1. Report No. FHWA/TX-11/0-6672-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle WHITE PAPER: STATE OF ITS INDUSTRY AND ASSESSMENT OF PROJECT TYPES		5. Report Date April 2011 Published: November 2011
		6. Performing Organization Code
7. Author(s) Edward J. Seymour, Nadeem Chaudhary, Dan Middleton, Robert Brydia, and Kristine Miller		8. Performing Organization Report No. Report 0-6672-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Project 0-6672
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080		13. Type of Report and Period Covered Technical Report: November 2010–April 2011
		14. Sponsoring Agency Code
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Project Title: Intelligent Transportation System (ITS) Strategic Plan URL: http://tti.tamu.edu/documents/0-6672-1.pdf		
16. Abstract This white paper describes the state of the intelligent transportation system (ITS) industry and provides a reference for use in soliciting ITS strategic plan inputs from stakeholders in Texas.		
17. Key Words Intelligent Transportation Systems, ITS, Strategic Plan	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov	
19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 48	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

WHITE PAPER: STATE OF ITS INDUSTRY AND ASSESSMENT OF PROJECT TYPES

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DISCLAIMER

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EXECUTIVE SUMMARY

This white paper provides a summary status of the intelligent transportation system (ITS) industry. The document is described in Task 4 of the project work plan and provides a description of U.S. state ITS planning trends and national ITS trends related to (a) private sector technologies, (b) federal connected vehicles initiatives, and (c) representative ITS deployments by other agencies. The paper also identifies candidate key project categories that are likely to be included in TxDOT's ITS strategy in the future. These key areas can serve as a reference for discussion with stakeholders in Texas as the ITS strategic plan is being developed.

Many regions in Texas developed ITS architectures that have provided a framework for investments in ITS. Those ITS architectures, their current programmed ITS projects, and a knowledge of the general state of the ITS industry are important elements to developing a thoughtful discussion about ITS needs and solutions. This white paper provides some background information regarding the ITS industry.

1. U.S. STATE DOT TRENDS IN ITS STRATEGIES

INTRODUCTION

This white paper includes a review of state trends in ITS strategic planning as part of the assessment of the state of the ITS industry. As part of this review researchers collected information from each state and summarized the experiences from 27 states. They also examined a U.S. DOT report that documents best state practices related to ITS strategic planning. This chapter summarizes those findings in a form that will be useful for TxDOT and their partners in developing an ITS Strategic Plan.

After reviewing these documents the researchers created summaries of key information including the following:

- Key information about ITS strategic planning including the types of stakeholders who were involved and the time horizon of the planning activity.
- Overall scope of the public outreach activities performed by the states including ITS websites, implementation of 511 services, and branding of the ITS initiative.

SUMMARY OF STATEWIDE ITS PLANNING

Researchers evaluated the presence of intelligent transportation systems for all 50 states and 5 U.S. territories. Of the 55 locations studied, evidence of statewide ITS architecture was found in 36.

- Twenty-nine have ITS websites.
- Twenty-two have branded ITS programs.
- Thirty-six have a Statewide Map link for traffic information. Several states (Utah and New Hampshire for example) have supplemental websites for road construction projects.
- Twenty-five locations have a Strategic ITS Plan.
    - Of these locations, four plans are over 10 years old, eight plans are 5–10 years old (2000–2004), 12 plans have been recently updated (2005–present), and one plan's version date was not listed.
    - Nine states have statewide architecture, and of these five plans have a 10-year time horizon. Ten additional states have a statewide architecture vision.

- Several states included stakeholders in the planning process. These states are Alaska, California, Colorado, Georgia, Illinois, Iowa, Kansas, Louisiana, Minnesota, Mississippi, Montana, Nebraska, Oklahoma, and Oregon. Table 1 provides detailed information about the breadth of stakeholder involvement in the ITS planning process in these states. As the table shows, in addition to state DOTS, most of these states included other state agencies, counties, cities, and commercial interests.

- Several of the plans included a description of the kind of stakeholder involvement that was used in the planning process. The majority of these states used surveys and focus groups to engage the stakeholders. Six states involved stakeholders in committees. Illinois and Kentucky were the only states that listed stakeholder involvement for all three types.

- Five states provide a list of stakeholders (Alaska, California, Iowa, Mississippi, and Oregon).

Stakeholders

The following table illustrates the diversity of stakeholders involved in the development of the ITS plans. States routinely involved the key ITS operational agencies and organizational units including state districts, counties, and cities. They also involved other public and private sector groups that could be users of ITS information.

Table 1. Stakeholders in ITS Planning Process.

State	State DOT	Other State Agencies	District/ Region	Counties	Cities	Commercial Interests	Public	Media Outlets	Advocacy Groups	ITS Service Providers
Alaska	x	x			x	x				
California	x	x	x	x	x		x		x	
Colorado	x		x							
Georgia	x	x	x	x	x	x	x		x	x
Illinois	x	x	x	x		x	x			
Iowa	x	x	x	x	x	x		x		
Kansas	x	x	x	x	x	x				
Louisiana	x	x			x	x				
Minnesota	x				x		x			
Mississippi	x	x		x	x					
Montana	x	x		x	x	x				
Nebraska	x	x		x	x	x			x	
Oklahoma	x	x	x		x					
Oregon	x	x		x	x	x				

Process for Stakeholder Involvement

The state plans used three general mechanisms to solicit input and build consensus. These included establishing an advisory committee, performing interviews and surveys, and leading focus groups and workshops. As noted in Table 2, a number of states used multiple approaches.

Table 2. Stakeholder Involvement Process.

State	Advisory Committee	Interview/ Survey	Focus Groups/ Workshops
Alaska		x	x
California	x		
Colorado	x		
Georgia			x
Illinois	x	x	x
Indiana			
Iowa		x	x
Kansas		x	x
Kentucky	x	x	x
Louisiana	x		
Minnesota		x	x
Mississippi			x
Montana		x	x
Oklahoma		x	x
Oregon	x		x

Time Horizon for ITS Strategic Planning

The ITS documents from the states generally had a 5- or 10-year time horizon established for ITS activities. Table 3 summarizes some of the findings for each state.

Table 3. Time Horizon for ITS Guidance.

State	Strategic Plan	Statewide Architecture	10-Year Term	Vision
Alaska	x	x	x	
California	x	x	x	
Colorado				x
Florida	x			x
Georgia	x	x	x	
Indiana	x	x		x
Iowa		x	x	
Kansas	x	x		x
Kentucky	x			x
Louisiana	x	x		x
Massachusetts		x		
Minnesota	x	x	x	
Nebraska	x			x
Oklahoma	x			x
Oregon	x			x
Virginia	x			x

Branding ITS for Traveler Information

In many cases a state has branded their ITS initiatives especially when they have taken on a significant role in distributing ITS information. For instance Florida uses the moniker "SUNGUIDE" to denote their ITS initiatives. The website http://www.sunguide.org/ is the portal for this brand. In some states the emphasis on branding is focused around 511 services. For example, California's "Smart-Traveler" links 511 services throughout the state.

