely available would support adoption. In the larger IT industry, it is recognized that one must cater to developers if one desires them to write applications for a given platform. In an attempt to fill this void, unofficial versions of standards circulate that may have errors or may be outdated, undermining the use of the standards. Secondly, the US DOT could push for existing standards to be completed to eliminate ambiguities. This may result in less-than-perfect results, but the alternative is vague or ambiguous standards that are not in fact standard. Thirdly, a more open forum should be established for sharing lessons learned as well as a more open process for standards development. Finally, there needs to be clear test procedures or validation processes so that accurate implementations of the standards can be confirmed.

5 USES OF REAL-TIME DATA

Real-time traveler information has a variety of internal and external applications. This information can provide users with situational awareness of the transportation network and can be provided through a variety of mediums, depending on who is receiving the information. Providing information to system users allows customers to make better decisions regarding the scheduling and routing of their trips to increase safety and reduce stress. In addition to providing users with information, the data stemming from real-time information applications can be utilized internally as well and allow agencies to improve their systems operations and performance.

5.1 Traveler Information

While travelers still require static information, they also appreciate real-time information when it is available to them for both familiar and unfamiliar trips. Both the public and private sectors strive toward the development of a ubiquitous real-time exchange of information with customers and a seamless integration of services. Effective real-time traffic information enables drivers to adjust their trip decisions to avoid congestion or at least to reduce the uncertainty of total trip time and estimate time of arrival. While traveler information may not necessarily reduce travel time, it can still enable users to account for day-to-day variability, hence increasing arrival time reliability. Users generally appreciate having traveler information, regardless of whether they can make any change to their trip behavior, due to reduced stress from knowing what future conditions will be. Across the four market segments, the increased situational awareness provided by real-time traveler information improves efficiency and reduces uncertainty. For all types of information, increased accuracy increases frequency and dependency of use.

The traveler information industry is also interested in using real-time traveler information applications to influence the decisions that travelers make including mode choice. Both the public and private sectors are interested in working with end-users to learn how real-time applications are used. The entire suite of real-time information can affect customer's decisions on what trips to take and what mode of travel to use. For example, when real-time parking information is available for a facility at or near a transit station, the knowledge of parking availability has been shown to be a powerful incentive to encourage drivers to switch to transit. Further encouragement can be added when the parking availability information is coupled with real-time transit information or static parking information such as attribute level data regarding parking spaces including its proximity to their final destination, pricing, and security.

Real-time transit traveler information is set apart in its ability to not only provide current overall system operational information, but also individual vehicle location information. This can include information related to service disruptions, vehicle arrival times, and even vehicle capacities. This information can serve as beneficial value-added service for both transit-dependent and transit discretionary riders. Approximately 60 percent of transit riders are transit dependent, meaning that while they will likely find real-time transit traveler information systems convenient, additional services will not likely increase their ridership. Conversely, 40 percent of transit customers are discretionary riders, meaning that improved services could increase the frequency of their ridership. For real-time traveler information services to increase transit ridership, discretionary travelers must trust the information being provided to them and find that it improves their transit experience. Transit ridership can further be increased by informing non-transit riders that high-quality and convenient transit services exist.

Like passenger vehicles, commercial vehicles often require real-time traveler information that provides situational awareness of local traffic and weather conditions. Such information can be used to optimize supply chains and freight movements, impacting the productivity and safety of commercial vehicles. While all types of vehicles are concerns with traffic, weather, routing, and parking, commercial vehicles often require information specific to their operational parameters. For example, instead of the local weather updates that most passenger vehicles would be interested in, trucks on long-haul routes might be interested in predicted weather conditions several hundred miles down the road. This information is of particular importance to commercial drivers because unlike automobile drivers, commercial drivers have a restricted number of hours of service that limit their driving time regardless of delays. Since drivers are often paid by the mile, they strive to efficiently use their hours of service and may decide to shut down in heavily congested traffic or severe weather. The decision to shut down is often difficult for many truckers, so any real-time or forecasted information that may improve their decision-making process is appreciated.

Some types of real-time information, particularly parking and freight information, require a certain level of predictive information. To improve parking decision making, customers need to receive parking information either before they leave for their destination or en route. Customers inquiring about pre-trip information are trying to make a decision on parking location well ahead of their arrival at the parking facility, meaning they seek some type of predictive information related to the location of available parking spaces upon arrival. Real-time, historical, and discrete event information can be combined via unique algorithms to provide a prediction of parking availability in the near future, particularly within the next 5 to 15 minutes. While some operators have developed the ability to forecast information, such algorithms are still in the development stage. Forecasting information is often impossible or inaccurate given limited data or inadequate algorithms. Additionally, developing an algorithm to forecast information is often an expensive and arduous undertaking, requiring each parking facility to examine its own historical trends and other factors that might impact availability. Furthermore, some private operators may not want to tell every patron that their facility is full, such as shopping malls or private truck parking facilities.

Long-haul commercial vehicles may also require a certain degree of predictive information. Due to the nature of their trips, having information for local conditions several hours down the road is optimal for route and schedule planning. For example, if long-haul truckers know that congestion or weather conditions are likely to be unfavorable on their current routes, they may decide to reroute or take a break earlier than initially anticipated.

5.1.1 Demographic Considerations for Information Dissemination

While all travelers appreciate real-time information, public sector information providers must realize that the various customer demographics necessitate different information requirements and preferences for accessing information. Many older users still prefer to access information through 511 services, while Web-based and wireless applications are more popular with younger users. When deploying a real-time transit information system, Portland TriMet initially planned to deploy numerous DMS at all of its transit stations, but decided to only focus on light rail locations because the majority of riders had cell phones and would just dial in requests for information. Generally, riders tend to use a small number of stops; therefore, accessing and memorizing bus-stop numbers for 511 systems is typical. Despite the convenience that real-time information systems are able to provide, many transit riders are not even aware of the entire suite of real-time information that transit agencies make available to them. Others riders are not able to acquire information because they do not possess the technology necessary to access it such as a Web-enabled computer or a cell phone. Furthermore, agencies must consider information dissemination requirements for passengers with disabilities, including visually impaired riders unable to see DMS.

5.1.2 Public Sector/Agency Operated Systems

5.1.2.1 Dissemination Mediums

A variety of mediums exist to provide real-time traveler information. While each is at various stages of development, providing information through as many mediums as possible promotes information dissemination to the widest group of customers. **Table 5.1** shows the potential methods that public agencies can use to provide real-time traveler information.

Table 5.1: Public Sector Real-Time Information Dissemination Methods

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
DMS	All	Medium	• Provide high-quality info at site • High profile	• Expensive • Not useful for advanced planning • Americans with Disabilities Act (ADA) issues • May require permits
Website	All	High	• Useful for pre-trip planning • Low expense • Highly customizable • Aggregate information from other sites	• Not accessible on site • Users may not have access on both ends of journey
Email Alerts	All	Low	• Low expense • Highly customizable	• Only available to limited number of customers that sign up for service

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
Smartphones / wireless	All	Low	• Accessible pre-trip and on-site • Third parties develop applications	• Only available to limited number of customers • Limited understanding of how to utilize
511	All	High	• Can be customizable and interactive • Highly accessible • Popular with older, less tech-savvy users	• User friendly interface can be difficult to develop, especially in multiple languages • Requires active promotion of transit agencies • May require memorization of commonly used routes
In-vehicle telematics (including PNDs)	Traffic, Parking, Freight	Low	• Expanding segment • Multimodal information	• Demonstrated, not widely deployed • Marketing and software integration difficulties
Radio	All	Low	• Low expense • Accessible pre-trip and on site • Popular with older, less tech-savvy users • Service provided by third parties	• Limited information available at all times
TV	Traffic, Transit	Low	• Service provided by third parties	• Not accessible on site • Users may not have access on both ends of journey
Automated Service Announcements (ASA)	Transit	High	• Provides peace of mind for riders • Transfers/ connection information	• Provides little real-time choice

Dissemination Medium	Applicable Modes	Frequency of Customer Use	Advantages	Disadvantages
Kiosks and Display Signs	Transit	Medium	• Popular with older, less tech-savvy, and ADA users • Provides peace of mind for riders • Transfers/ connection information	• Only available in terminal or at stop

5.1.2.2 Considerations for Dissemination

System designs must be sensitive to include accessibility options to meet Americans with Disabilities Act (ADA) regulations and lower-income rider needs that may not have access to all methods of information dissemination. Agencies are working with these communities to best meet their needs in providing appropriate alternative solutions. To prevent adversely affecting these communities and facing potential lawsuits, agencies must involve these communities early in the planning process. They must think carefully about how information is disseminated to the traveler population, ensuring that the needs and preferences of user groups are met, balancing various types of information. DMS, while extremely useful for many situations, are not a panacea for all locations due to cost, potential for vandalism, and lack of need. Website access is often not readily available to customers and to many travelers at both ends of their journey. Smartphones increase connectivity but are not widely implemented yet. Furthermore, not all applications are compatible with each other given the many different Smartphone, Smartphone operating systems, and platform-dependent applications. Smartphones are also often only a viable option for technologically adept customers desiring information immediately. Another consideration for implementation is the involvement of the ADA community, as required by law. Accommodations must be made for riders with visual or auditory impairments. While practical and financial reasons prevent providing accommodation for every disability at every transit station, transit agencies must involve the ADA community early on in the implementation of a real-time system to ensure the development of a holistically compliant system that addresses the community's needs through technology and pragmatism. Agencies must be conscientious regarding what real-time information disadvantaged communities require.

Information must be presented to users in an intuitive way so they can quickly assess it and make a decision. For example, highway travel times can display the time travel to a specific location, but including the distance along with the travel time can improve the percentage of travelers reading the message and their ability to make an informed decision. For travelers receiving parking information, telling a driver that there are 30 spaces available means little if the user is unfamiliar with the context of the facility. Instead, more broad categories should be used to explain parking conditions. For example, a green indicator that means plenty of parking is available, a yellow indicator meaning that parking is limited, and a red indicator meaning that parking is currently unavailable can be more easily processed.

Although a robust system has yet to be deployed, truck parking deployments use many of the same dissemination methods as passenger vehicles, including DMS and the Internet. To receive forecasts, truckers can tune to HAR. Ideally, parking facilities will be networked so drivers can easily be diverted to the next nearest parking space. Even though numerous drivers use them regularly, NTSB recommends that systems do not encourage drivers to use cell phones while in motion.

5.1.2.3 Usage Statistics for Public Sector Systems

One state DOT indicated that it sees much higher market penetration from its traditional traveler information systems (namely its Web site, which averages 15,000,000 monthly hits versus 5,000 followers to its Twitter site). Despite the higher percentage of use, it has received positive publicity from local media for reaching out to new audiences through the use of the innovative social networking tools.

Transit agencies track usage statistics for their 511 systems and Website services to evaluate the impact and support the required operations and maintenance expense. **Table 5.2** documents observed usage metrics from several prominent transit agencies, and **Figure 5.1** shows the growth in 511 deployments and usage from June 2001 through May 2009.

Table 5.2: Observed Usage Metrics from Sample Transit Agencies

	BART, San Francisco, California	Denver RTD, Colorado	TriMet, Portland, Oregon
Percentage of travelers that use information	Unknown	At least 50 percent	Unknown
Number of Web site requests received for real-time information per month	880,582	11,000	330,000
Number of IVR requests received for real-time information per month	N/A	2,000	N/A
511 phone requests for real-time information	40,772	Unknown	Unknown

Source: 511 Deployment Coalition

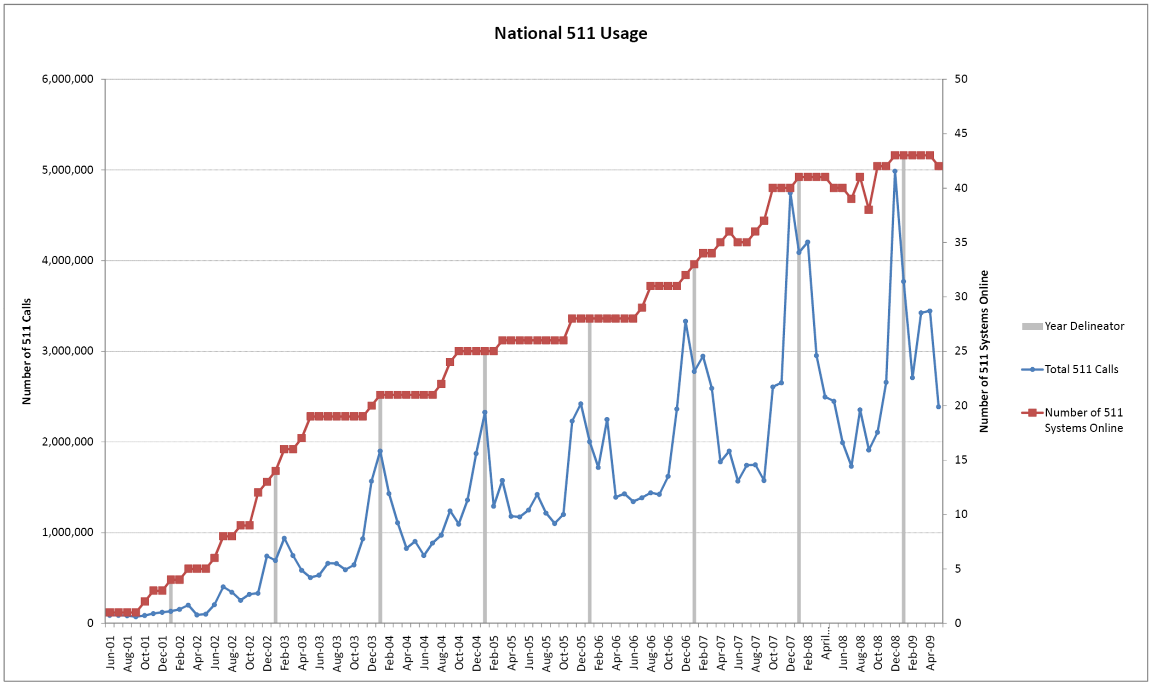


Figure 5.1: National 511 Deployment and Usage Trends

5.1.3 Private Sector Traveler Information Services

5.1.3.1 How Commercial Drivers Use Real-Time Information

While commercial vehicles desire similar information to passenger vehicles, there are some significant differences in the information they require and how they use it. Many truckers would rather see events of greater magnitude that would interrupt a long-haul trip, as opposed to the commuter information used by many passenger vehicles. They also require information across jurisdictional boundaries, including information several hours down the road such as future closure information. Commercial vehicles may also require additional information such as shipper/consignee hours of operation or information regarding oversize/overweight restrictions and permitting.

The next generation of telematics is providing more information to drivers, including turn-by-turn directions and weather information. Drivers appreciate the information they receive, particularly information regarding the "last mile" to their destination. Generally, more-granular information provided is always better. Commercial drivers are only allowed a certain number of hours of service. Therefore, unlike a passenger vehicle driver that is more likely to use real-time information to reach a destination as soon as possible, a commercial vehicle driver may decide to alter his/her driving schedule to maximize driving efficiency. Depending on the value of their cargo and when it is due at its destination, real-time information may be of particular value to commercial operators.

5.2 System Management and Operations

In addition to providing real-time traveler information to customers, transportation agencies can leverage the information stemming from real-time applications to improve their own internal operations, including management of their own fleets and infrastructure. For example, information can be used to monitor conditions, increase the accuracy of transit schedules, or improve the utilization at a parking facility.

5.2.1 Traffic Management and Operations

Real time data used for traffic management plays an important role in roadway operations. Active traffic management is only beneficial if the data provided to an operator or a system is accurate and timely. Traffic management centers utilize sensors, cameras and incident responders to provide the operators with information to manage traffic. Freeway management is more prevalent than arterial management due to the greater availability of information for major highways. For arterials, real-time intersection and system detection data is crucial for signal operations.

5.2.2 Fleet Management and Operations

In addition to real-time traveler information, many agencies use GPS AVL for improvements in vehicle fleet management and operations. Although AVL is costly to install and maintain, it is the only effective method for tracking vehicle location, which is necessary to provide the level of service that customers have come to expect. Even if it is not disseminated to users, tracking schedule adherence can indicate whether vehicles are behind or ahead of schedule to allow for improved spacing that avoids platoons of clustered vehicles. Transit agencies often focus their attention on their highest-capacity routes, where bus headways are as frequent as every 3 to 5 minutes during peak periods.

Carriers, particularly larger carriers, are using real-time applications to improve their operations, including improved routing, scheduling, and driver efficiency. Since some telematics systems provide multi-lateral communication (driver, dispatcher, manufacturer and vendor), instruments on the truck can also serve to diagnose the vehicle's en route operating efficiency, including fuel efficiency, mechanical specifications, and software updates. However, while possible, many of these changes to operating parameters have yet to be enacted, with few carriers using these systems as standard equipment.

Geofencing – Telematics provide dispatchers with an opportunity to better manage the specific location of their vehicles, for both security and operational efficiency purposes. Telematics allow dispatchers to "geofence" their vehicles, whereby a vehicle's route and operating characteristics (speed, driving pattern, etc.) can be prescribed. If the vehicle deviates from the prescribed operating characteristics, the vehicle is flagged to a dispatcher who can liaison with the driver to assess a problem. Geofencing is becoming increasingly common, particularly for high-value and HazMat shipments. Geofencing and prescribed routing will likely become more common as systems are deployed to more vehicles and sensors are able to track vehicles with greater precision. While some drivers are hesitant to be tracked in such detail, most drivers appreciate being tracked because it removes the pressure of being creative to get to their destination on time. Geofencing provides a unique opportunity for carriers to increase the security and efficiency of freight shipments.

5.2.3 Parking Management

Once data is obtained from parking sensors, it is possible to build information models on arrivals, departures, occupancy, duration, and availability, as well as information reflecting demand. Networked meters can deliver information regarding current operational and payment conditions and historical transactions, which can be used to produce a complete real-time and historical view of compliance, violations, actual versus potential revenue, and options for improving pricing and policy.

Pricing Signal for Reservation-based Systems – In general, moving from a "free" to a "pricing" model often greatly impacts customers' decision to use a parking facility, including systems with reservations, signaling what customers are and are not willing to pay for and how much they are willing to pay. However, at the BART Rockridge implementation, even when a charge became associated with the program, 800 people (approximately 66 percent) stayed with the program, indicating that customers are willing to pay for the valued-added service they receive from parking information and the ability to make a reservation. Instead of "paying" with their time by showing up early to secure a space and risking whether one was available, these customers were willing to pay a fee to secure a guaranteed parking space. In addition to transit stations, reservation systems can also be associated with entertainment events, especially those where tickets are frequently purchased online in advance (concert, professional sports game, etc.), and a parking reservation can be bundled as part of the transaction.