ITS branding is also seen within and across state boundaries. The Kansas City SCOUT brand is sponsored by the Missouri Department of Transportation (MoDOT) and the Kansas Department of Transportation (KDOT). The website http://www.kcscout.net/ shows its traffic conditions map and provides links for mobile web alerts. The multi-state I-95 Corridor Coalition

sponsors traffic information along I-95 from Maine to Florida. Their website is
http://www.i95travelinfo.net/. Table 4 identifies some of the statewide branding.

Table 4. Statewide Branding.

State	Brand
Alaska	Iways
Colorado	CoTrip
Delaware	DelTrac
Florida	SUNGUIDE
Georgia	NaviGAtor
Illinois	Getting Around Illinois
Indiana	TrafficWise
Iowa	Trip Guide
Kansas	KanDrive
Michigan	MiDrive
Minnesota	Guidestar
Mississippi	MsTraffic
Missouri	Traveler Information Map
New York	New York MOVES
Oklahoma	Pathfinder
Oregon	Trip Check
Rhode Island	RhodeWays
Tennessee	SmartWay
Utah	CommuterLink
Virginia	Smart Travel
Washington	Moving Washington
Wisconsin	Smart Ways

In addition to statewide branding some areas have begun to brand regional
implementations of ITS services. The Houston region promotes traveler information from their
website http://traffic.houstontranstar.org/. Other regions in Texas also have regional websites
such as the Dallas/Fort Worth region (http://dfwtraffic.dot.state.tx.us/) and the Lubbock
TransView ITS area (http://its.txdot.gov/LBB/lbb.htm).

511 FOCUS

Many states are currently providing 511-based traveler information. The U.S. Department of Transportation website http://www.fhwa.dot.gov/trafficinfo/511.htm identifies the states that have deployed 511. Operation of a 511 website is a routine part of the 511 deployment process, and this U.S. DOT website contains links to those 511 sites for 43 locations. Figure 1 shows the states that have implemented 511.
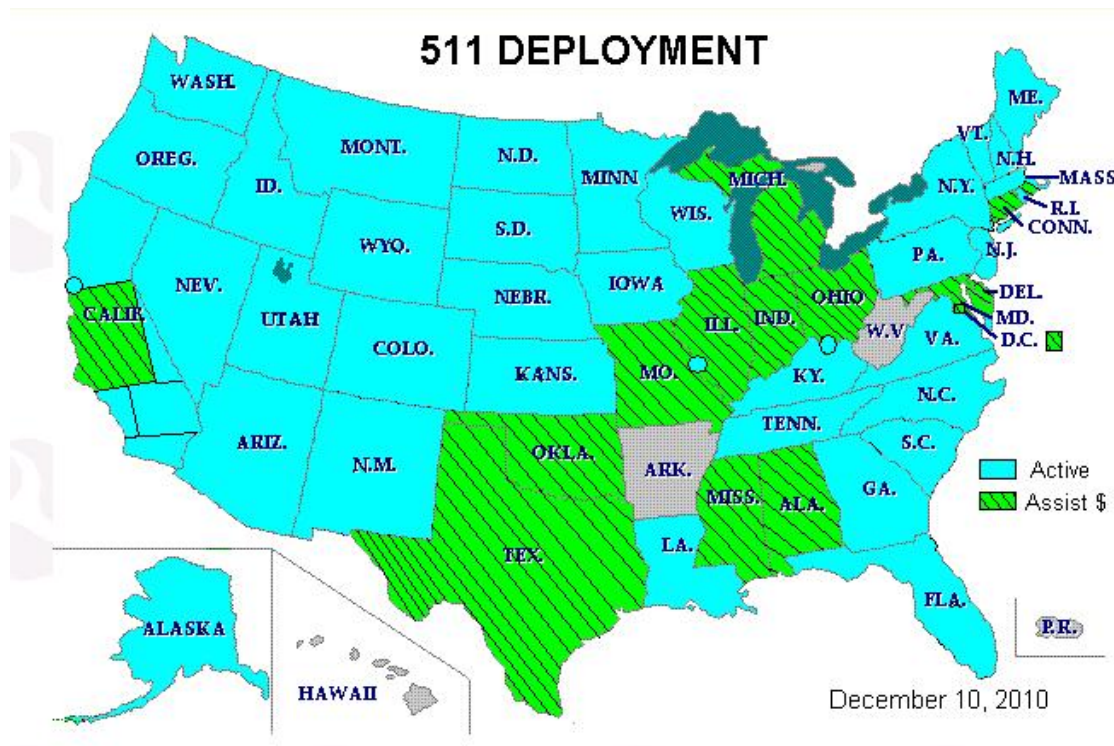
Figure 1. States with 511 Deployments.
From http://www.fhwa.dot.gov/trafficinfo/511.htm

As a part of 511 deployments states routinely have a reference website that points to statewide and regional governmental sponsored websites in that state. Examples are shown in the following table. For example, the California Smart-Traveler website http://www.dot.ca.gov/caltrans511/ links to ITS website resources in San Diego (http://www.511sd.com/ sponsored by SANDAG) and to the San Francisco Bay Area traffic conditions website http://www.511.org/ sponsored by the Metropolitan Transportation Commission (MTC). Caltrans also sponsors a real-time freeway conditions map at http://www.dot.ca.gov/dist11/d11tmc/sdmap/showmap.php.

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Operation of a 511 website is a routine part of the 511 deployment process. Examples of agencies that provide 511 websites are: Colorado (http://www.cotrip.org/speed.htm), Idaho (http://hb.511.idaho.gov/main.jsf), and Maine (http://www.511.maine.gov/main.jsf).

BEST PRACTICES

FHWA's *Best Practices of Rural and Statewide ITS Strategic Planning* conducted 12 in-depth studies and performed detailed surveys of agencies that were involved in ITS planning (*1*). The objective of the report was to capture best practices, including the planning process, which can be transferred to other jurisdictions. Chapter 11 of that report summarizes guidance highlights from the case studies. The best practice guidance includes the following:

- Develop system inventories with stakeholder involvement.
- Identify user needs with stakeholder involvement.
- Partition urban and rural needs to ensure that rural needs are adequately identified separate from traditional urban congestion issues.
- Develop an ITS vision using the national ITS architecture's "user services" and "user services objectives."
- Use workshops and focus groups to develop goals and objectives for ITS.
- Define ITS user services objectives on a regional basis to address specific objectives, meet customer needs, and target solutions to specific problems.
- Develop performance criteria or measures-of-effectiveness (MOEs) to screen national ITS architecture market packages.
- Develop a clear association between market packages and identified needs/problems.