5.3 Performance Measurement

Extensive data must be collected to properly measure the effects of new parking facilities or policies. Collecting data related to factors such as economic conditions, enforcement practices, and gas prices allows planners to examine impacts over time and explain variations in behavior. This will provide researchers and policy planners with information regarding how policies affect congestion and turnover and how policies can be used to improve overall programs.

In municipal street systems like SFPark, real-time information will improve efficiency for enforcement personnel through immediate notifications of expired meters and eliminating the need to check every meter. Furthermore, customers will have the option to top up their parking meter from their cell phone; so enforcement can be characterized as a public benefit instead of a punitive damage for forgetting to refill a parking meter.

Real-time freight information applications can also be used to expand knowledge of freight flows around the country, within a region, or across a particular border. Aggregating freight data from individual vehicle locators, weigh-in-motion detectors, or wireless safety inspections helps both the public and private sectors improve their handle of when and who is utilizing heavy freight corridors and how commodities are flowing. Increased data sharing will encourage data aggregation and improve the understanding of freight movements. The federal government has already taken an interest in tracking commercial vehicle origin-destination via the FHWA's Freight Performance Measures Initiative, but believes that conducting additional probing would serve to increase understanding, including discovering additional locations where real-time freight information is needed.

Real-time information can also be leveraged to track vehicle and driver performance. Telematics can track fuel consumption and optimization. Dynamic routing improves efficiency, allowing for decreased fuel consumption. It also allows operators to more accurately track revenue per mile, number of trips required, and other long-range planning activities. Also, some systems have features that allow carriers to track the safety performance of their drivers, including speed and transmission information.

5.4 Usage Trends

5.4.1 Social Networking

An important emerging trend is the use of social networking tools (such as Twitter, Facebook, or blogs) by DOTs and regional transportation organizations as a traveler information dissemination tool. Several DOTs have recently incorporated some of these tools into their information dissemination strategies. A few years ago, a popular strategy emerged for DOTs to use podcasts to provide weekly updates for major construction activities or for large-scale event pre-advisories. Even though podcasts are applying newer online strategies to reach expanded audiences, they were not intended to be updated in real time. Twitter and Nixle are two social networking tools that are gaining prominence. Several DOTs, including WSDOT, Kansas DOT, and Virginia DOT, are using Twitter to provide traffic and travel condition updates. Texas DOT uses Twitter for statewide emergency notifications, but the Houston TranStar program has established a Twitter site where users can single out specific corridors to follow and receive notifications. This allows users to pre-select specific corridor updates and minimize receiving a myriad of regional information and details that might not be relevant.

One of the challenges with Twitter is that it is open to allow users to also post content, so DOTs have very little control over user-generated content that might appear on their Twitter pages. Maintaining accuracy on these fast-moving and user-populated sites could impact overall quality.

Social networking has the potential to become another substantial medium of communication between transit agencies and customers and among customers. Online applications like Facebook, RSS feeds, and Twitter can share information related to congestion, incidents, and construction and are especially popular with younger users. Transit agencies must be aware of the potential legal issues that surround their use, including restrictions regarding a municipal organization being part of a public forum.

5.4.2 Safety Concerns

Safety groups are concerned that providing in-vehicle information to commercial vehicles can be potentially dangerous if it causes a distraction to the drivers. Some jurisdictions even ban cell phone usage while operating a vehicle. Furthermore, recent NTSB recommendations have indicated that new commercial vehicle information applications should refrain from using cell phones for information dissemination. In-vehicle communication systems provide a safer option for truckers to obtain information such as systems that use 16-character message displays on the truck that provide just enough information for the driver to make a quick decision about whether to pull over and view the entire message or if it is a message that can wait for the next time they are already pulled over. The next generation of telematics is utilizing hands-free voice and mapping instead of requiring any text to be read. Truckers are readily accepting the use of these devices when available to them, and vendors are willing to work within the confines of the new recommendations to provide safer, better systems.

5.5 Real-Time Data Usage Gaps

5.5.1 Traffic Usage Gaps

There is a gap regarding the sharing of traffic data between different departments. For example, the Operations department often does not think to share data with the Planning department, and vice versa. The same may be the case for traveler information programs. Different departments often deploy their own data collection systems and do not adequately leverage each others' efforts. While each department has its own data needs, there is still a gap with respect to lack of sharing data between departments and programs.

5.5.2 Transit Usage Gaps

5.5.2.1 Understanding of Real-Time Information Usage Gap

Transit agencies lack an understanding of how transit riders use real-time information, including detailed usage statistics to understand how travelers access information and how the information affects their travel choices. Furthermore, transit agencies also need to improve their understanding of the needs of various types of transit riders, including the needs of discretionary versus captive riders, younger versus older riders, and other demographic groups. Obtaining a more complete understanding of individual users could broaden the usage of transit information and promote market sustainability.

5.5.2.2 Mode Switching Gap

A critical function that still must be developed is how to better leverage accurate real-time transit information to encourage users to switch to transit from their personal vehicles. One way to leverage this would be to include information about available transit services when drivers search for auto travel information. In most urban areas in the United States, a very small fraction of travelers have used transit services in the recent past and thus are not well informed about the services available and their quality. It is critical to increase awareness of good transit alternatives, and where they exist, to travelers planning to make trips by automobile. In select locales, Google has begun to suggest public transit routing when someone enters a driving destination in Google Maps and a transit alternative is available and timely. The government can play a role in encouraging this, or even mandating it where government funds are being used to help provide the information service. The US DOT's Integrated Corridor Management (ICM) Initiative seeks to create additional intermodal linkages, including providing real-time information to encourage mode switching such as comparative travel times. Several agencies are working toward deploying systems that provide transit and parking information to highway drivers including I-35 in Minnesota and I-80 in California. The US DOT aims to continue deployment through ICM over the next several years.

5.5.3 Parking Usage Gaps

5.5.3.1 Effects of Smart Parking Policies

Smart parking is still a budding industry with little understanding of how new technologies can be leveraged to change driver behavior. Because of this, many municipalities still do not understand how to appropriately use real-time parking information to improve parking policies, increase transit ridership, or decrease overall vehicle-miles traveled. Additional studies must be conducted to develop a better understanding of how drivers respond to smart parking, including time limits, new enforcement practices, and pricing signals.

5.5.4 Freight Usage Gaps

5.5.4.1 Training Gap

Some non-tech-savvy truckers lack the technical expertise to use the newest real-time freight information systems, including both public and private systems. This is particularly an issue with independent owner-operators who do not have the support of a large company to encourage them to learn to use more advanced systems. Even if states, intermodal facilities, or border crossings are able to provide accurate and useful information, it is only useful if a substantial portion of the driver population uses it regularly. Freight information providers need to work with the trucking community to educate drivers in accessing the information provided.

5.5.4.2 Data Usage Analysis Gap

Few studies or surveys have been conducted to determine how truckers prefer to receive and use real-time freight information, including how many truckers regularly use public sector information, how they prefer to receive it, and how it impacts their choices. Many experts are able to speculate on these issues, although little hard data is available to support their intuitions. Some origin-destination studies may provide some insight, although even these are limited.

5.6 Closing the Gap and Roles for the US DOT

Although real-time traveler information is already benefiting many customers, additional outreach conducted by the US DOT and its partners will further encourage usage and information exchange. This includes promoting traveler information to a variety of potential customers, including daily commuters, out-of-town travelers, and fleets. This could also include marketing campaigns and incentive programs. In addition another gap needed to be bridged is the sharing of traffic data between different departments. An example of this would be to facilitate data sharing between operations, planning and traveler information groups. Since all groups may deploy their own data collection systems there is a need encourage various groups to leverage what others are doing already.

The US DOT can also play a critical role in encouraging state agencies and the private sector to standardize approaches to how information is presented to the public as the United States moves closer to a seamless national network of traveler information. However, moving toward this network should take into consideration recent laws against cell phone usage and recommendations from NTSB, which encourage the government and industry to avoid traveler information systems that require truckers to use cell phones, as they increase the risk of crashes.

New methods for allowing truckers and other travelers to communicate in ways that limit distraction will improve overall safety.

Finally, the US DOT can lead an effort to better understand how travelers use real-time information, especially in developing market segments like transit, parking, and freight, to broaden the usage of real-time information and promote market sustainability. This includes an understanding of how various user groups (e.g., commuters, tourists, lower income, disabled) are taking advantage of real-time services.

6 COSTS

The deployment of real-time traveler information systems throughout the country provides the opportunity for millions of travelers to make informed decisions about their routes and schedules. But needless to say, this deployment comes at a cost. While costs for traveler information systems are not easily isolated because much of the detection infrastructure is deployed to support other operations programs, this section seeks to provide several example capital and operating cost estimates for various field technologies, communications, and central systems that could be used as a starting point in the planning stages of real-time traveler information systems deployment.

6.1 System Costs

6.1.1 Traffic

The deployment of real-time traveler information systems throughout the country provides the opportunity for millions of travelers to make informed decisions about their routes and schedules. With this deployment comes cost. This section provides several example capital and operating cost estimates for various field technologies, communications, and central systems that could be used in the deployment of a real-time traveler information system.

To effectively manage and maintain a real-time traveler information system, central ATMS software is used to collect, organize, and disseminate transportation data. The cost of these systems varies widely, but a statewide system that provides a typical level of field device and incident management costs approximately $3,000,000 per deployment and requires a degree of ongoing maintenance and support.

Table 6.1 and **Table 6.2** list planning-level cost estimates for various types of equipment and communications used to support traveler information programs, the expected equipment life, and the O&M costs. **Table 6.1** gives cost estimates for various roadside devices that are commonly deployed to capture data for distribution. **Table 6.2** provides cost estimates for various methods of communication used to obtain the data collected from the roadside devices. As would be expected, the majority of the costs are recognized upfront, with an average equipment life span of 12 years.