The following list highlights those key findings. These recommendations have applicability to the Strategic Plan process in Texas and will be discussed with the Project Monitoring Committee.

- ITS Strategic Plan is a road map on how to implement a system of technology-based strategies over time. It provides a starting point for bringing ITS projects and systems together into an integrated system to solve the regional needs in the most effective manner. Specifically, an ITS strategic plan should:
  - o Follow a structured approach to ensure proper coverage of all issues.
  - o Have a vision.

- o   Identify needs, goals, and objectives.
- o   Permit input from key stakeholders in the region.
- o   Identify integrated solutions that can permit evolution as state of the art changes.
- o   Have plans on how to leverage funding opportunities to sustain adequate funding (i.e., including ITS components into major construction projects, initiating major ITS projects, and exploring federal funding and public-private partnerships).
- o   Includes ITS concept definition (Phase I), ITS framework development, and Implementation plan (Phase II).
- o   Address costs and responsibilities of operations and management.
- o   Estimate planning level costs.
- o   Identify potential benefits in relation to goals/objectives and performance criteria.
- In developing the strategic plan, note:
- o   There is no single right approach.
- o   The plan may need to be updated to accommodate changes in conditions.
- o   Strategic planning is most effective when undertaken as an integral part of the transportation planning processes.
- o   In addition to their input to identify needs, the plan should engage the stakeholders at an early stage to:
  - ▪   Identify their roles and responsibilities.
  - ▪   Identify expectations from their agencies.
  - ▪   Develop decision-making structure.

The document identified two types of stakeholders listed in Table 5. The document also suggested that the plan should have mechanisms (i.e., educational workshops, outreach materials, scanning tours, conferences, etc.) to ensure sustained stakeholder participation in the regional ITS program.

Table 5. Types of Stakeholders.

Traditional Stakeholders	Nontraditional stakeholders
- Transportation Agencies (e.g., Federal, State, County, City) - Local Government Agencies - Public Transit Agencies - Toll Authorities - Regional Planning Agencies - Regional Transportation Planning Agencies (RTPAs) - Metropolitan Planning Organizations (MPOs) - Councils of Governments (COGs)	- Emergency Medical Community - Public Safety and Law Enforcement Agencies - Fire and Rescue Groups - National Parks - Business and Industry Groups - Information Service Providers (ISPs) - Communications Carriers - Tourism Bureaus - Weather Services - Other Government Agencies and Departments

WHY DEVELOP ITS REGIONAL ARCHITECTURE

Part 950 of the Code of Federal Regulation, which became active in April 2001, requires that ITS projects funded by Highway Trust Fund and Mass Transit Account conform to the national ITS architecture and U.S. DOT adopted standards. Conformance implies the use of national ITS architecture in developing regional architecture.

ITS regional architecture, which should be consistent with statewide and metropolitan planning process, guides the development of ITS projects and programs and is consistent with the strategic plan. It describes system elements, their relationships to one another, and how the ITS projects in the Strategic Plan will work together in a coordinated manner. The regional architecture ensures institutional agreement and technical integration. It is a living document that should be frequently updated to adapt to changing needs, new opportunities, and evolving technology. As a minimum, it consists of:

- Description of the region.
- Identification of participating agencies and other stakeholders.
- Identification of ITS projects and systems to be implemented.

- An operational concept that identifies agency roles and responsibilities in the operation and implementation of the identified ITS projects and systems.
- Agency agreements required for the operations and maintenance of the ITS projects identified.
- System functional requirements.
- Interface requirements and information exchanges with planned and existing systems.
- Identification of ITS standards to be used for supporting Regional and National interoperability.
- The sequence of ITS projects required for implementation.

2. PRIVATE SECTOR DATA

In order to effectively manage the use of transportation infrastructure and to inform travelers about the existing and predicted roadway conditions, accurate and timely performance data are required by both infrastructure operators and travelers. Traditionally public agencies have deployed vehicle sensors and cameras, and they have distributed this information to the public. The business model has been as follows:

- Public sector investment for performance monitoring and control.
- Free distribution by public agencies of information to travelers, other public agencies, and private information providers.

This approach has been used since the late 1960s and 1970s when the FHWA began investing in the Urban Traffic Control System (UTCS) Project (*2*). However, private sector companies have recently begun to provide increasing amounts of data with increasing accuracy. Anecdotally these companies have indicated that the sources for their data are increasing exponentially with less reliance on traditional data providers such as public sector agencies. INRIX® was spun out of Microsoft® research in 2004 (*3*). NAVTEQ® began as a privately held company in 1985, and it became a public company in 2004 (*4*). AirSage® was founded in 2000 (*5*). TomTom® was founded in 1991 (*6*).

In addition the growth of smart phones has provided an increasing number of opportunities to monetize transportation information and an increasing number of ways to engage travelers in gathering transportation information through social networking. The iPhone®, introduced in 2007, has accelerated this environment (*7*). Many of the traffic applications for mobile devices are supported on popular platforms including iPhone, Android®, BlackBerry®, and others. As an example INRIX Traffic is supported on the iPhone, iPad®, and Android (*8*).

MARKETPLACE REVIEW OF PRIVATE SECTOR PROVIDERS

The Texas Transportation Institute (TTI), working under a Battelle Technical Support and Assistance contract for FHWA's Office of Transportation Operations, developed a marketplace review of private sector transportation service providers (*9*). Portions of those results are also being incorporated into TxDOT Research Project "Synthesis of Uses of Real-

Time Commercial Traffic Routing Data" (*10*). The Battelle project surveyed six private companies:

- AirSage.
- American Trucking Research Institute (ATRI)®.
- INRIX.
- NAVTEQ.
- TomTom.
- TrafficCast®.

Table 6 summarizes the results of the survey. Providers are using a combination of global positioning system (GPS) data from fleet vehicles, consumer devices, and cell phone applications, as well as data from fixed sensors installed and maintained by other agencies, and fixed sensors installed and maintained by the data provider.

Across the providers, there is no one single data source model in use. Correspondingly, there does not appear to be any single business model in use. Each provider has developed a somewhat well-defined niche or area, although many providers spoke about a desire to break out of that niche and expand their potential market, perhaps with new data offerings.

Even the fleet-equipped GPS data sources show a wide range of diversity. While no provider would detail their fleet arrangements for protection of their business practices, several spoke in general about the range of fleet types. From long-haul trucking, to delivery vehicles, to taxicabs, providers have actively sought data from whatever fleets are available. Many spoke about continuing to expand their fleet coverage as the best method of accessing additional data points.