Table 6.1: Roadside Equipment Costs for Traveler Information

Unit Cost Element	Life (years)	Capital Cost	O&M Cost (per year)
Microwave Vehicle Detection System (MVDS) – NEW	7	$25,000	$150
Microwave Vehicle Detection System (MVDS) – REPLACE (sensor only)	7	$8,000	$150
DMS with Structure	10	$180,000	$4,500
HAR Site	20	$50,000	Not available
CCTV Camera	7	$45,000	$2,250
Basic RWIS ESS	15	$78,000	$8,000

Table 6.2: Communications Costs for Traveler Information

Unit Cost Element	Life (years)	Capital Cost	O&M Cost (per year)
Fiber Optic Backbone (per mile)	30	$175,000	Not available
Dial-up Communications	30	N/A	$500
Wireless Communications Link – Unlicensed (5 miles or less)	30	$12,000	Not available
Wireless Communications Link – Licensed Backhaul	30	$150,000	Not available
Wireless Communications Tower	30	$250,000	Not available

Costs for traveler information systems are not easily isolated because much of the detection infrastructure is deployed to support other operations programs. However, cost data is readily available for dissemination technologies and systems, such as 511. Operating a 511 system requires either contractual procurement or in-house infrastructure and resources. A recent study of 511 systems across the United States concluded that costs for systems will vary based on the system size, complexity, available data, and whether it is regional/multimodal versus a statewide system, but the average cost per call of a 511 system is $1.08.

ESS are also deployed for traveler information. In 2003, FHWA published *Weather in the Infostructure,* an extensive study of the deployment of ESS in metropolitan areas with a population above 1 million. Based on the cost information in this report, RWIS deployments would cost approximately $25,000 on the central, or TMC, side of the deployment. The field device costs range from $10,000 to $50,000 and average $30,000 per site.

Costs for private sector probe-based data will evolve with this relatively young market. For now, the best available cost data is from the I-95 Corridor Coalition, which published its contractual initial and recurring costs. On a per-mile basis, there is a significant cost savings for private sector-based flow data as compared with sensor-based deployments, although it should be recognized that probe data is not the same as sensor data. It does not collect traffic volumes or occupancies, although for traveler information applications, these are usually not important. It is more fitting that agencies would deploy sensors where other operational strategies, such as ramp meters, require those data types and probe data in areas where traveler information is the primary need. **Table 6.3** shows the costs for probe-based options and infrastructure-based options.

Table 6.3: Flow Data Costs

	Infrastructure Based/Typical	Probe Based (I-95 Corridor)
Initial capital cost (per centerline mile)	$26,000	$900
Annual recurring cost	$150	$750
5-year Est. Cost	$26,600	$3,900
10-year Est. Cost	$27,350	$7,650

With resource challenges in today's DOTs, one of the key challenges for agencies is the ability to effectively maintain infrastructure, and detection is one of the foundational components of urban area freeway management systems. New technologies and alternatives may provide a more cost-effective option than traditional detection systems currently in use by many public agencies.

6.1.2 Transit

6.1.2.1 Incremental Costs

AVL systems require a large capital investment and substantial operating cost to operate and maintain, but are necessary to implement real-time systems. However, real-time transit traveler information is a relatively low marginal capital cost when AVL systems and automated scheduling systems have already been procured as part of an existing transit management system. Therefore, real-time information is often a relatively inexpensive incremental capital investment after other ITS are already in place. Furthermore, larger transit agencies will most likely have already configured their schedule and routing information with advanced proprietary software systems such as Trapeze FX or Giro Hastus that support integration with real-time communications systems.

However, agencies that have yet to deploy AVL systems will incur substantial additional cost to develop the ITS infrastructure to support them. Smaller agencies running simpler transit scheduling systems, often on Microsoft Excel, will incur substantial additional effort and costs to integrate their schedules with real-time system vendor's commercial solutions. However, Google Transit expansions and upgrades may encourage additional transit agencies to begin providing more standardized information.

It is often difficult to determine where costs for a traveler information project begin and another ITS project end. Cost structures for real-time transit information can be difficult to determine when considering that they are often built on top of other ITS. For example, Los Angeles Metro's entire ITS network, including communications, AVL, and APC, costs approximately $100 million to deploy. While these costs should not be entirely associated with real-time traveler information systems, such systems would be impossible without them. With often only $500,000 to $1,000,000 required to procure and deploy the necessary software, hardware, and communications, real-time information system costs are often small compared to other capital costs, such as the acquisition of additional transit vehicles.

For example, Minneapolis only spent approximately $110,000 on developing a traveler information Website, mostly in market research and programming costs. However, the system was built on a project undertaken by Minnesota DOT several years prior that included the installation of an extensive ITS transit network, which cost the state approximately $1 million. It was only because of this previous deployment that the Website was able to be launched for such a small sum.

Despite these difficulties, many agencies have been able to track the system costs of real-time traveler information. A 2003 Transit Cooperative Research Program (TCRP) Report entitled, *Real-Time Bus Arrival Information Systems* surveyed transit agencies across the country, discovering that total implementation costs for real-time information programs ranged from $60,000 to $70,000,000 with an average total implementation cost of approximately $5,000,000.

Pricing models for AVL procurements with real-time functionality can vary substantially depending on the vendor. Los Angeles Metro invested $15,000 per vehicle in capital costs for deployment of an integrated ITS solution that includes AVL and real-time traveler information. Despite the high capital costs, any associated vendor and operating costs for 12 years are bundled as part of the cost. Conversely, San Francisco's upfront costs for its real-time information system were substantially less ($1,500 per vehicle), but the agency is also responsible for a $30 monthly communications cost and an additional $30 monthly software licensing cost, resulting in a total cost of $10,140 over the same 12-year period.

6.1.2.2 Operational Costs

Cost allocation difficulties continue with operations and maintenance costs, where program costs are often bundled together, particularly communications costs. Communications costs can be substantial considering that each packet sent incurs a charge. Many implementations also require additional staff time that is difficult to tie directly to a traveler information program. In addition to capital and communications costs, other costs incurred on behalf of real-time traveler information programs include software purchases and maintenance costs.

Real-time traveler information system vendors that host the service generally charge a standard operating fee based on the size and complexity of the real-time system. Smaller agencies with simpler routing systems will incur smaller charges than larger, more complex systems. In addition, standard communications fees are incurred for cellular communications that provides tracking for the data. Although each bus often transmits only 2.5 MB of data monthly, communications costs usually range from $12 to $35 per vehicle. New communications technologies such as WiMAX and LTE may provide more cost-effective methods to disseminate information.

6.1.2.3 Cost-Saving Measures

The overall cost of deploying real-time systems as an add-on to AVL is often relatively small, usually comparable to the cost of a couple of transit buses. Furthermore, when compared to the cost of buses, implementing real-time information actually has the ability to allow substantial costs savings. While not feasible in all scenarios, transit agencies could opt to scale back bus service by removing a few buses from less-popular routes in favor of providing real-time information, yet still increase the overall satisfaction for all routes.

Some transit agencies have learned through their experience that the most effective methods for providing information to the general public do not necessarily include large infrastructure costs. For example, many transit agencies have decreased their focus on the deployment of expensive DMS in favor of programs to increase the degree to which customers utilize the Internet and their cell phones to receive information, which allow for a better overall level of service. Such policies help to curb infrastructure costs by focusing on the use of devices that customers already own.

6.1.2.4 Sample Costs

Table 6.4 shows an estimate of the costs incurred by Denver RTD upon implementation of its real-time transit information system. While each real-time system will incur very distinct and separate costs, Denver's cost structure can serve as a general indication for the costs that may be incurred by other agencies.

Table 6.4: Denver RTD Real-Time Information System Costs

	Entire Cost of AVL and other systems required for real-time info backbone		Cost of components that only serve a real-time function	
	Deployment	O&M	Deployment	O&M
Total Cost	$50 million (1993 dollars)	$4million annually	Signs $2,500 each	Network Attached $100, Cellular $700
Cost per Vehicle	$5,000	$3,700	Unknown	Unknown

6.1.3 Parking

Cost factors vary depending on the type of facility being used and the degree of complexity of the sensor system being installed. Additionally, the type and level of accuracy of information provided also affects cost. **Table 6.5** summarizes the typical per-space cost of real-time parking information. Space-by-space lots tend to be much more expensive to implement and maintain. Vendors specializing in deployment in garages and other closed facilities often assess capital costs on a per-space basis, often $450 to $750 per space with additional O&M costs of 3 percent to 8 percent per year.

Entry/exit systems are more cost effective to deploy than space-by-space systems, and therefore more popular for public sector deployments. They utilize more cost-effective implementation methods including cheaper count in/count out magnetometers and wireless sensors at strategic locations within the facility, instead of more costly vehicle presence detectors. Although they vary in cost depending on size, complexity, and other factors, total implementation costs are in the hundreds of thousands of dollars and annual operating costs in the tens of thousands of dollars. WMATA is currently deploying a real-time parking information system at its Vienna metro station, with expected capital costs of approximately $200,000 for an entry/exit system spanning 5,400 spaces across 2 garages and 2 surface lots.

On-street parking system costs vary based on the volume of sensors and data being collected, with larger systems able to achieve greater economies of scale. One vendor described its costs running approximately $300 per space for a system installation on new spaces as well as a maintenance fee of $10 per space per month. Installing a network for parking spaces with existing meters is often possible at a discount, approximately $175 per space.

Table 6.5: Typical Per-Space Smart Parking Costs

Parking System	Costs	
	Capital	Annual O&M
On-street	$300	$120
Entry/exit	$40	$2
Space-by-space	$600	$30

6.1.3.1 Potential Cost Savings

Still, budget limitations often limit the number of sensors that can be deployed and the granularity of data received, especially in publicly deployed systems. Substantial cost savings can be achieved by choosing to implement a parking information system that fits the unique needs of the parking operator, including sensors that provide the right granularity of information and dissemination methods that meet the needs of system users. Public sector deployments with tight budgets in particular are choosing cost-effective operations. For example, using magnetometers has proven substantially more cost effective than inductive loop detectors, often available for a tenth or a hundredth of the cost and less affected by snow and other weather conditions.

Another critical factor in cost-effective operation is low power engineering on both sensing and networking equipment. For example, newer parking sensors being utilized can operate for 5 to 10 years on two AA batteries. This allows for installation of sensors at very low cost by not requiring wiring, core drilling to provide space for large batteries, or labor to frequently replace batteries.

In addition to providing information to potential users, real-time parking information can also be disseminated to enforcement personnel, informing them of the locations of vehicles in violation of parking ordinances. Smart parking allows enforcement personnel to more effectively issue citations, thereby increasing revenue and decreasing the need for enforcement staff.

One of the most important elements in disseminating real-time information to drivers in immediate vicinity of parking facilities is signage. It is imperative to deploy signage that is appropriate to meeting the needs of system users, including determining appropriate locations and determining whether fixed or variable message signage are required to display the necessary information. Since the usefulness of DMS is limited, such signs should only be deployed to limited, high-traffic areas. Funds may be better spent on other information disseminations methods.

6.1.4 Freight

6.1.4.1 Public Sector Systems

Providing freight-specific information as an add-on to an existing 511 system or Website can be achieved for a relatively small marginal cost once existing ITS is already in place. Basic hardware and software can be leveraged to utilize existing information, including additional methods to pass freight-specific situational awareness to commercial carriers via Websites, email blasts, or providing an interstate 511 service via a toll-free number. The Florida Department of Transportation's decision to add an 800-number to its 511 service for en route truckers required minimal cost, but has allowed truckers increased access to real-time information.

Building systems that provide real-time information at intermodal facilities, border crossings, and other freight bottlenecks may incur significant expense. Whatcom Council of Governments spent approximately $2 million on the development of its southbound real-time border crossing information system, including detection, signs, and communications equipment. However, the system does not exclusively benefit commercial vehicles, as passenger vehicles can also utilize information from Whatcom's deployment.

As the project is still underway, specific cost information related to C-TIP is still unavailable, but the project administrators are considering cost-effective and sustainable methods to implement the project. While the government is willing to provide research seed funding, it hopes that it can build an economically sustainable model in which a commercial operator could take over the project in exchange for collecting subscription fees from the carriers and other participants. The project also seeks to provide information via Web services, which are more efficient and less costly. A similar approach could be utilized for border-crossing implementation, especially where pre-clearance truck-only lanes could be implemented. An improved border crossing with real-time freight information is in development at the Otay Mesa East crossing near San Diego, California.

Table 6.6 displays some of the costs that may be associated with adding freight-specific information to existing ITS. These costs assume that a 511 system for passenger vehicles is already in place.

Table 6.6: Typical Public Sector Freight Information Deployment Costs

Development of freight info clearinghouse and data integration	$500,000
Freight-specific 511 system	$250,000
Website Development	$100,000
Consulting fees	$200,000
Total	$1,050,000

6.1.4.2 In-Vehicle Telematics

An increasing number of carriers are finding real-time freight information to be a worthwhile investment to improve their operating efficiency. However, trucking is a low-margin industry, where carriers often lack the investment capital necessary for such tools, even with the potential of a high return on investment.

In recent years, the costs of in-vehicle communications and fleet management tools have become much more affordable and ubiquitous. Entire after-market packages can now be installed and maintained for approximately $500 to $2,000 per truck per year, including communications costs. Schneider Trucking's recent procurement of a new fleet management system for its entire fleet required a $40 million upfront cost. However, as opposed to its legacy system, which only used expensive satellite communication, its new system will leverage more cost-effective WiFi and cellular networks when possible, decreasing overall communications costs.

Some manufacturers are including lower-end telematics that provide basic functionality, such as vehicle tracking, as standard equipment. Such systems only cost manufacturers several hundred dollars to include, and basic operations is bundled with purchase for the first year or more, with affordable operating costs after this initial period. Volvo Link is a cheaper alternative to after-market options, although it provides less functionality. The basic system is bundled into the cost of the truck for at least the first year. Following the trial period, a cost of 15 cents per message is associated with use.

6.2 Trends and Cost Impacts

6.2.1 Willingness to Pay

The traveler information industry has evolved greatly since the early days of ITS. At various times and in various segments, it was seen as more of a public sector role and, at other times, as more of a private sector role. While the public sector appears to be taking on a greater role in traveler information under the banner of 511 programs, the private sector continues to search for sustaining business models as both vendors and data providers. Several years ago, it was believed that the private sector could develop sustainable business models for traveler information services, and much research was conducted regarding what travelers wanted, the benefits of traveler information services, and the elusive "killer app" that would spawn greater demand. To date, however, it is not well known what value individual consumers place on traveler information. Complicating matters is that as technologies and delivery mechanisms change, their willingness to pay will also change. For example, an in-vehicle navigation system is likely to increase the utility of the same information previously accessed on a Web site simply because it is delivered in the vehicle when it is more timely and relevant.

Willingness to pay may be seen as a matter for the private sector and of no consequence to the public sector, which is funded through ITS programs. However, the value individuals place on traveler information has important consequences for how much a public agency should be willing to pay for traffic data, either in the form of deploying its own sensors, systems, or programs, or through purchasing data from the private sector. Furthermore, the value individual travelers place on information as a function of its accuracy is important for the public and private sectors alike as they make investment decisions.

6.2.2 Costs to Sustain Current Business Models

The traveler information market has always been a mix of the public and private sectors. Over time, the role and business models employed by the private sector have evolved. Many different approaches to public-private partnerships have been tried, and some have succeeded for a time, while others have not. As previously noted, new business models emerge as technologies evolve over time. Current models in use by private sector firms are different from those of the past. To date, it is not known whether those models are sustainable. By bundling traveler information with other location-based information services and delivering them in new ways, such as via mobile devices or in-vehicle systems, there are new opportunities to earn revenue from information, including the ability to provide multi-modal information. For public sector business models that rely on purchasing information (particularly traffic information) from the private sector, it is important to assess the sustainability of the companies with which they are contracting. If these firms are not able to survive, the public sector will need to abandon current strategies and fall back to a position of relying on its own data collection efforts.

6.2.3 Declining Costs of Technology

The costs of providing real-time traveler information are decreasing. Declining costs for sensors, communications, data storage, and data retrieval are accelerating real-time information opportunities spawned by new forms of communication and business models. In general, costs for sensors and communications infrastructure are decreasing while quality rises. Sensor size is also decreasing, equating to a decrease in the cost of installation. These new technologies and methodologies are providing for more cost-effective implementations. Additional vendors and more information and media bundling should continue to force prices down.

Vendor prices for in-vehicle telematics are declining as systems become more ubiquitous. Qualcomm's systems commanded high prices when it first came to market in the 1990s, but such technologies have become more of a commodity in recent years, forcing prices down. Telematics operating expenses used to cost approximately $4,000 per truck per year including communications, but have recently dropped to $500 to $2,000 per truck per year. New technologies are allowing Bluetooth connectivity, communicating the information to a provider who can then give diagnostic information to a carrier for only $45 per month, all done through a Smartphone. Web services will provide a more efficient and less costly approach to an information-sharing platform, which is especially important for trucking and drayage companies that operate on low margins.

Although Schneider Trucking's recent procurement of a new fleet management system for its fleet required a $40 million upfront cost, it will improve performance and decrease operating costs. As opposed to its legacy system, which only used expensive satellite communication, the new system will leverage more cost-effective WiFi and cellular networks when possible.

Cheaper, ubiquitous wireless technology through WiFi/WiMAX is increasingly able to provide more agency and customer connections. Interfaces based on XML standards allow relatively cheap integration, making data available across multiple operators. However, while prices have gone down for individual media, there is a new focus on providing media alternatives and a variety of information dissemination methods for customers.

In addition to the decreasing costs of technology and communications, alternative approaches to obtaining data that do not rely on building and maintaining expensive infrastructure will decrease the costs of producing information. This includes new opportunities in the form of new, attractive, user-friendly traveler information and multimodal trip planning Web services via the Web, VoIP, and mobile devices such as Google Maps, MapQuest, HopStop, and BusMonster. However, there are questions regarding whether the low-cost product is of sufficient quality to generate the revenue for current business models to be sustainable, and whether current probe-based models require more data points than what is currently available and, if so, whether that additional data can be obtained cost effectively.

6.2.4 Public Sector Budgetary Constraints

Despite decreasing prices, traveler information services are costly for public agencies to maintain. There is a gap in the funding and personnel resources needed to sustain their programs. Many agencies are left without the ability to raise additional capital for real-time information investments, instead needing to focus on just maintaining present service levels. For some transit agencies, funding issues and the ability to sustain operational costs prevent them from deploying real-time systems, despite the ability to add on real-time traveler information as a marginal cost to existing AVL systems. Real-time system operational costs to maintain and validate data, maintain communications links, and provide network management are increasingly difficult to fund in the current economic climate. It is crucial to develop cost-effective deployment methods that minimize the transit agency's ongoing operating costs. Los Angeles Metro's policy is to maintain its core service of providing transit, opting to contract out the dissemination of information to companies that specialize in providing information.