A number of providers spoke about the changing marketplace in terms of the amount of data now available. While low availability of data used to be the paradigm a few years ago, the new paradigm is the vast availability of data and the comparative richness of the sources. Some providers spoke about past moves to change their models and business practices to actually reduce the number of individual data sources, primarily migrating to consumer GPS information. More than one provider spoke of receiving millions, if not billions, of individual data points per day.

Table 6. Summary of Data Provider Information.

	AirSage	ATRI	INRIX	NAVTEQ	TomTom	TrafficCast
Data Available [a]	S, TT, I, Q, V	S, TT, Q	S, TT, I, Q, V	S, TT, I, Q, V (portion of network)	S, TT, I, Q	S, TT, I, Q
Services Available [b]	D, A, PM	D, A, PM	D, A	D, A	RD, A, PM	D, PM
Data Source	Cell phone, 911, traffic counts	GPS on commercial truck-only fleets	State installed sensors, commercial fleets, consumer GPS	State installed sensors, commercial fleets, consumer GPS	Consumer GPS, Fleet GPS	State installed sensors, commercial fleets, consumer GPS, Bluetooth systems
Aggregation Levels for Historical Usage	None; as captured	1 mile, 1 minute	15–60 minutes	15 minutes	1 hour	15 minutes
Accuracy Checks Performed	Visual camera count, Probe vehicles.	Anomaly checking done, routines not disclosed.	Independently verified in large-scale testing.	Data checks prior to map matching. Comprehensive drive testing.	Data checks prior to map matching.	Simple-adjacent points compared, some clients doing accuracy checks.
Documented Quality Levels	None provided. Stated they meet Section 511 requirements.	None—burden is on receiver of data.	Accuracy above 95%. Availability above 99.9%.	None provided.	None provided. Stated they can meet Section 511 requirements.	None provided. Stated they can meet Section 511 requirements.

NOTES:

(a) Data Available: "S"=Speed, "TT"=Travel Time, "I"=Incidents, "Q"=Quality, "V"=Volumes, "GPS"=GPS fleet

(b) Services Available: "D"=Discrete Data (individual data points), "A"=Aggregate Data" , "PM"=Performance Measures

National Coverage: Not listed in table. All providers indicated national coverage, except TrafficCast, which is currently in urban areas.

Map Matching: Not listed in table. All providers except ATRI indicated a minimum use of TMC. ATRI uses mileposts. INRIX, NAVTEQ, and TomTom also use proprietary segmentation smaller than TMC.

FINDINGS

Coverage

A listing for national coverage is not included as part of the summary information in Table 6. As identified in the notes following the table, with the exception of TrafficCast, all providers indicated a national coverage capability on main roadways, typically down to the primary arterial level. This would correspond to Functional Class (FC) 3 roadways in the Traffic Message Channel (TMC) mapping system.

Map Matching

All of the private sector data providers provide their data mapped to some system that allows for the geographic identification of the roadway segment to which it applies. With the exception of ATRI, which uses mileposts, all providers utilize TMC as a minimum. INRIX, NAVTEQ, and TomTom also have proprietary mapping that allows data to be mapped to segments at a finer (smaller) resolution than TMC.

Data Available

Speeds (S) and travel times (TT) were the prevalent data provided, available from all the vendors as historical data. All vendors also stated the provision of some type of quality (Q) data, although the specific information provided varied by provider. All vendors except ATRI stated the availability of Incident (I) data. AirSage and INRIX stated the availability of Volume (V) data across the network, while NAVTEQ stated the capability for a portion of the network. Volume data come from a variety of data sources including fixed sensor data sources installed and maintained by public agencies, camera counts, and probe vehicles. Data availability on a per-lane basis is still in its infancy as a provider offering, although a number of respondents stated offerings under research and development.

As expected, the key data of the providers are speed and travel-time data, in both historical and real-time contexts. Associated with those data is the provision of quality or metadata expressing items such as confidence intervals, sample sizes, or other quality indicators. However, there is little consistency in terms of what is actually provided as a quality indicator. This appears to be a negotiable item in contracts.

Some of the data providers use consumer GPS devices to some degree. These data may not arrive in sufficient quantities to include in real-time information but can be added to the existing data sets once they are uploaded at a later date by consumers. Providers spoke of receiving data in this manner that range in age from a few days to several months.

A similar situation exists pertaining to arterial coverage. Some of the data models use data from consumer GPS devices. These data may not arrive in sufficient quantities to include in real-time information but can be added to the existing data sets once they are uploaded at a later date by consumers.

While only one vendor claimed to have per-lane information available, additional respondents indicated they were actively working to provide this level of data service. The responses to other types of data included the use of Bluetooth® data and fleet diagnostics, such as engine parameters. These would primarily be of use only to the original GPS-equipped fleets.

Services Available

The interviewer asked providers if they offered the following types of data products, differentiated as historical or real-time data:

- Raw data for purchase.
- Refined/aggregate data for purchase.
- Data warehousing.
- On-demand data access.
- Performance measures.

Raw or discrete data are defined as the individual or discrete data elements or points. While providers said they would not sell fleet GPS data, many providers do sell the complete data stream on individual points, stripped of any identifying information. When purchasing discrete data, a consumer would get all of the individual speed or travel time points within a section, within a timeframe, whereas they would only get one value under the purchase of aggregate data.

Aggregation Level

The principal service offering, however, is refined or aggregated data. Aggregate data are available from all of the responding providers on a historical basis. What is different across

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the providers is the level of aggregation. Some providers use 5 minutes, others use 15 minutes, and still others use 60 minutes. ATRI provides the lowest level of aggregation, at 1 mile or 1 minute. Other providers vary from 15 to 60 minutes. In part, the differences are due to the wide variety of data sources. On any given device, GPS data are typically recorded at 1-second intervals but that can be altered. Data from fixed-point sensors are typically recorded at 20-, 30-, or 60-second intervals. Cellular data might be recorded at sub-second levels.

Data Sources

Each provider essentially had a unique (to some degree) set of data sources. While there was some overlap, no responding provider utilized exactly the same data model as another provider. Providers are using an expansive range of data sources including GPS data from fleet vehicles, commercial devices, cell phone applications, fixed sensors installed and maintained by other agencies, fixed sensors installed and maintained by the data provider, and cell phone location.

Data Filtering

The interviewers also asked providers to detail the manner in which their data could be analyzed. All respondents indicated the ability to do data filtering or sorting based on typical parameters such as date, time, roadway, region, state, or data source. The provision of these capabilities stands to reason because they are somewhat inherent in any database or archive, although the extent or level of discreteness can vary greatly.