As travelers expect more and more information, the public sector fulfills its mandate of providing information, and agencies face budget cuts, a gap exists in what the public sector can provide. There are limits on agencies' ability to deploy and maintain sensor networks to achieve broader coverage of traditional detection systems. For other types of information such as incidents and construction, there are gaps in the ability of agencies to keep that information up to date. As agencies are forced to do more with less, these gaps only grow.

6.3 Costs to Fill Gaps

6.3.1 Traffic

The cost elements in this Section provide a starting point for a planning-level discussion of the costs of expanding coverage to something close to "all roads, all modes, all the time" or the requirements under the RTSMIP proposed rulemaking. However, traveler information programs include many other costs for data collection as well as dissemination. Additional data collection costs include programmatic and design costs for construction and software systems integration costs. Dissemination requires central support for the maintenance and back-up of databases. Maintaining real-time incident and construction information requires personnel dedicated to the tasks of updating information and coordinating input from other districts and agencies.

A simplified general cost estimate to meet the RTSMIP requirements has been developed based on the cost elements in the previous section and readily available data from the Office of Policy Information, the US Census Bureau, ITS Deployment Tracking data, and the 2003 *Weather in the Infostructure* report developed for FHWA. The cost estimate includes estimates for each of the four types of information required—roadway or lane-blocking traffic incident information, roadway weather observation updates, travel time along highway segments, and implementing or removing lane closures for construction. In addition, it includes an estimate for the implementation of a statewide ATMS upgrades and replacements. A number of simplifying assumptions were made in the derivation of these costs, as follows.

Central System

- It is assumed that each state would require a central ATMS for the consolidation of data and that each state has one major system to consider, though that is clearly not always the case.
- If systems last approximately ten years, it may be assumed that five states would need to upgrade their systems in any given year. If five additional systems would need upgrading ahead of schedule to accommodate new major deployment, 10 states would need to completely upgrade their ATMS software platforms. The cost of a full replacement is assumed to be approximately $3 million.

- It is assumed that the remaining 40 states have a system in place that can accommodate significant expansion of devices. It is assume the integration cost for these systems would average $200,000.
- It is assumed that all other costs such as system maintenance and operators are already reflected in existing systems and are not additional costs.

Incident Information

- It is assumed that incidents can be collected from existing sources but that additional database management staff would be needed to maintain the system.
- It is assumed that maintenance of construction information would be handled by the same database management staff as for incidents, or that these two roles together would equate to one full-time equivalent staff person.

Roadway Weather

- It is assumed that the existing roadway weather data provided by public and private entities would need to be supplemented with a nationwide deployment of RWIS stations. Cost estimates were developed using FHWA's *Weather in the Infostructure*.
- It is assumed that the metropolitan area needs would be addressed by the cost estimate provided in FHWA's *Weather in the Infostructure* (based on composite scoring and road miles), but with 2003 costs escalated to current estimates.
- It is assumed that 10 percent of the non-metro roadway miles have RWIS sensors deployed requiring coverage on the remaining 90 percent of non-metro mileage, which would require RWIS sensors at an average of one per every 100 miles.

Travel Times

- It is assumed that existing sensor deployments would be maintained up to one per mile but not expanded geographically.
- It is assumed that all future geographic expansion of real-time travel time data would come from probe-based data sources.
- It is assumed that 50% of all existing sensors need to be replaced, but that replacement costs include the sensor, planning and installation costs only, not infrastructure that would be existing such as pole, cabinet, communications, etc.

Table 6.7 outlines the derived cost estimate for the deployment of RTSMIP. **Table 6.8** through **Table 6.12** provide supporting data.

Table 6.7: General Cost Estimate for RTSMIP Deployment

Subsystem			Initial Costs	Recurring Costs (Annual)
Central System				
ATMS Upgrades – new systems	$3,000,000 per system	10 systems	$30,000,000	(5%) $1,500,000

ATMS Upgrades – Integration of new devices	$200,000 per system	40 systems	$8,000,000	(5%) $4,000,000
Subtotal (Central System)			**$38,000,000**	**$1,900,000/ yr**
Traffic Incident and Construction Lane Closure Information				
Database Operator	$150,000 per year per state	50 states	$7,500,000	$7,500,000
Subtotal (Lane Closure Management)			**$7,500,000**	**$7,500,000/ yr**
Roadway Weather Observation Updates				
RWIS Coverage in 61 Metropolitan Areas[1]	(See *Weather in the Infostructure*)	61 metro areas	$38,800,000	(5%) $1,940,000
RWIS Coverage in Non-Metro Areas[2]	$38,000 per RWIS sensor	360 sensors	$13,680,000	(5%) $684,000
Subtotal (Road Weather Information)			**$52,480,000**	**$2,624,000/ yr**
Travel Time Along Highway Segments[3]				
Urban Area Detection[4]	$8,000 per sensor	3,450 sensors	$27,600,000	(5%) $1,380,000
Metro Area Mileage without Detection[5]	$900 per centerline mile[6]	10,800 miles	$9,720,000	$8,100,000[7]
Subtotal (Travel Times)			**$37,320,000**	**$9,480,000/ yr**
NATIONWIDE SYSTEM TOTAL			**$135,300,000**	**$21,144,000 /yr**

Notes:
1 – See Table 6-8
2 – See Table 6-9
3 – Only required in Metro areas over 1 million in population
4 – See Table 6-10
5 – See Table 6-11
6 – Probe-based method of data collection was assumed for the non-metro roadways; $900/mo includes first year startup costs
7 – Recurring costs for probe data are assumed to be $750/mo according the to the I-95 Corridor Coalition contract

Table 6.8: Interstate and Urban Freeway Mileage

	Interstate	Urban Freeway	Totals
Metro Areas (population > 1 million)	12,029[1]	5,689[1]	17,716
Remainder of U.S.	34,643	5,226	39,869
Totals	**46,672[2]**	**10,913[2]**	**57,585**

Notes:

	Interstate	Urban Freeway	Totals

1 – Derived from National Highway Planning Network (roadway mileage by functional class (GIS line data) overlaid with 2007 US Census Bureau CBSA population estimates
2 – FHWA Office of Policy Information, Highway Statistics, Public Road Length by Functional System, 2007

Table 6.9: Derivation of RWIS Costs (Metro Areas)

	Units	Unit Cost	Cost
RWIS Sensors	832	$38,000[1]	$31,616,000
TMC Units (Assume 2 TMC per Metro Area)	122	$30,000[2]	$3,660,000
Development and Engineering (10%)			$3,527,600
Total Metro Area Costs (Rounded)			**$38,800,000**

Notes:
1 – Escalated from 2003 *Weather in the Infostructure* cost estimate of $30,000
2 – Escalated from 2003 *Weather in the Infostructure* cost estimate of $25,000

Table 6.10: Derivation of RWIS Costs (Non-Metro Areas)

	Units	Unit Cost	Cost
Interstate and Urban Freeway Miles (outside 50 largest metro areas)	39,869		
Miles requiring coverage (90%)	35,882		
RWIS Sensors (one per 100 miles)	359	$38,000[1]	$13,642,000
Total Non-Metro Area Costs (Rounded)			**$13,642,000**

Notes:
1 – Escalated from 2003 *Weather in the Infostructure* cost estimate of $30,000

Table 6.11: Derivation of Urban Area Sensor Costs

	Units	Unit Cost	Cost
Interstate and Urban Freeway Miles (within 50 largest metro areas)	17,716 mi		
Miles with existing sensor coverage (39%)	6,909 mi		
Existing sensors needing replacement (50%)	3,454 mi	$8,000[1]	$27,632,000
Total Metro Area Sensor Costs (Rounded)			**$27,600,000**

	Units	Unit Cost	Cost

Notes:
1 – Planning level figure assumed to include planning, engineering, etc. Assumed spacing of one sensor per mile

Table 6.12: Derivation of Costs for Travel Times for Areas without Detection

	Units	Unit Cost	Cost
Interstate and Urban Freeway Miles (within 50 largest metro areas)	17,716		
Miles without existing sensor coverage (61%)	10,807	$900[1]	$9,726,300
Total Metro Area Probe Data Costs (Rounded)			**$9,720,000**

Notes:
1 – Probe data costs for I-95 Corridor Coalition ($750/mi + $150/mi mobilization in year 1 only)

6.3.2 Transit

The most practical method for estimating the costs to deploy real-time transit information to the entire transit network is to estimate the costs for deploying AVL to transit vehicles currently without it, for additional signage, and for additional software and communications infrastructure needed for the systems. The following tables also break out these costs for deployment for all transit vehicles as well as for just buses. Because buses mostly run in mixed traffic and not on dedicated track, they are more likely to have issues with detours and running behind schedule. Thus, focusing the expansion of real-time information on buses may be more practical. The following information only considers the costs associated with deploying full real-time information to the 94 transit agencies that responded to the 2007 RITA ITS Deployment Survey.

Table 6.13 shows the number of transit vehicle that are currently equipped with AVL and real-time information capabilities.