Accuracy Checks

The data providers were very circumspect about discussing any accuracy checks they perform to validate their data offerings. With the exception of ATRI, which stated that none are performed, most providers did not disclose specific checks or algorithms. TrafficCast did state that a part of its general methodology included simple adjacent point comparison routines but also stated that it employed more sophisticated methods. INRIX, in part due to the comparisons performed by the I-95 corridor coalition, stated that large scale client testing has verified its data. NAVTEQ claimed that it does extensive drive testing across all types of roadways in all markets at all times of the day and days of the week. With the exception of ATRI, all providers stated

they have an extensive data-checking process in place to ensure overall data quality. A number of providers also have integration routines employed to merge data from disparate sources into a seamless coverage of their network. However, they did not provide descriptions of these routines.

Quality Levels

With the exception of INRIX, data providers were also circumspect about the quality levels they meet. INRIX explicitly claimed an availability of more than 99.9 percent and an accuracy of greater than 95 percent.

The interviewers asked providers if they were aware of, and were capable of meeting, the requirements in the FHWA Final Rule on the "Real-Time System Management Information Program," which took effect December 23, 2010 (*11*). While the providers were aware of the ruling, there was no concern associated with either the time frame for implementation or the requirements. In general, based on the information provided during the survey as far as data latency and availability, the existing data parameters would appear to exceed the FHWA rule-making requirements. Only one provider (INRIX) had a specific comparison (available on their website) of information regarding the FHWA requirements and their standard numbers for reporting time frames, accuracy, and availability. Providers were aware of the requirements and expressed no concern over meeting the real-time requirements and by extension, accuracy and availability levels for historical data.

Pricing

In general, the availability of pricing information was minimal. Most providers appear to negotiate each purchase individually. Pricing is tied to the usage of the data. Data that are used for a single application employs one price point. Data used for multiple applications requires a different price point. Providers also make a distinction between uses, such as modeling or O-D studies, and derivative products, such as summaries distributed to external sources. While providers did not disclose the various price points, all stated that they exist.

Data Imputation

This aspect of data primarily applies to real-time information and is not detailed as a line item in Table 6. Providers responded in one of two ways when asked about data imputation, or filling in the gaps in real-time data. A number of providers stated they have the ability to impute based on their historical data archives and data-checking routines. Providers also stated that they flag such data as being all or partially composed of historical versus real-time data. INRIX explained in detail how the quality measures associated with any particular data point would change based on the amount of historical data being used. Essentially, the confidence interval expressed for the data point, such as a speed or travel time, would range from very high with no historical data in use to very low with significant historical data in use. ATRI does no data imputation at all.

Data Provision

Providers were asked to detail the ways in which they provided data to their customers. For real-time usage, the universal answer was some type of data feed, typically Extensible Markup Language (XML) updated on a 1-minute interval. Providers also stated that they could provide map outputs, but those processes are still fed in the background by a data feed. Smart phone displays were also a standard answer, but they are also powered by a background data feed.

For the historical context, a wider variety of data provision mechanisms is possible. Some providers utilize an Internet-based portal access to the database, and customers can perform and save their own query results. Other providers execute the query for the customer and ship the resulting data file via electronic mail or CD-ROM. Typically, they provide the file in either XML or Comma Separated Variable (CSV) format.

QUALITY OF COMMERCIAL SERVICES

During January and February 2011, TxDOT held meetings with INRIX and NAVTEQ. Both companies indicated they were experiencing an exponential rate of growth in the amount of data they were receiving. In addition, both companies expected the rate of growth to be exponential for at least the next five years (*12, 13*). The expectation from the companies is that both the extent of data coverage and the data quality will continue to increase in the next 5–10

years. This outlook is consistent with information generally available from other traveler information service providers.

In order to assess quality today, TTI performed an analysis of two commercial traveler information service providers along I-35 in Austin, Texas. The data gather from the companies was compared with a deployment of Bluetooth readers serving as a benchmark reference (*14*). Three measures of real-time link speed accuracy were used in this evaluation:

- Average absolute error (mph) – as compared to the benchmark's 95 percent confidence interval.
- Average error (bias, in mph) – as compared to the benchmark's 95 percent confidence interval.
- Percent of speed values within 5 mph of the benchmark's 95 percent confidence interval (%).

All three accuracy measures are computed as compared to the benchmark's 95 percent confidence interval. By comparing to the 95 percent confidence interval, the evaluation acknowledges that the benchmark does have measurement error, just like the service provider. When the 95 percent confidence interval is narrow (e.g., lots of Bluetooth matches and low variability), then the benchmark error is low. If the 95 percent confidence interval is wider, then the benchmark error is higher. The true speed value can only be known if the speeds of all vehicles traversing the link are recorded.

To characterize the accuracy of speed data in several different congestion ranges, these three accuracy measures were calculated and reported in four different ranges (based on the Bluetooth-based benchmark speed values):

- Light flow: greater than 60 mph.
- Transition: 45 to 60 mph.
- Slowing: 30 to 45 mph.
- Stop-and-go: less than 30 mph.

The "light flow" category is often disregarded following accuracy evaluations for the following reasons:

- Service providers have different policies for capping free-flow speeds that exceed the posted speed limit.

- Light flow is the predominant traffic condition for the majority of the day. Because of this, service providers could provide a free-flow speed throughout the entire day and they would likely be close to the benchmark most of the day. Therefore, combining the accuracy during light flow and heavy congestion has a tendency to dilute any poor performance that would occur during heavy congestion.

To determine how the evaluation results on I-35 in Austin compared with evaluation results in other locations, the results from 2 years of INRIX evaluation conducted along I-95 in six states by the I-95 Corridor Coalition were used. The findings and conclusions follow:

- The accuracy results from both service providers along I-35 in Austin are better than the accuracy results obtained along the I-95 corridor. There are several possible reasons for better accuracy during this limited I-35 evaluation. Given the small differences in the two sets of evaluation results, there is no cause for concern about either evaluation effort. Possible reasons for the difference: 1) the four links along I-35 are near the Austin Central Business District, where the possibility of gathering larger probe vehicle samples (which typically means better accuracy) is greater than in rural or suburban areas; 2) the I-35 evaluation encompassed one month, whereas the I-95 evaluation includes 2 years, which means a greater possibility of capturing extreme traffic-disrupting events for which the service providers may be less accurate.

- For all four links combined, the average absolute error was less than 5 mph for both service providers. When considering the error on each link, the average absolute error increased on some links and speed categories, but still remained below 7 mph. As a comparison, the contract requirement for the I-95 Corridor Coalition is 10 mph (i.e., average absolute error must be less than 10 mph or contractor payment can be withheld). The southbound Woodward-to-Stassney link was the least accurate, but the differences in average absolute errors between links are typically less than 2 or 3 mph for both service providers.