Table 6.13: Vehicles Equipped with AVL and Real-Time Information

Transit Types	Measurement	Equipped with AVL	Display Real-Time Traveler Information
Fixed Route Buses Only	Vehicles with Technology	26,381	11,569
	Total Vehicles	43,233	43,233
	Percent	61%	27%
Other Transit Vehicles	Vehicles with Technology	9,103	1,313
	Total Vehicles	27,825	27,825
	Percent	33%	5%
All Transit	Vehicles with Technology	35,484	12,882

Transit Types	Measurement	Equipped with AVL	Display Real-Time Traveler Information
Vehicles	Total Vehicles	71,058	71,058
	Percent	50%	18%

Source: RITA ITS Deployment Survey, 2007

Table 6.14 shows an estimated cost to equip vehicles with AVL as well the additional cost to equip them with the additional communications equipment and software applications necessary to support real-time information.

Table 6.14: Average Equipment Capital Costs

Per Vehicle Capital Incremental Cost to Equip with AVL	Per Vehicle Capital Cost to Equip with Electronically Displayed Automated or Dynamic Traveler Information to the Public
$8,000	$4,000

Source: RITA Benefits, Costs, Deployment, and Lessons Learned, 2008

Table 6.15 shows the estimated total capital costs to deploy AVL and real-time information to the 31,664 buses and 26,512 other vehicles currently unable to display real-time information to travelers.

Table 6.15: Total Deployment Capital Costs

Transit Types	Incremental Cost to Equip with AVL	Incremental Cost to Equip with Electronically Displayed Automated or Dynamic Traveler Information to the Public	Total Incremental Cost to Equip with AVL and Electronically Displayed Automated or Dynamic Traveler Information to the Public
Fixed Route Buses Only	$135,000,000	$125,000,000	$260,000,000
Other Transit Vehicles	$150,000,000	$105,000,000	$255,000,000
All Transit Vehicles	**$285,000,000**	**$230,000,000**	**$515,000,000**

Table 6.16 shows the estimated cost to deploy signage to the new real-time systems. A cost per sign of $6,000 is assumed with one sign deployed for every 20 transit vehicles, based on the *RITA Benefits, Costs, Deployment, and Lessons Learned: 2008 Update.*

Table 6.16: Estimated Signage Deployment Costs

Signage Capital Costs	Cost per Sign	Vehicles	Average Vehicles/Sign	Additional Capital Cost
Signs for Buses	$6,000	32,000	20	$9,600,000
Signs for Other Transit Vehicles	$6,000	28,000	20	$8,400,000
Signs for All Transit Vehicles	$6,000	60,000	20	$18,000,000

Table 6.17 estimates the total capital costs associated with deploying real-time traveler information to unequipped vehicles.

Table 6.17: Total Deployment Capital Costs

Transit Type	Total Capital Cost
Fixed-Route Buses Only	$270,000,000
Other Transit Vehicles	$265,000,000
All Transit Vehicles	$535,000,000

Source: RITA Benefits, Costs, Deployment, and Lessons Learned, 2005

Table 6.18 estimates the average annual operating costs associated with real-time information, including the software and communications costs associated with deployment.

Table 6.18: Annual Operating Costs

	Annual Costs/Vehicle	Approx. Number of Vehicles	Annual Costs
Software			
Buses Only	$400	32,000	$12,800,000
Other Transit Vehicles	$400	28,000	$11,200,000
All Transit Vehicles	$400	60,000	$24,000,000
Communications			
Buses Only	$700	32,000	$22,400,000
Other Transit Vehicles	$700	28,000	$19,600,000
All Transit Vehicles	$700	60,000	$42,000,000
Total Annual Operating Costs			
Buses Only	$1,100	32,000	$35,200,000
Other Transit Vehicles	$1,100	28,000	$30,800,000

	Annual Costs/Vehicle	Approx. Number of Vehicles	Annual Costs
All Transit Vehicles	$1,100	60,000	$66,000,000

6.3.3 Parking

Assessing the cost to fill the gaps of real-time parking information is complicated by the limited number of deployments currently in existence and the inability to assess the total number of spaces that would benefit from real-time information. Unlike other modes, where complete coverage would be beneficial to travelers, many parking facilities are never full, meaning that real-time information is unnecessary.

Table 6.19 though **Table 6.24** seek to estimate the costs to deploy real-time parking information systems across the country, based on the estimated deployments per city, spaces per facility, and number of spaces that may benefit from smart parking information. The tables estimate the number and type of spaces for which real-time parking information is provided for each implementation to a central business district, airport, or transit station. Deployments/ implementation refers to an estimate for the number of parking facilities required for a large scale real-time parking information system, including multiple entry/exit, space-by-space, and on-street monitoring systems. Even in large metro areas, only spaces that regularly reach capacity would require real-time information. Spaces/deployment represents an average estimated number of parking spaces required per smart parking deployment. The estimates shown are based on existing deployments, including San Francisco and Los Angeles. The cost-per-space estimate is based on averages from previous smart parking deployments. As has been observed in previous deployments, it is assumed that central business district deployments will require some entry/exit, space-by-space, and on-street systems. Airports will only require entry/exit and space-by-space systems. Transit stations will only deploy entry/exit systems.

Table 6.19: Central Business Districts – Capital Costs

Parking System	Deployments/ Implementation	Spaces/ Deployment	Cost/ Space	Total Cost/ City
Entry/Exit	15	5,000	$40	$3,000,000
Space-by-Space	5	5,000	$600	$15,000,000
On-street	1	10,000	$300	$3,000,000
Total				$21,000,000

Table 6.20: Central Business Districts – O&M Costs

Parking System	Deployments/ City	Spaces/ Deployment	Cost/ Space	Total Cost/ City
Entry/Exit	15	5,000	$2	$150,000
Space-by-Space	5	5,000	$30	$750,000
On-street	1	10,000	$120	$1,200,000
Total				$2,100,000

Table 6.21: Airports – Capital Costs

Parking System	Deployments / Implementation	Spaces/ Deployment	Cost/ Space	Total Cost/ Airport
Entry/Exit	5	2,000	$40	$400,000
Space-by-Space	1	2,000	$600	$1,200,000
Total				$1,600,000

Table 6.22: Airports - O&M Costs

Parking System	Deployments / Implementation	Spaces/ Deployment	Cost/ Space	Total Cost/ Airport
Entry/Exit	5	2,000	$2	$20,000
Space-by-Space	1	2,000	$30	$60,000
Total				$80,000

Table 6.23: Transit Stations – Capital Costs

Parking System	Deployments/ Implementation	Spaces/ Deployment	Cost/ Space	Total Cost/ Station
Entry/Exit	20	4,000	$40	$3,200,000

Table 6.24: Transit Stations – O&M Costs

Parking System	Deployments/ Implementation	Spaces/ Deployment	Cost/ Space	Total Cost/ Station
Entry/Exit	20	4,000	$2	$160,000

6.3.4 Freight

Assessing the cost of filling the gaps for developing a robust real-time freight information network revolves around deploying segments to three market segments. **Table 6.25** and **Table 6.26** show the costs associated with deploying a freight-specific add-on to an existing real-time traveler information system, including a 511 and Website component. The total costs consider the cost of deploying such systems to the 34 states in the contiguous United States that currently lack freight information.

Table 6.25: Freight-Specific Add-ons – Capital Costs

Cost/ Deployment	Deployments	Total Cost
$350,000	34	$11,900,000

Table 6.26: Freight-Specific Add-ons Costs – O&M Costs

Annual Cost	Deployments	Total Cost

$7,000	34	$238,000

Information pertaining to the costs associated with deploying freight information systems to intermodal facilities and border crossings is somewhat limited, especially considering that many of the deployments have been pilot programs and business models are still being developed. C-TIP, a pioneering intermodal facility in Kansas City, Missouri, is currently funded via a $250,000 federal grant with an estimated annual operating cost of approximately $10,000 once the system is online. A real-time border crossing information systems in at the Peace Arch and Pacific Highway crossings in Blaine, Washington, required capital costs of $2,000,000, with estimated annual operating costs of approximately $40,000.

7 CONCLUSIONS

The availability of the real-time traveler information market has expanded greatly across the various modes of surface transportation in recent years. In many areas of the country, users are leveraging real-time information to improve their transportation-related decisions and their quality of life. In addition to the benefits that real-time information provides to travelers individually, it helps to increase the overall efficiency of the transportation network and allows public transportation agencies to improve the management of their systems.

Despite the gains made, continued collaborative efforts are required by the public and private sectors to ensure that the vast and complicated real-time information network coalesces into a more meaningful and seamless information source. Although business models are still developing in many real-time information markets, it is clear that the public sector must continue to play a large role in deploying real-time information systems, even with the private sector as a partner. The US DOT plays a crucial role in coordinating the efforts of the state and local government and private-sector partners. Based on the research conducted for this report, the following conclusions represent actions that will further the development of real-time information systems to continue to improve transportation safety, security, and efficiency:

7.1 Standards

Develop National Standards on Real-Time Information

Every state/region is doing something different with 511 and other real-time information applications, although a majority of them follow the same concepts. The US DOT/FHWA has an opportunity to develop national standards for 511 implementation beyond what is currently provided in the 511 Implementation Guidelines. This would support the interoperability of systems and seamless transition for the traveler between system areas.

Help to Improve Data Quality and Define Quality Standards

Public agencies are interested in support from the government to better ensure data quality. This support can be in the form of white papers, proof of concept, research, or analysis of existing systems. Quality standards can be developed on the national level to ensure that the amount of infrastructure-based data collection devices or probes would satisfy a basic level of quality for the dissemination of that data to the public. Linking the quality of data with the revenue provided to collect that data would help increase the standard for quality.

Help to Improve Data Exchange Standards

The US DOT could and should do more in the arena of real-time data exchange and traveler information standards. To date, many standards are not as widely used as they should be, and this hinders the ability to widely share and use information, which improves data quality. The US DOT should make standards freely available, push for key existing standards to be completed to eliminate ambiguities, provide a more open forum for sharing lessons learned as well as a more open process for standards development, and provide clear test procedures or validation processes so that accurate implementations of the standards can be confirmed.

Standardize Approaches to Collect and Share Information with the Public

There are gaps in information gathering and dissemination that could be mitigated if there were a standard methodology applied to:

- **Construction Data** – Real-time data collection for actual lane closures, delays, and other impacts to traffic from the construction activities can be shared with the traffic management agencies to disseminate more accurate information to the traveler.
- **Communications Protocol for Sharing Data** – The methods for collecting, storing, and sharing data can be in multiple forms/protocols, which makes sharing information with new agencies and new users a challenge to overcome. The information that is important to active traffic management and traveler information can be standardized on a national level to be able to share data more easily and potentially provide interoperability between local or state systems.
- **Sharing Additional Information with Third-Party Companies to Disseminate to the Traveler** – This would include dynamic information on managed lanes or pricing information as an example of information that the consumer would benefit in knowing prior to entering the managed lane.
- **Attribute Information** – When choosing a parking space, customers benefit from increased knowledge of facility attributes including hours of operations, security features, entry/exit, and cost.

7.2 Resources

Understand the Implications of Section 1201 of SAFETEA-LU

The private sector is supportive of these real-time requirements, but the public sector has some reservations for the federal requirements due to funding and resource implications.

Fund ITS Programs

States and local agencies continue to need funding support to implement ITS to collect data on roads, fleets, and parking facilities, and for more than just traveler information purposes. If the direction of the market remains that the public sector deploys detection devices to collect public data, then funding will continue to be required for maintaining and enhancing programs.

Improve the ITS Deployment Tracking Database

Although it remains the best source of information available on the national level, the ITS Deployment Tracking Database has notable gaps. The uniformity (lack of) of survey results is an issue. Ensuring the survey gets to the right people who have access to the right information is crucial. This is particularly true for arterial information. It is recommended that efforts be focused on maintaining contacts within key agencies who can provide the needed information. Further, data can be obtained from other sources. Vendors are knowledgeable of where their systems are deployed and what their capabilities are. In particular, there are far fewer signal system vendors than there are signal systems. Gathering information from these firms could garner a good return for the effort.

7.3 Research and Development

Research and Evaluate the Benefits of Investing in Data

Define the benefits of investing in real-time data. While there are numerous agencies and areas in the country that are educated on the opportunities for collecting data in the market today, there are some areas that are not yet thinking about how they can use that data.

Facilitate the Development of Technologies and Applications

Supporting the development of technologies through funding and partnerships with the private sector, such as is occurring with IntelliDrive^{SM}, SafeTrip-21, and Mobile Millennium in California, allows the government to show support and new use of innovations and allows the private sector to implement the value-added applications. Emerging market segments like parking and freight are further behind in the development of effective and affordable technologies. Helping agencies to understand what innovations are available and testing those innovations to determine benefits and justifications for widespread use would benefit agencies looking for new opportunities in providing good quality data to their customers.

Encourage the Development of Additional Communication Methods

Funding for research in the areas of DSRC, WiFi, WiMAX, and other open-air communication networks for obtaining real-time data also can support the development of real-time information across all modes.

Conduct Research to Improve Understanding of Real-Time Information Usage

Additional understanding of how travelers use real-time information is needed, including how the information they receive affects the decisions they make. This is especially crucial in developing market segments like transit, parking, and freight. This information can be used to focus outreach efforts, broaden the usage of information, and promote market sustainability.

7.4 Partnerships

Encourage Partnerships

Partnerships that utilize interagency deployments and coordination should be promoted. The relationships should focus on multi-modal regional real-time information and involve coordination between agencies and the private sector. Such partnerships can include the modal integration of real-time information for interagency coordination to consolidate data between state DOTs (traffic) and transit agencies (transit). In addition to public sector partnerships, commercial vehicles need to be an active partner in the development of real-time freight information, including through incentives that encourage participation.

Provide a Qualified Vendor List and Qualified Methods List for Public Agencies to Receive Data

Work to provide a qualified vendor list for providing data and possibly partner with ITS America to develop this. Recommended data collection methods for public agencies to consider implementing would be beneficial for local agencies.

Encourage the Public Agencies to Leverage the Private Sector Strides in Data Collection Techniques and Technologies

The private-sector data is broader in geographic scope than what the public-sector-operated systems can collect. The private-sector competition will keep prices reasonable, which may be able to demonstrate that they are equivalent or lower than the cost for public agencies to deploy data collection devices and provide traveler information services such as 511. There needs to be a bigger market and more demand from customers in order to make prices competitive.

Negotiate Data Collection Activities at a National Level

The US DOT/FHWA should explore the idea of negotiating with the private sector on a national level (perhaps similar to the GSA Schedule) that would provide data on a local or state level. This could not only provide a standardized method for distributing the data to public agencies, but could also support the reliability of that data due to the larger-scale application.

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9 APPENDIX: LEXICON

Table 9.1 presents a lexicon of industry terms to provide clarity and consistency throughout the document.

Table 9.1: Traveler Information Lexicon

Term	Definition
Real-Time Traveler Information	Information that provides travelers across a variety of transportation modes with situational awareness regarding current infrastructure conditions including information related to incidents, congestion, service disruptions, weather, and associated fees
Smart Parking	Real-time parking information and the associated management practices stemming from its use
511 System	Method to disseminate traveler information via a telephone number (511) with interactive voice recognition (IVR) or an associated Website that provide situational awareness of local infrastructure
Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1201	Federal law that sets up the Real-Time System Management Information Program (RTSMIP), which seeks to: • Establish an RTSMIP in all States • Monitor traffic and travel conditions of the major highways • Share information to address congestion problems and facilitate traveler information
IntelliDrive[SM]	US DOT initiative to enable vehicle-to-vehicle and vehicle-to-infrastructure wireless communication to promote safety, mobility, environmental, and convenience applications, including real-time traveler information
Commercial Vehicle Infrastructure Integration (CVII)	US DOT initiative to enable vehicle-to-vehicle and vehicle-to-infrastructure wireless communication for commercial vehicles to promote safety, mobility, environmental, efficiency, and security applications, including real-time traveler information
Fleet	Groups of motor vehicles owned or leased by a business or government agency, rather than by an individual or family, including transit agency buses and commercial trucks and buses
Telematics	Electronic unit in a vehicle that is used to wirelessly communicate information directly between the vehicle and a service provider, including between commercial vehicles and their dispatcher; also known as fleet management system or in-vehicle communications systems
Smartphone	Mobile phone offering advanced wireless and data capabilities, often with PC-like functionality

Term	Definition
Infrastructure-Based Sensors	Stationary data collection devices that monitor a specific point of the transportation network. Includes in-pavement or non-intrusive detectors that measure vehicle presence, volume, and speed.
Probe-Based Sensors	Probe-based detection includes location transmitting mobile devices in vehicles operating within the infrastructure. Used to track the movements of specific vehicles (e.g., transit vehicles) or to obtain a sample of traffic vehicle speeds over a length of roadway.
Portable Navigation Device (PND)	A portable consumer electronics device, typically aftermarket, which is used in a vehicle for turn-by-turn directions, some of which provide real-time traffic information. Examples are sold by Garmin, TomTom, Magellin, etc.
Business Model	A planned approach taken to achieve a desired return on an expense or investment. For a private sector for-profit entity, this is the plan for achieving a profit that will sustain or grow the business. For the public sector, it defines its role with respect to the private sector for the procurement or exchange of goods to meet goals of the agency.
Flow Data	Includes real-time speeds, travel times, usually on a road-segment basis. Can be obtained from sensor-based or probe based.
Freeway/Traffic Management Systems	This refers to a suite of technologies and functions that actively manage day-to-day traffic as well as abnormal conditions such as incidents, detours, or closures. Field equipment is monitored, and in some cases controlled, from a central facility; operators at the central facility implement operational strategies to respond to real-time conditions. Key functions include traffic management, traveler information, incident management and response, weather response strategies, and event management strategies. Real time data from detection and surveillance systems supports the implementation of operational strategies.
Automatic Vehicle Location (AVL)	Wireless transmitter on a vehicle that enables real-time vehicle information, including current location and speed. Most often uses a GPS, a communications link between vehicle and dispatcher, and tracking software program.
Advanced Parking Information Systems	Real-time parking information that tracks the number of available parking spaces within in a facility and aggregates information for facility operators'. Often also include applications to disseminate information to customers.
Recurring/Non-recurring	Recurring congestion is caused when the number of

Term	Definition
Congestion	vehicles trying to use the roadway system exceeds the available capacity including during normal peak periods. Non-recurring congestion is caused by temporary disruptions that take away part of the roadway from use including incidents, work zones, and weather.
Dynamic Routing	Routing that is dynamically discovered by a software application while a vehicle is in-route to a destination. The vehicle is then instructed how to use this update route.
Global Positioning System (GPS)	Communication between a transponder and a satellites to provide positioning and navigation information
Congestion Pricing/Pricing Model	System of charging users of a transportation network a surcharge for use during peak periods to reduce congestion. Congestion pricing systems are enables by real-time traveler information
Public-Private Partnership	Contractual agreements formed between a public agency and a private sector entity that allow for greater private sector participation in the delivery and financing of transportation projects.
Life Cycle Costs (Capital, Operations & Maintenance)	Total cost of ownership over the life of an asset. Capital costs refer to the costs to obtain the asset. Operations & Maintenance (O&M) costs refer to annual upkeep costs

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