- For the second measure, average error or bias, there was a slight difference between the two service providers, but the difference is less than 2 mph. NAVTEQ data were less biased at low speed ranges, and INRIX was less biased at mid-range and higher speeds. The bias is an indicator of whether a service provider consistently reports

speeds that are higher or lower than the benchmark. For example, the NAVTEQ data bias in the two higher speed ranges is about −3 mph, which indicates that NAVTEQ consistently reports speeds in this range that are lower than the benchmark. Note that this could be caused by capping the reported speeds at the posted speed limit. The greatest bias for INRIX data is in the lower speed ranges, where it is between 2 and 3 mph. This means that INRIX consistently reports speeds higher than the benchmark in these speed ranges.

- The third measure, percent of values within 5 mph, shows similar results for both data providers, except that INRIX has better results in the 45 to 60 mph speed category. At slower speeds (0 to 30 mph), both data providers were within 5 mph of the benchmark interval about 85 percent of the time. At transition speeds (30 to 45 mph), both providers were within 5 mph about 65 percent of the time. INRIX also had better results than NAVTEQ in the free-flow category, but as mentioned earlier, accuracy in this speed category is often ignored or downplayed.

- On this heavily-traveled stretch of I-35, the large sample sizes from Bluetooth produce a more accurate travel time result. However, the average error for both INRIX and NAVTEQ (the two leading providers TTI evaluated) were always less than 7 mph. The key question is how much accuracy is needed for the application. For example, ±7 mph is adequate for a citywide red-yellow-green speed map. But is this accurate enough for posting freeway travel times? If you assume a 4-mile segment at 30 mph true average speed, then the true travel time is 8 minutes. If the provider's error is ±7 mph, then the reported travel time could be 6 minutes (37 mph) or 10 minutes (23 mph), so average travel time error at this speed and segment length is ±2 minutes. Is that acceptable? San Antonio already posts travel times as a 2-minute range (e.g., 6–8 minutes).

- TTI's evaluation only considers accuracy and does not include other factors that TxDOT should consider when making decisions about traveler information. The most important other factor is life-cycle cost/maintenance, with mobilization a lesser consideration. The I-95 Corridor Coalition operators did some back-of-the-envelope calculations that indicated that the life cycle costs were comparable between Bluetooth traffic monitoring and private sector traffic data. The mobilization refers to

how quickly district-wide traffic information could be provided; Bluetooth reader installation in a cabinet is definitely quick, but the larger traffic information companies can flip a switch today and have real-time data flowing for all major roadways in Austin District (and statewide for that matter).

3. CONNECTED VEHICLE INITIATIVES

The U.S. Department of Transportation Research and Innovative Technology Administration (RITA) initiated a series of connected vehicle research initiatives. These include technologies, applications, policy and institutional issues, and communications (*15*). This initiative parallels the ITS structure that was launched in the 1990s with similar categories of activities.

An architecture was developed for ITS that defined the services that ITS provides (i.e., market packages). In the connected vehicle realm RITA is currently defining connected vehicle applications for safety, mobility, and environmental services. In the ITS architecture a communications layer identified the communications technologies and systems that support information exchange. For connected vehicles dedicated short range communications (DSRC) technology is being examined for vehicle-to-vehicle and for vehicle-to-infrastructure applications. In both cases an emphasis on institutional issues and topics is important because of the desire to mainstream the initiative. The current applications in RITA's research portfolio follow (*16*):

- Vehicle-to-vehicle safety.
- Vehicle-to-infrastructure safety.
- Real-time data capture.
- Dynamic mobility applications.
- Environment.
- Road weather.

TIME FRAME

At this time the connected vehicle initiative is in the research stage and is being guided by RITA. The high level roadmaps that describe these initiatives typically run from 2010 to the beginning of 2015. For instance, the roadmap applications for the environment define foundational analysis in CY 2010–2012 and candidate application evaluation from CY 2012–2014.

Each of the roadmaps has a similar structure and timeline. However, in the case of the vehicle-to-vehicle initiative the research will provide supporting data for a National Highway

Traffic Safety Administration (NHTSA) rule making decision. NHTSA anticipates that vehicle-to-vehicle communications will support a new generation of motor vehicle safety systems (*17*). The potential rule may set requirements for inclusion of vehicle-to-vehicle communications in new vehicles.

There could also be requirements for inclusion of communications from the vehicle to the roadside—for instance to include the current or forthcoming signal light status of a traffic signal for a safety application. In the connected vehicle research program the Signal Phase and Timing (SPaT) research initiative is focused on communicating traffic signal information to mobile devices (*18*). These types of applications provide a need to communicate with publicly-owned infrastructure. The objective is to improve safety. But a consequence with today's typical transportation business delivery models is that public agencies must also provide the funds for the additional roadside equipment capability.

PUBLIC AGENCY PARTICIPATION

At this time few states and operating agencies are participating in the connected vehicle initiative. Some states with an historical involvement in the automotive industry are active partners with the U.S. Department of Transportation research program. For instance, Michigan is hosting a connected vehicle test bed in Detroit (*19*). Florida, California, and New York have also hosted some connected vehicle initiatives. In Texas, Harris County is considering the addition of traffic signal priority capability that is consistent with connected vehicle technologies. In general public agencies are not yet involved in this technology except through minor, focused installations or through federally sponsored research initiatives.

4. STATE OF ITS DEPLOYMENTS IN THE USA

A recent study for RITA analyzed the U.S. Department of Transportation ITS tracking database to develop trends in ITS deployments (*20*). In some areas there has been a significant trend in deployment of ITS technologies and services. For instance Figure 2 shows a steady increase in the deployment of Automatic Vehicle Location (AVL) devices on transit vehicles.
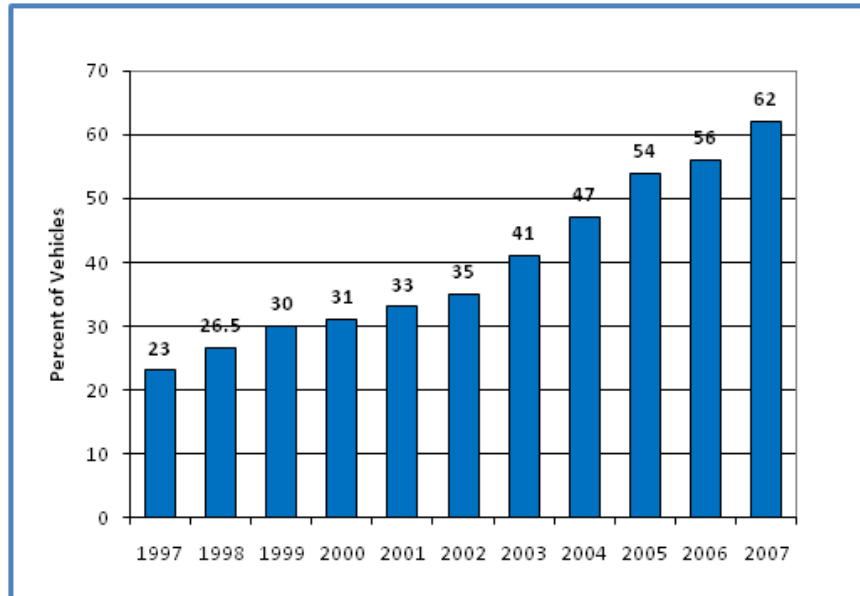

Figure 2. Fixed-Route Transit Vehicles Equipped with Automatic Vehicle Location.

While the number of transit buses has been increasing, the percentage of buses that have transit signal priority has stayed below 10 percent.
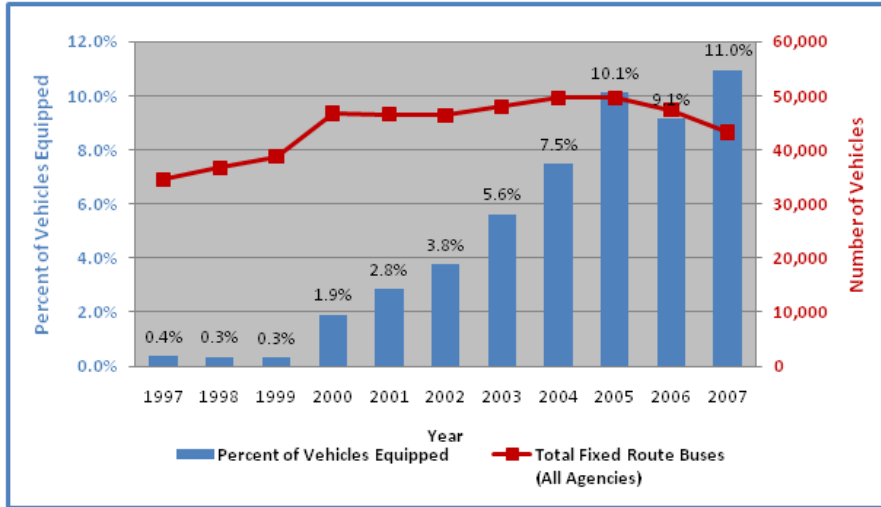
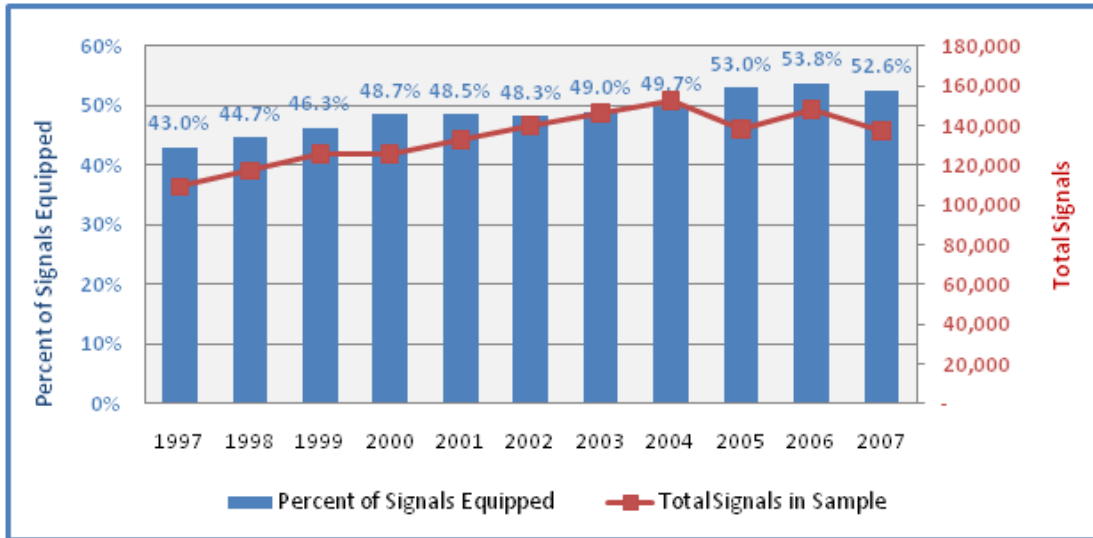**Figure 3. Transit Signal Priority Equipped Fixed-Route Buses.**

Electronic tolling capability has dramatically increased during the last few years.
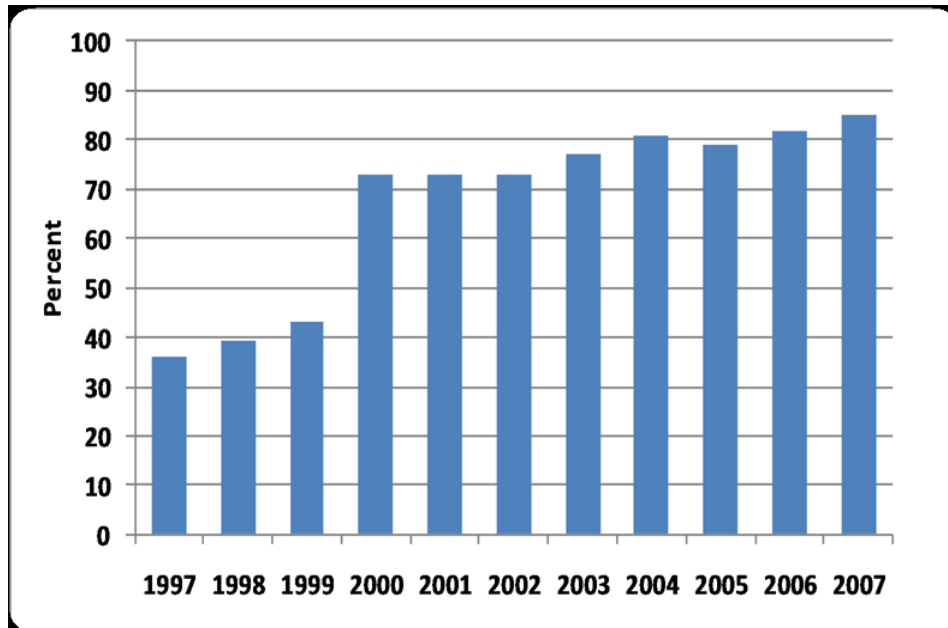
Figure 4. Percent of Toll Lanes Using ETC.

The total number of traffic signals that are under central control and monitoring has only slightly increased during the last dozen years and remains around 50 percent.

Figure 5. Traffic Signals under Closed Loop or Centralized Control.

5. ANTICIPATED ITS SERVICES

ITS planning is traditionally based on the ITS architecture framework (*21*). Any statewide ITS architecture in Texas should be grounded on that foundation. But it should also be based on challenges and conditions unique to the state and to the economic, environmental, and institutional frameworks in Texas. This chapter begins a discussion of supplemental emphasis areas relevant to a statewide strategic plan.

The review of ITS initiatives in other states, the federal, and private sector research initiatives that are emphasizing connected vehicles, and the emerging state of ITS technologies, allow the TxDOT planning process to identify evolving trends in ITS services and investments. The following categories of services and project types can serve as a foundation for discussion with stakeholders while developing the statewide ITS strategic plan. The project team will develop a list of themes like these to solicit stakeholder needs. In addition to those services other themes will be identified by the project team and could include special events, military bases, evacuations caused by weather and catastrophic events, and weather needs.

CHANGE IN TRAVELER INFORMATION OVER TIME

An example of this emphasis area is the initiative in the Dallas/Fort Worth area to provide 511 traveler services. TxDOT has been exploring this same application and is working with the region to broaden 511 deployments statewide. Another example is posting of travel times on dynamic message signs on controlled access facilities. TxDOT districts have been displaying travel times during the last few years, toll roads such as NTTA (North Texas Tollway Authority) have been posting travel times, and TxDOT is examining this service along State Highway 130 east of Austin.

While these are near-term in nature, the marketplace is rapidly changing. Handheld and other nomadic devices are being widely sold in the marketplace. It is now possible to purchase a portable navigation device that provides voice prompted navigation that takes into account real-time traffic conditions. The cost of this device is currently between $100 and $200. This same capability is also offered on some smart phones. During the next few years the capability of these devices is likely to increase while costs have been trending down. This will aid market

penetration and decrease the reliance on public agency traveler information in the medium to long-term time frame.

The trend of private sector delivery of transportation information services is consistent with the national ITS architecture perspective. The architecture guidance documents highlight a separation of transportation management and transportation information services as part of the ITS strategy (*22*). The expectation is that transportation information will increasingly become a private sector activity.

The role that TxDOT plays in traveler information should be assessed in the ITS Strategic Plan. TxDOT and its partners need to determine the level of traveler information that public agencies will provide. Example questions that can be addressed for deployment scenarios include: a) will these agencies provide only a minimal base level of service such as dynamic message signs at major roadway junctions, b) will they provide roadway safety information such as road closures status due to high water, c) will they provide increased services in urban areas to address congestion and incident management, and d) will they provide enhanced services on key evacuation routes such as I-45 between Houston and Dallas.

INTEGRATING MULTIMODAL ITS SYSTEMS

Throughout the country agencies are working together more closely to provide coordinated transportation services. The I-95 Corridor Coalition extends from Maine to Florida and has an objective to work "together to accelerate improvements in long-distance passenger travel and freight movement" (*23*). In Dallas, Texas, the Integrated Corridor Management Project is attempting to produce modal shifts from vehicle to transit during times of significant transportation disruptions and capacity issues (*24*). The TranStar Greater Houston Transportation and Emergency Management Center is another example of a coordinated regional partnership (*25*).

ITS is an important element in these partnerships and coalitions both for providing traveler information and for managing infrastructure. In addition, the underlying technologies involve shared assets and interdependent actions. For example shared communications infrastructure and coordinated display of messages on multiple agency dynamic message signs is important to effective operations. TxDOT's use of ITS center-to-center communication standards in their Lonestar systems is another example of key underlying technologies. The ITS Strategic

Plan can explore the resources and institutional relationships that are required for effective operations.

INCREASED EMPHASIS ON SMARTER WORK ZONES

Texas is a growing state. Since 2000, it has grown 12.7 percent, nearly twice the rate of the nation (*26*). With an increasing demand for mobility and an increasing number of people, there will likely continue to be major construction and reconstruction projects along congested corridors—no matter how funded. The 2030 Committee report described the trends of increased demand on the Texas roadway network and reduced revenue from the motor fuel tax (*27*). These trends are likely to raise the importance of well executed roadway projects including construction work zone practices and technologies. The projects along I-35 in the Waco District and the I-635 project in Dallas exemplify the complexity of building and reconstructing in congested environments. The expectations and objectives for ITS in infrastructure construction projects can be assessed in the ITS Strategic Plan.

EVACUATION AND OTHER EMERGENCY SERVICES

Evacuation from the Texas Gulf coast is a critical issue for the state of Texas and for nearby states such as Louisiana. Hurricanes Katrina and Rita in 2005 are recent examples of the demands placed on the transportation system as millions of people relocate from endangered coastal areas to more protected venues. The role of TxDOT was expanded because of these events to assume traffic management authority over designated evacuation routes and to coordinate distribution of fuel along the routes (*28*). Because of this recognized need TxDOT recently added ITS instrumentation to the I-45 corridor between Houston and Dallas. The ITS Strategic Plan can examine the kinds of resources that are needed to effectively respond to evacuations and other emergency services.

INFRASTRUCTURE MANAGEMENT

Decreasing transportation revenues means that TxDOT and its partner agencies must make the best use of funds to repair and maintain existing infrastructure and ITS assets. To capture the capability of ITS to assist with infrastructure management, the ITS architecture has "market package" elements that relate to infrastructure monitoring (*21*). Because Texas is a

geographically large state it can benefit more from infrastructure monitoring than a typical state. The ITS Strategic Plan is an opportunity to emphasize the effective maintenance of infrastructure such as pavements, bridges, tunnels, culverts, hardware, vehicles, and equipment.

FREIGHT MOVEMENT

Freight traffic is expected to grow at twice the rate of passenger vehicle traffic (miles traveled by truck will increase by 120 percent) as the Texas economy grows over the next 25 years. Trucks and trains in rural and urban corridors are a key part of the economy and must travel on reliable timetables (*27*). The ITS Strategic Plan can seek input regarding freight movement including the impacts of forthcoming events such as widening of the Panama Canal and access to key freight hubs such as Alliance Airport, DFW International Airport, and the Port of Houston.

PRICING

TxDOT and its partners are reviewing a number of congestion solutions including tolled alternative lanes and variable road pricing. The U.S. Department of Transportation is also supporting pricing strategies through its Value Pricing Pilot Program. The role of pricing and alternative business models for delivery of transportation services will be a theme that is discussed with stakeholders.

COSTS OF PUBLIC SECTOR ITS

Balancing public agency needs for delivery of ITS services and the growing limitations of fiscal budgets is challenging. At the same time technology is rapidly changing with respect to capability and cost. A key theme in the conversation about ITS will be costs associated with procurement, maintenance, and operations.

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